



**TRADE AND INDUSTRY CHAMBER**

**FUND FOR RESEARCH INTO INDUSTRIAL DEVELOPMENT,  
GROWTH AND EQUITY (FRIDGE)**

**STUDY TO PROVIDE AN OVERVIEW OF THE USE OF ECONOMIC  
INSTRUMENTS AND DEVELOP SECTORAL PLANS TO MITIGATE THE  
EFFECTS OF CLIMATE CHANGE**

*Draft Final Report*

February 2010

Genesis Analytics (Pty) Ltd

12 February: **VERSION 1.1**

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## EXECUTIVE SUMMARY

### INTRODUCTION

This report investigates the viability of using economic instruments to mitigate greenhouse gas (GHG) emissions in South Africa. The aim of this report is to gain a better understanding of the actual policy mechanisms which are available to achieve emission reductions, and their potential impacts on different South African sectors within the context of South Africa's industrial policy framework. The findings of the study will contribute to the national discourse around GHG emission reduction regulation, and empower industry to engage with government constructively to develop the most efficient and effective policy mechanisms to move South Africa to a low-carbon economy in the long term. In addition, the project will highlight what abatement options are available to individual sectors. This Executive Summary presents a summary of the key findings and recommendations to emerge from the research.

### AVAILABLE EMISSIONS REDUCTION POLICY INSTRUMENTS

Market failure due to the negative externalities arising from greenhouse gas emissions provides the rationale for policy interventions to move the economy to a socially optimal level of emissions, where the cost of damage is exactly equal to the cost of abatement.

Instrument category	Instrument name	Description	Mechanism to reduce emissions
Regulation	Performance standard	Regulator sets some kind of target for the level of emissions that producers must comply with or face penalties	Quantity
	Technology standards	Regulator determines minimum technological standards that producers must comply with or face penalties	Technology
	Information disclosure	Labelling requirements inform consumers about the carbon content of goods. This may lead to substitution towards less carbon-intensive goods.	Quantity/ Price
Using markets	Taxes	A tax is set on emissions to force producers to internalise the full cost of their activities	Price
	Subsidies	Incentives are provided to subsidise the cost to producers of reducing emissions or to encourage R&D in climate-friendly technologies. Subsidies can include public or private funding provided to science councils, universities etc to advance research focused on GHG mitigation.	Price
Creating markets	Cap and trade schemes	A certain cap on emissions quantities is determined and producers then face a decision to reduce emissions internally to meet the cap, or purchase emission reduction permits from those able to beat their caps more cost effectively.	Quantity
Voluntary	Voluntary commitments	Mitigation activities voluntarily agreed to by producers. Often used in the early stages of environmental policy consideration to aid adaptation before more stringent measures are introduced. Can include government-led initiatives such as consumer awareness campaigns.	Quantity/ Technology/ Price

**GHG mitigation instruments**

*Source: Genesis Analytics, 2010*

The table above outlines the various policy instrument options available to address this market failure. Internationally there is a move towards market based mechanisms to provide the central instrument in a suite of climate policy interventions. Whilst from an economic theory perspective market instruments are more efficient than their regulatory counterparts, ultimately the particular country and sector context will determine the most appropriate instrument to use.

## CRITERIA FOR INSTRUMENT CHOICE AND DESIGN

A number of considerations are pertinent when designing a climate mitigation policy suite, and should determine whether and which instruments suite a specific context.

**Environmental effectiveness** refers to the ability to achieve reduced emissions. **Economic efficiency** means that an instrument encourages of „least-cost abatement’ over the short and long term. Instruments which encourage **substitution** by consumers to lower-carbon products and processes increase efficiency. Maintaining and creating **competitiveness** in a global economy transitioning to a low carbon future is crucial for maintaining growth. The **administrative requirement** related to the implementation of mitigation instruments affect the cost of using the instrument, as does the **data and information** required to **successfully implement an instrument**. **Distributional effects** are another particularly pertinent consideration for developing countries, as is **fiscal affordability** of the overall policy suite. **Buy in and support** for the instrument is important to avoid resistance. Climate change policy instruments must be **compatible with the broader policy environment** to ensure policy coherence. Finally, there must be **flexibility** within the policy suite to allow firms to adjust to the fluctuations of the economic cycle.

The criteria mentioned in the previous paragraph is not applied to the available policy options to evaluate their attractiveness within a larger suite of policy options.

### Regulatory options

Regulatory options to emissions reductions are arguably the most straightforward mitigation options. Theory shows regulatory instruments generate a less efficient outcome and generally market-based interventions are proving more attractive to policymakers internationally. Nevertheless regulation may have a place as part of a larger suite of policy options.

- *Performance standards* are environmentally effective and administratively simpler than other instruments. However, unless the government has a high level of information about individual firms and abatement technologies, performance standards are not economically efficient, and are therefore unsuitable as a mainstay of an economy’s mitigation policy suite. They may be useful where there are few emissions sources (or many homogenous sources) and a high degree of information exists around these.
- *Technology standards* are also economically inefficient, and do not have the environmental effectiveness advantage of performance standards. However, they can be effective in achieving large reductions quickly where a low cost substitute technology exists but has not been widely adopted for reasons of market failure.
- *Information disclosure* rules are fiscally affordable and encourage substitution, but the level of environmental efficiency depends on consumer preferences.

## Using markets

The advantage of **market based policy instruments** (is that they are economically efficient, and require less information than regulation; government need only understand the abatement cost curve for the country or industry as a whole, not for each individual firm.

- *Taxes* additionally provide flexibility in that firms can choose whether to abate or pay the tax in each year. However, taxes are not as environmentally effective as quantity based instruments, as they target emissions indirectly through the price mechanism. A lack of data around mitigation costs at a sector level will lead to uncertainty over the level of mitigation which occurs. Taxes also tend to be unpopular. They can also become regressive over time, if measures are not put in place to counteract this. A significant advantage of a tax is that it generates fiscal revenue, which could be recycled to strengthen progressivity, ensure revenue neutrality, or further incentivise emission reductions.
- *Subsidies* can be economically efficient in the short term, and are popular with the private sector. However, their drawbacks are that they impose a cost to the fiscus, and that in the medium to long term they are not environmentally efficient as there are likely to be more entrants to polluting sectors (or prevent firms from exiting the market).

## Creating new markets

The creation of new markets can capture both the environmental efficiency of a quantity instrument and the economic efficiency of a price instrument. *Cap and trade* will achieve a specified emission reduction volume, but depending on government's information around abatement costs, the price in the market is uncertain. Additionally, it may be highly volatile for reasons including timing, lumpy investment profiles, and future policy uncertainty. Depending on the allocation mechanism for initial allowances, the mechanism can generate fiscal revenue which is equivalent to that of a tax. This is however unlikely in the initial years of the scheme. Cap and trade schemes include significant complexity in the design and establishment of the scheme. Transaction costs are also high. Liquidity of the scheme is important to realise the mechanism's benefits, and market concentrations can be problematic. Cap and trade does enable participants to make use of sophisticated risk management mechanisms to smooth their transition to a low carbon economy.

## Voluntary mechanisms

Voluntary mechanisms can utilise any of the instrument types discussed above, but are voluntary in nature. Whilst being useful for generating data, preparing industry for mandatory measures and overcoming resistance, these instruments tend to be ineffective at any serious level of mitigation.

## THE SOUTH AFRICAN CONTEXT

### Greenhouse gas emissions structures

79% of the country's emissions profile is made up of emissions associated with energy, with the remainder being industry process emissions, and methane from waste management and agriculture. The high contribution of energy is largely due to the country's reliance on coal for

electricity generation. From an institutional perspective, two organisations dominate South Africa's GHG emissions, accounting for 56% of total emissions (Eskom 44% and Saso 12%).

The structure of the electricity generation market (Eskom is a state-owned monopoly) and the prominence of developmental goals have combined to keep the price of electricity artificially low historically. This has caused a number of problems from both a climate change and growth perspective, not least the decreased incentive for investment in new power generation capacity which resulted in the recent capacity shortfall experienced by Eskom. Cheap electricity also meant that industrial, commercial and household users of electricity have had little incentive to use it efficiently or to invest in more efficient alternatives. Inexpensive electricity has historically been instrumental in attracting energy-intensive firms to South Africa, and large capital investments then caused the economy to become "locked-in" to a pattern of high energy consumption.

### *Energy Sector Policy Implementation*

The implementation of energy policy to address this situation is currently highly fluid and uncoordinated, with no clarity on a long term plan in place or under development. A number of initiatives aligned with Cabinet's climate vision are under development, but these remain stalled by the lack of a long term co-ordinated approach. For the time being, it seems likely that the main emphasis will remain on coal-fired electricity generation. Substantial increases in the price of electricity are expected over the next few years as the price is aligned with the real cost of generation, provided that the National Energy Regulator of South Africa (NERSA) allows electricity prices to rise to cost-reflective levels. This should act as a natural stimulus for the adoption of more efficient practices and technologies. Increasing the cost of electricity so that it reflects the full cost of production is important in order to reduce the distortion in the electricity market as well as to incentivise energy efficiency.

Current developments in the South African electricity market introduce a complex and potentially contradictory range of incentives into the energy economy. In this context, current climate mitigation policy instruments such as the REFIT and an electricity carbon tax could possibly be ineffective or even act as incentives for emissions intensive behaviour. It is imperative that any climate change policy suite act as a stimulus for policy co-ordination within the energy sector. Climate change policy should also be designed to align with current (and proposed) energy policy instruments aimed at conserving electricity use and encouraging renewable and nuclear energy uptake.

### *Modelling the Peak, Plateau and Decline Trajectory*

Cabinet's Peak, Plateau and Decline trajectory is based on the modelling undertaken in the Long Term Mitigation Scenario (LTMS) process. Four scenarios were modelled, none of which go far enough to align with the Cabinet's trajectory in the long term. It appears that aggressive energy efficiency will be sufficient to meet the Peak (aligned with the 2020 34% reduction from baseline emissions offered at Copenhagen), but substantial progress will need to be made in laying the groundwork for the reductions from the remaining technologies modelled in the LTMS (renewables, nuclear, electric cars, passenger modal shift, carbon capture and storage etc) and more, post 2020. The „Use the Market' scenario in the LTMS, modelling the imposition of an escalating carbon price comes closest to the medium and long term ambitions of Peak, Plateau and Decline, seeming to indicate that a price mechanism is likely to provide the heart of the long term mitigation policy suite. This is aligned to international climate mitigation policy thinking and direction. The government has shown commitment to Cabinet's mitigation policy

vision, but faces a number of other policy challenges. South Africa is still a developing country with high levels of poverty and unemployment, so any climate policies must be incorporate the need to grow the economy, create jobs and limit the impact of policies on the poor.

## CLIMATE CHANGE, INDUSTRIAL POLICY AND INDUSTRIAL COMPETITIVENESS

The impact of climate change policies on industrial competitiveness is ambiguous. While climate change creates many opportunities for firms through the development of new markets for low-carbon environmental goods and services and increased efficiencies as a result auditing their production processes, there is a concern that having to internalise the cost of GHG emissions may reduce the international competitiveness of sectors. The impact of climate change policies have to date been relatively small and dwarfed by factors like trade barriers and transport costs. The reason for this is that carbon leakage effects have been largely offset by technology spillovers. The cost impacts of climate change policies, however, vary widely between sectors, and that there are usually a minority of sectors (typically upstream sub-sectors using energy and GHG-intensive processes to produce low value-added products) that are significantly affected. The socio-economic challenges that face South Africa mean that climate change mitigation needs to be balanced with the need for sustained economic growth. In the long term this report finds that climate change policies will support the stated industrial policy objective of diversifying the South African economy away from its current over-reliance on energy- and capital-intensive upstream resource-based manufacturing, and sectors that are no longer viable in South Africa in a carbon-constrained world should thus be allowed to migrate to other parts of the world. In the short to medium term, however, vulnerable sectors should receive support to move towards a more environmentally sustainable growth path built around higher value-added and knowledge-based production and production processes that produce fewer GHG emissions.

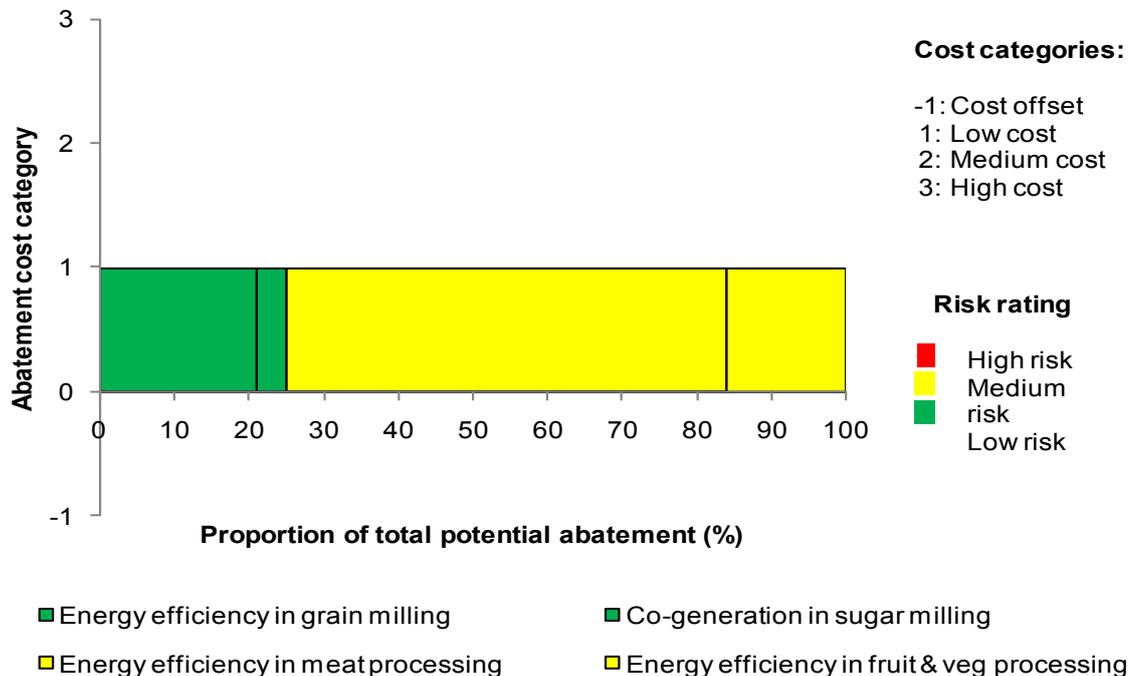
## CLIMATE POLICY IN SOUTH AFRICA: POLICY POINTERS

Best practice guidelines identified for climate change mitigation policy include: Taking a *strategic and holistic approach* to climate mitigation policy, and ensuring *coherence* with other policy areas. *Transparency* is vital to building consensus for the policy instruments chosen. *Long, loud and legal* policies provide the private sector with certainty for planning. *Implement policy slowly, but do it right* to avoid costly reviews and changes which introduce uncertainty.

## SECTOR CASE STUDIES

Severe data limitations make it impossible to create accurate standard abatement cost curves in South Africa at present. *An innovative methodology was developed* to overcome this limitation and *to provide the maximum insight regarding cost, riskiness and abatement potential of available emissions reduction options in a number of focus sectors*. The methodology employs a case study approach based on the use of “indicative abatement cost curves” (IACCs) constructed with the strongest available data for each abatement option in each sector to highlight the attractiveness of the main emissions reduction options open to each focus sector (see section and section for details of the methodology). It must be noted, however, that **the current approach serves as an information tool only**. Much more detailed cost and emissions data (which do not currently exist in South Africa) is needed before it can serve as the basis for policy formulation (see section ).

### Agro-processing



#### IACC: Agro-processing

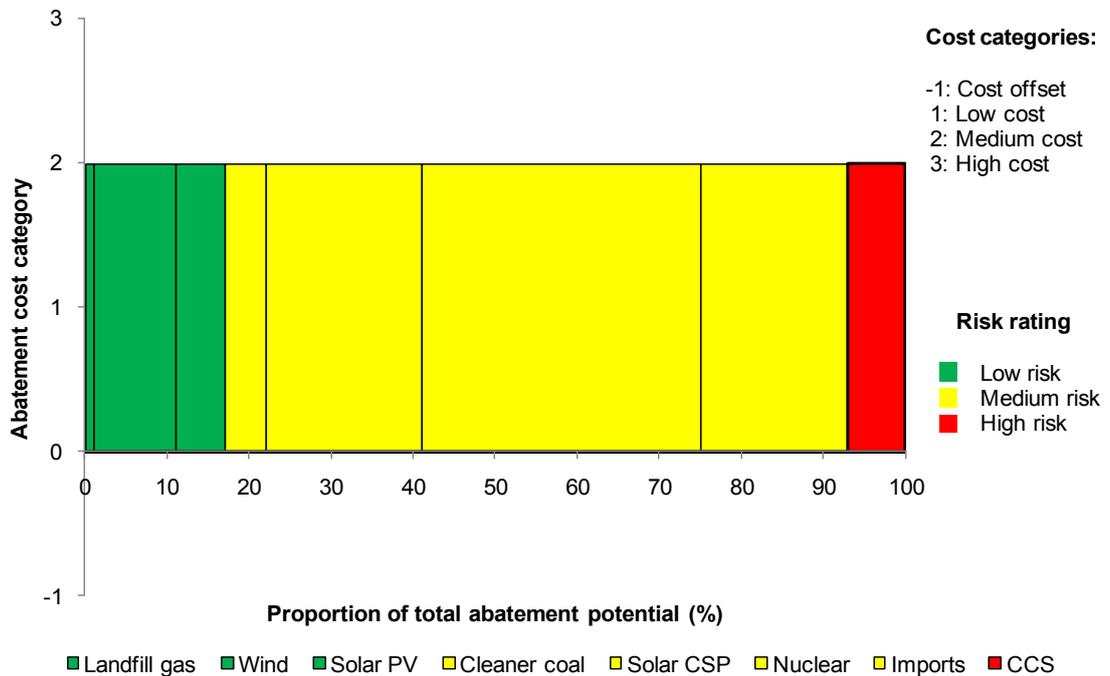
Source: Genesis Analytics, 2010

The Agro-processing case study suggested that climate change is not currently considered a business imperative in this sector. A considerable amount of effort is thus recommended to raise awareness of climate change issues and the particular risks and opportunities it poses for the food industry. In order to develop and implement an awareness programme, research is required to determine quantitative estimates of energy use and GHG emissions. Only five significant mitigation options were identified in this sector. One of these factors, namely solar cooling in the fruit industry, was not included in the IACC because of the lack of available quantitative estimates relating to its attractiveness. The lack of availability of data illustrates that a review of GHG emissions on a sector-wide and sub-sector-wide basis is an imperative for the Agro-processing sector to meaningfully engage in any debate on GHG mitigation and to provide input into the development of GHG mitigation strategies. In summary no significant action can be taken by the food industry unless clarity is obtained on what baseline GHG emissions are. Based on the cost and risk ratings of available mitigation options in the Agro-processing industry, the *attractiveness of available mitigation options* was ranked as “average”.

### Electricity generation and supply

The electricity supply sector is currently dominated by a single utility. Although Eskom is already undertaking various activities in exploring renewable energy, the utility is faced with an imperative to build new base load supply to meet the growing demand in the country. Meeting this growing demand, at least in the medium term, will be done through building new coal fired power stations. It is likely that IGCC (a “cleaner” coal technology) will eventually be used in South Africa, although the next power stations to be built will use supercritical coal technology.

Given the dominance of energy emissions in South Africa's total emission there is a need for ongoing and increased efforts in building renewable energy capacity, in addition to using cleaner coal technologies. Research is required into the most efficient ways of exploiting renewable energy. The electricity supply case study suggested wind, nuclear and solar CSP as the most promising technologies (with medium abatement and low to medium implementation risks, and the potential to contribute 20% or more to the sector's overall greenhouse mitigation). It is noted that in order to ensure grid stability, a range of responses is required; no single technology presents an overall solution for the sector.



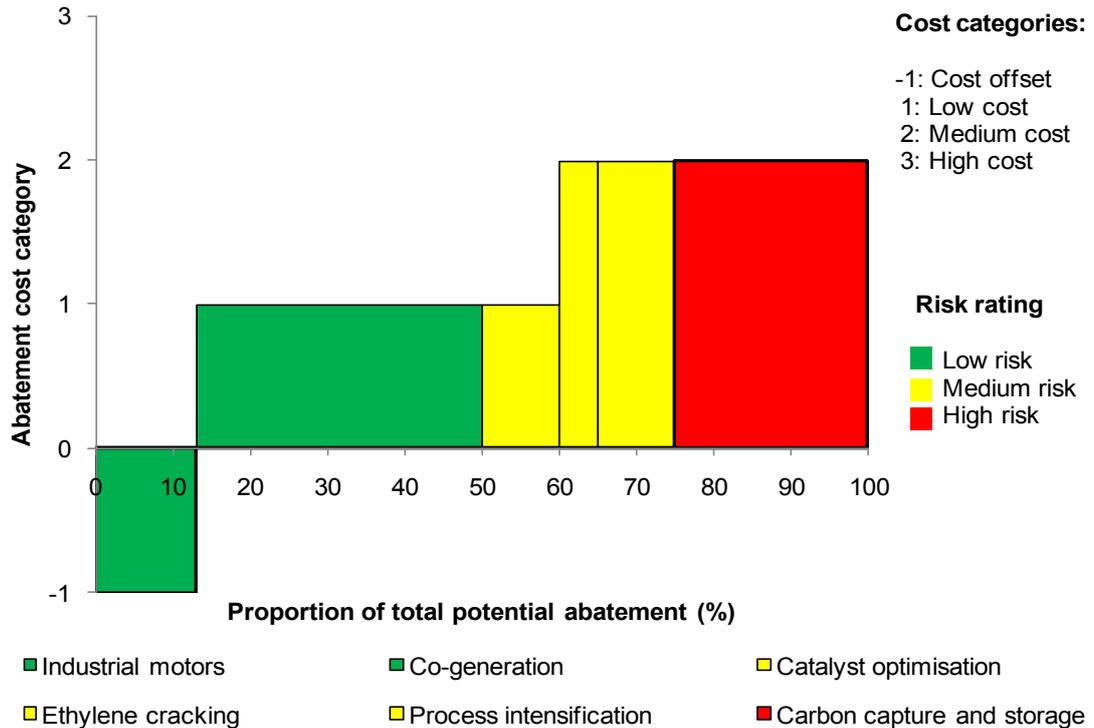
### Electricity generation and supply

Source: Genesis Analytics, 2010

Based on the cost and risk ratings of available mitigation options in the sector, the attractiveness of available mitigation options was ranked as "poor".

### Chemicals

There is a lack of reliable GHG emissions data for the Chemicals sector. According to the LTMS the production of nitric acid, carbide and ammonia generate the bulk of chemical sector emissions. The development of a chemical sector GHG emissions inventory should thus initially focus on the production of these chemicals. However, it is possible that there are other processes that are major sources of GHG emissions. Electricity constitutes a significant proportion of the chemical industry's overall energy spend. Energy efficient technologies are thus likely to become a significant source of competitive advantage in this sector. Significant revenue growth for specialty chemical firms may also be derived from the development and marketing of chemical products which help to reduce energy consumption as well as materials for new energy technology (e.g. solar photovoltaic cells and fuel cells).



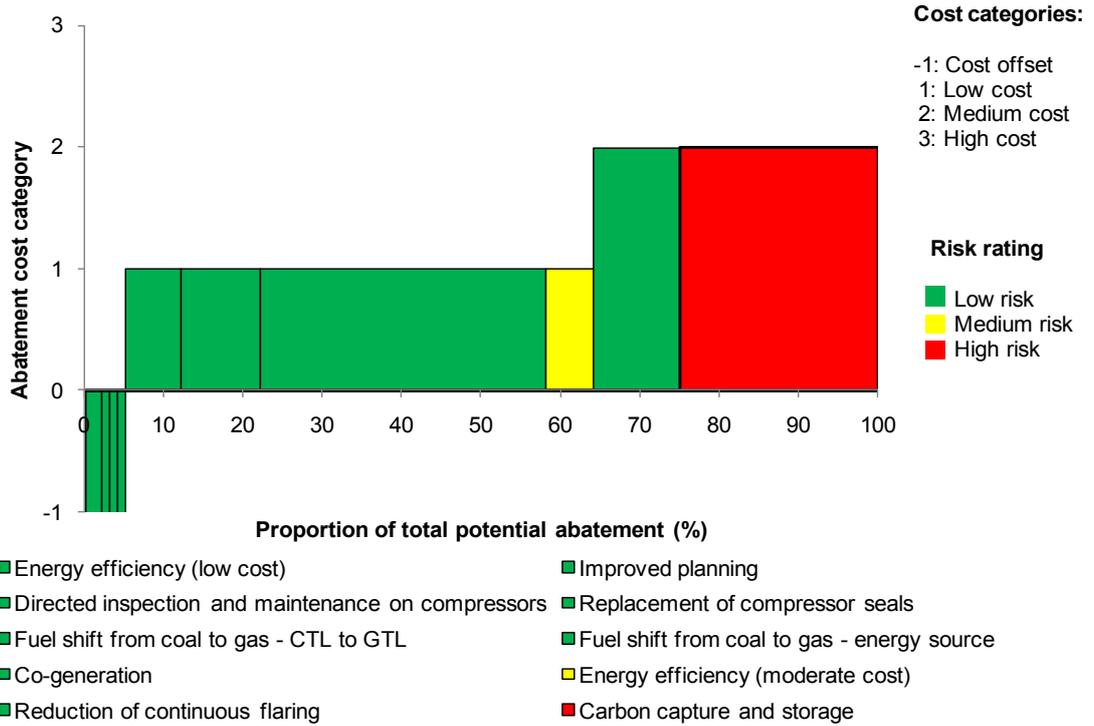
### IACC: Chemicals

Source: Genesis Analytics, 2010

Based on the cost and risk ratings of available mitigation options in the sector, the attractiveness of available mitigation options was ranked as "average".

### Liquid fuels

To get a better understanding of mitigation options, the cost of available technology options, and the reductions that each technology could achieve, the liquid fuels sector needs to undertake plant level investigations of major sources of emissions. The abatement potential and costs of emissions reduction in the South African liquid fuels sector will depend on the industry's ability to implement on-site combined heat & power systems, reduce flaring and implement energy-efficiency opportunities, as well as on the future feasibility of carbon capture and storage. Alternative fuel sources such as natural gas also offer potential to mitigate GHG emission, as does improved planning. Because emissions reduction information in this industry tends to be project specific, the industry needs to be incentivised to share information dealing with climate change mitigation issues. Given South Africa's current "lock-in" on coal-to-liquid CTL as a guarantor of national fuel security, further research to develop alternative processes to retrofit CTL should also be considered. For benchmarking purposes it would be beneficial for local companies to improve their level of expertise in the usage of international protocols to quantify their GHG emissions.



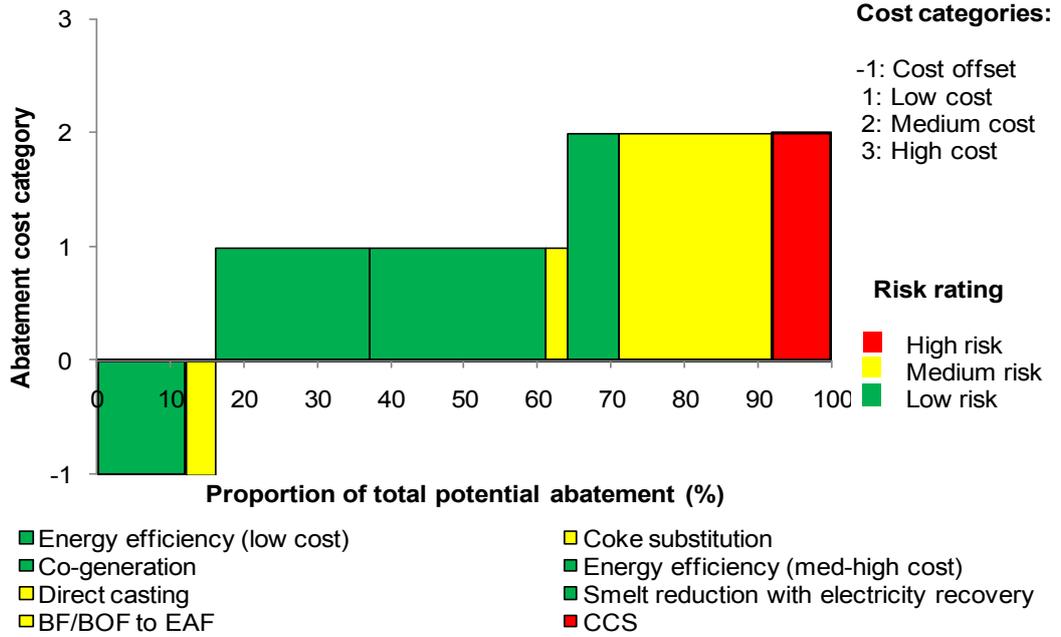
**IACC: liquid fuels**

Source: Genesis Analytics, 2010

Based on the cost and risk ratings of available mitigation options in the sector, the attractiveness of *available mitigation options* was ranked as “average”.

Iron and steel

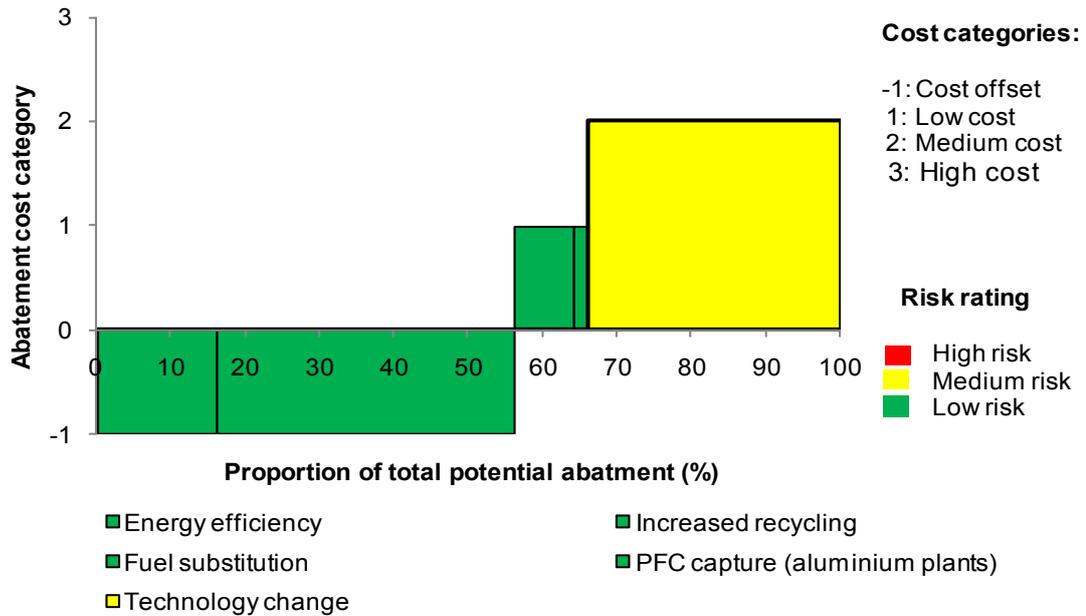
Typically in the order of 10 to 15% of total energy costs can be captured by energy reduction options with payback of less than two years. The primary barriers to realising these opportunities are typically organisational. Most companies already understand the rationale of switching to different approaches to cast and roll some specific steel products, e.g. direct casting. However such technology changes imply high switching costs and some level of risk, particularly if market conditions are uncertain and credit tight. These projects generally have positive returns over the long term, allowing a gradual migration to these technologies, e.g. new build only. Increased steel recycling and shifting technology from the blast furnace route to the electric arc furnace offers the most significant mitigating potential. However, this shift is somewhat constrained by the availability of scrap metal required by the EAF. An important mitigation option is therefore to increase iron and steel recycling in the SA economy.



**IACC: Iron and steel**  
 Source: Genesis Analytics, 2010

Based on the cost and risk ratings of available mitigation options in the sector, the attractiveness of available mitigation options was ranked as "average".

Non-ferrous metals

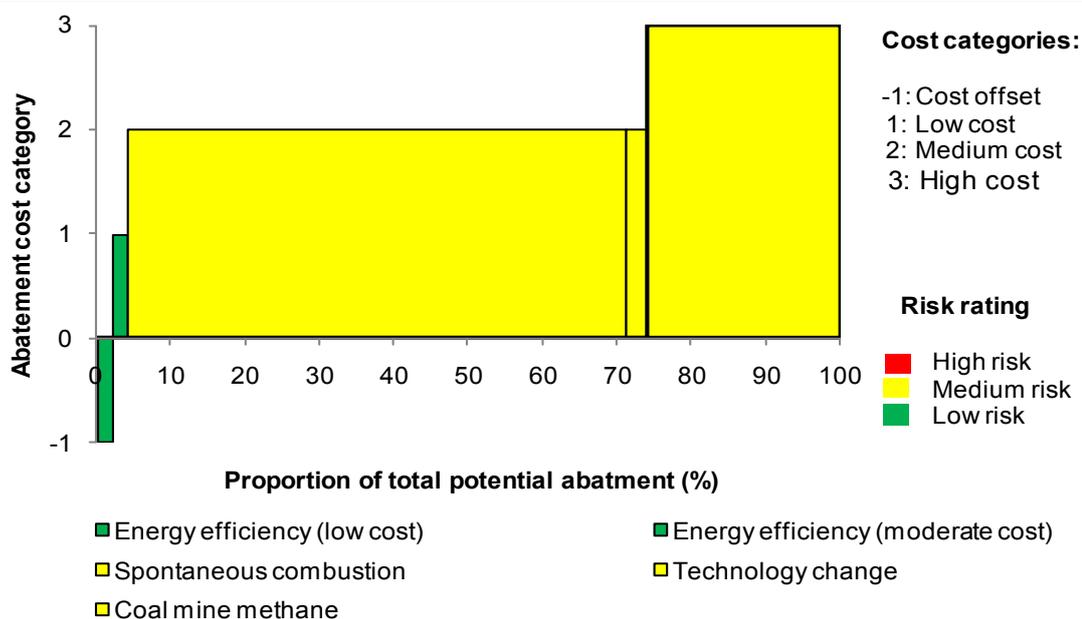


**IACC: Non-ferrous metals**  
 Source: Genesis Analytics, 2010

Sector-specific data is almost non-existent on the costs and emission reduction potentials associated with the various abatement options. Furthermore, indications are that those options that have received attention, e.g. PFC reduction from aluminium, are relatively insignificant for the sector. There is a strong need for the industry to establish baselines in terms of both emissions from the sector and the costs and emission reduction potentials associated with the various technologies identified here. Statistics on recycling are also very poor, which makes it difficult to assess the potentially large abatement potential from increased recycling. Based on the cost and risk ratings of available mitigation options in the sector, *the attractiveness of available mitigation options was ranked as “attractive”*.

### Mining

Globally mitigation opportunities within the mining sector have tended to focus on coal mine methane projects (e.g. as seen by the large number of these projects taking place under the auspices of the Clean Development Mechanism). However, South African coal mines have relatively low concentrations of methane, and projects to capture and utilise the methane have generally been thought not to be economically viable. This might become less true in the future as deeper “gassier” coalfields are exploited. Furthermore, technological advancements may make this feasible even in low concentration mines. Nonetheless, fugitive emissions from coal mines are a very significant source of GHG emissions in South Africa. It is therefore an essential area to target, even though these projects are likely to prove costly. It is recommended that the cost of methane projects are further scrutinised to see if they are in fact prohibitive.



IACC: Mining

Source: Genesis Analytics, 2010

Energy efficiency mitigation opportunities will yield relatively minor results. These should still be pursued since their GHG savings are still significant in absolute terms. However, many of these measures are not routinely implemented on South African mines. The reasons for this need to be investigated and measures and incentives put in place to encourage their uptake (e.g.

overcoming inertia, and educating sector members as to the opportunities that exist). Spontaneous combustion does not occur at all opencast coal mines, and depends on the mining method and the nature of the overburden (its carbonaceous content) for underground mines. It is also a significant problem on waste dumps and abandoned mines. Low technology mitigation measures are reasonably successful, although fairly costly. Coal fires arising from spontaneous combustion is largely overlooked by the international community. The coal mining sector needs to be proactive in this regard through collaborative research projects.

Based on the cost and risk ratings of available mitigation options in the sector, the attractiveness of available mitigation options was ranked as “poor”.

### Case studies: general conclusions

The sector case studies showed that data on GHG emissions, abatement opportunities and mitigation costs is not readily available in South Africa. The data that does exist is too high-level to effectively inform policy development, which requires data at an individual process and SIC code to evaluate the impact of climate policies on individual sectors. It is therefore important that a detailed national GHG emissions inventory is developed which is in line with Statistics South Africa’s SIC system. Additional detailed primary research is also required on the mitigation opportunities available to individual sectors. Detailed information can play a crucial role in identifying how best South Africa can capitalise on the opportunities offered by GHG mitigation. In the shorter term, if South African firms and industries can brand themselves as a “green” alternative, this could prove a substantial competitive advantage in developed country markets where consumers are much more discerning on sustainability issues.

### Case studies: Key observations

A number of insights emerge (which will inform subsequent analysis) when the 7 IACCs in this section are considered together:

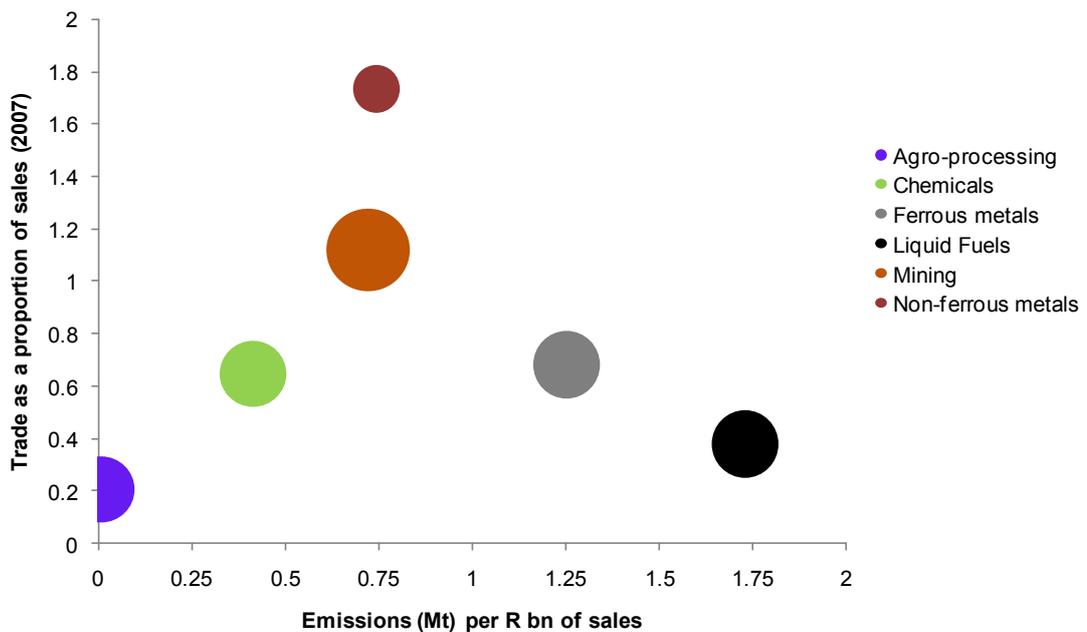
- In only 2 sectors (Liquid fuels and Chemicals) are significant amount of potential abatement reliant on high risk technologies.
- In all but 2 sectors (Electricity supply and generation and Mining) there are a number of low risk options available with negative or low cost ratings.
- In only 3 sectors (Chemicals, Iron and steel and Non-ferrous metals) do negative cost options make up more than 10 percent of total potential abatement.
- Only 1 high cost abatement option was identified (in the mining industry).
- 2 sectors face significantly poorer abatement opportunities than the rest. They are Electricity generation and supply and Mining.

## **IMPACT OF CLIMATE POLICIES ON INDIVIDUAL SECTORS**

In order to evaluate the likely impact of carbon policies on individual sectors, a methodology was developed based on international precedents. The methodology utilises a proxy for the ability of the firms to pass on carbon costs to consumers without losing significant market share (which is ultimately what determines the impact of carbon policies on a sector) and three proxies for the likely cost increase that firms could face as the result of the introduction of a carbon price, to evaluate the vulnerability of sectors to competitiveness issues as a result of

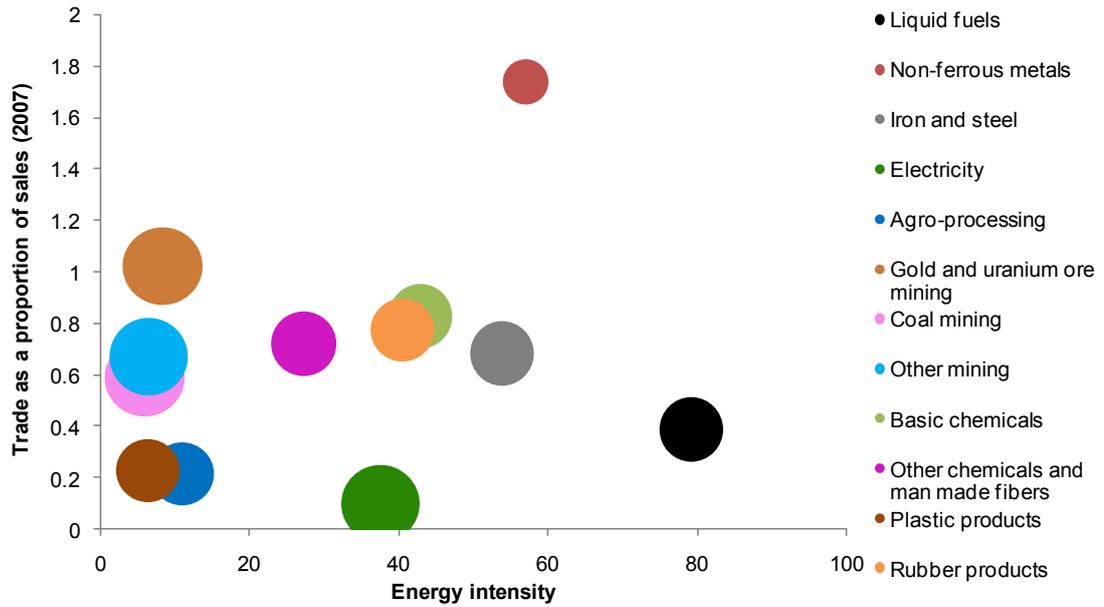
carbon policies. Trade intensity is used as the proxy for the ability to pass on costs. Three proxies for likely cost increase are used because data issues make it unclear much confidence can be assigned to the results any one proxy. The three proxies are: emissions intensity (calculated based on best-available data); energy intensity; and electricity as a proportion of the total cost of firms. Sectors that sit towards the edges of the graphs that follow are considered to be more vulnerable to climate policies than sectors that sit towards the XY axis intersection (these sectors are likely to encounter higher costs as a result of a price on GHG emissions and have less scope to pass on costs to consumers).

In addition, a qualitative measure of the attractiveness of the abatement options available to sectors based on the IACCs in the case studies are used to further inform the vulnerability of firms to climate policies. The larger the bubbles the less attractive the abatement options available to firms are believed to be, and thus the more vulnerable they will be to carbon policies.



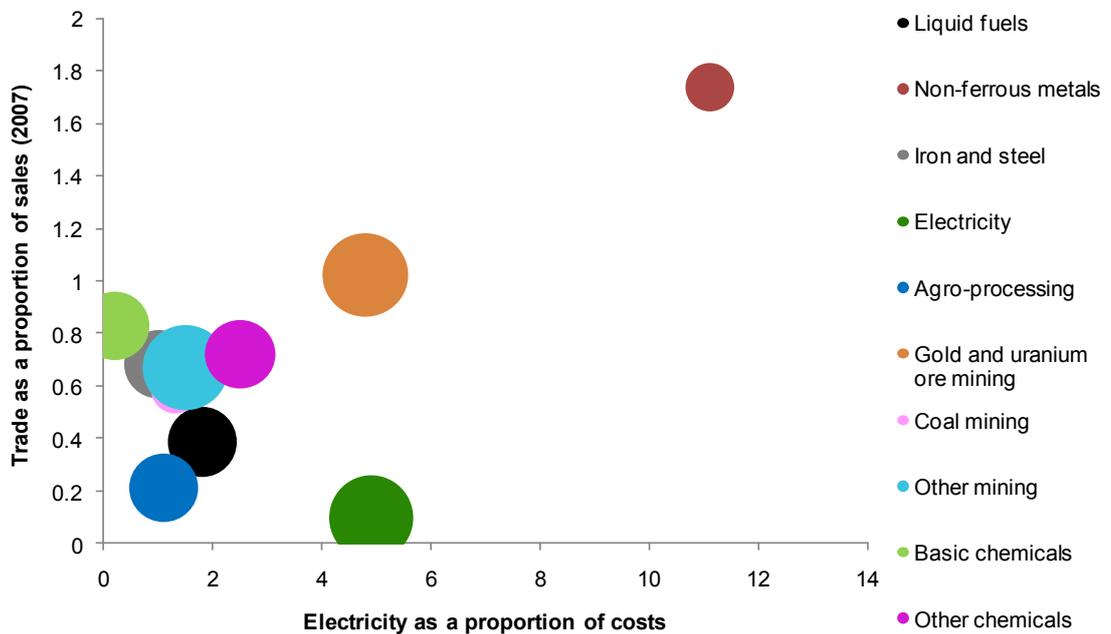
**Vulnerability to climate policies (emissions intensity as cost proxy)**

*Source: Genesis Analytics, 2010*



**Vulnerability to climate policies (energy intensity as cost proxy)**

Source: Genesis Analytics, 2010



**Vulnerability to climate policies (electricity costs as cost proxy)**

Source: Genesis Analytics, 2010

The proxy chosen for exposure to carbon costs can have a significant influence on the outcome of the analysis. The liquid fuels sector was found to be the most emissions intensive (emissions per unit of revenue) and the most energy intensive (energy costs in relation to value-added), while the non-ferrous metals sector was the most electricity intensive (electricity cost as a proportion of total costs) and also the most exposed to international trade. Mining is

also heavily traded and gold and uranium mining was found to be very energy and electricity intensive. The basic chemicals, rubber products and ferrous metals sectors also appear to be relatively vulnerable to carbon costs as a result of a combination of high energy intensities and significant exposure to international trade. The assessment of the attractiveness of abatement options available to sectors indicates that the quantitative indicators alone potentially overestimate the vulnerability of the non-ferrous metals and ferrous metals sectors to carbon costs, while underestimating the vulnerability of the liquid fuels and mining sectors.

The analysis indicated that all the focus sectors (with the exception of agro-processing) are likely to be considered emission-intensive and trade-exposed based on best available data. Overall the findings of this analysis are consistent with international evidence that the likely impact of climate policies vary significantly between sectors, and that there are usually a few sectors that are expected to be disproportionately impacted. In the South African context, Liquid fuels and Non-ferrous metals seem to be particularly vulnerable to competitiveness concerns as a result of climate policies.

## **CLIMATE CHANGE INCENTIVES IN SOUTH AFRICA**

From an economic theory and fiscal affordability perspective, incentives should play a supportive as opposed to a central role in the country's climate policy suite. Currently, the set of climate mitigation policies in place in South Africa is dominated by incentives, a situation which requires balancing out by other forms of policy instruments going forward. Given their fiscal burden, incentives should be used only where they are the most appropriate policy instrument. Theory advises that the use of incentives should focus either on addressing market failures, or smoothing the transition from one pricing environment to another. Whilst the REFIT is a highly appropriate use of an incentive mechanism (to address a market failure), additional intervention is required to unlock the institutional issues constraining its implementation. The use of tax exemption incentives for energy efficiency can be argued as less appropriate. Energy efficiency interventions also suffer from a market failure, but one which is likely to be automatically addressed as the electricity price inevitably rises. Energy efficiency is a negative cost mitigation option which faces non-price barriers which are more appropriately addressed through alternative policy mechanisms. Tax exemptions for the CDM may provide a stimulus to the use of this international mechanism, but again, other barriers still need to be removed before this incentive can take effect.

No incentives exist for R&D in any specific low emission technology currently, and these are recommended, both for the development of areas of competitive advantage for South Africa, and to adapt low emissions technologies to domestic circumstances. The current incentive package is focused exclusively on the energy sector with no transport sector incentives. Technologies such as the electric car may well afford the country a competitive advantage if their development is sufficiently resourced. Similarly, no incentives exist yet to smooth the transition to a low carbon economy for sectors vulnerable to a future carbon price. This is anticipated to be critical for a highly emissions intensive country like South Africa.

## CONCLUSION – THE WAY FORWARD

### Timeframes

As a developing country, South Africa has been able to delay its emissions peak to 2020 whilst retaining credibility in the international arena. In order to meet this peak, the LTMS shows that the country must embark immediately on an aggressive energy efficiency programme (the Start Now) scenario, whilst preparing the way for including a significant level of renewables and nuclear generation into the electricity grid, together with mitigation technologies in transport (electric cars), liquid fuels (carbon capture and storage) and others.

Therefore, apart from a few notable exceptions, the country has time to develop an optimal mitigation policy package to drive the implementation of the remaining LTMS wedges from 2020. These exceptions include ensuring the success of an aggressive energy efficiency drive, identifying areas where the country can capture new sources of international competitiveness, avoiding lock-in to technologies and new industries which will hamper emissions reduction into the future, and ensuring that policy, the regulatory environment, institutions, data, financing and technologies are in place to begin the implementation of low carbon options come 2020 if not before.

### Policy development guidelines: use of economic instruments

In order to achieve the optimal level of GHG emissions abatement on a continuous basis, the cost of emissions must be incorporated into the price signals of the international economy. Economic theory indicates that this is most efficiently done through the use of a broad based economic or price instrument. A range of appropriate regulatory and incentive instruments will be important to support the emergence of a carbon price over time. These should be used to:

- accelerate investment in clean technologies whilst the carbon price is still too low to counteract their risk;
- in areas where non-price barriers exist which are more appropriately targeted through a non-price mechanism and before a significant carbon price comes into effect; and
- support vulnerable sectors to transform to a low carbon economic environment.

The LTMS scenario which comes closest to the medium and long term ambitions of the Peak, Plateau and Decline trajectory is „Use the Market’, which models the imposition of an escalating carbon price. *At present, however, there is insufficient information available regarding GHG emissions and abatement options at a sectoral level in South Africa to accurately determine what the impact of a given carbon price will be on individual sectors.* The timeframe discussion above, together with the analysis of optimal policy design outlined earlier in this paper recommends that climate policy development is approached slowly, with an emphasis on getting correct data, building consensus, and providing long, loud and legal policy signals so that the private sector has sufficient policy certainty to ensure optimal investment planning.

It is anticipated that the South African climate policy suite will eventually comprise a number of complimentary policy instruments, tailored to the country’s specific circumstances. The components of this suite of policies will be the outcome of a policy development process that is likely to include extensive stakeholder engagement. The rest of this section thus provides

recommendations for possible policy options which could be considered for inclusion in the eventual suite of policies:

**Generate Data.** It is strongly evident in the sector case studies that there is a critical lack of data at a sectoral level in the country. In a sector like Agro-processing, for instance, it is almost impossible to draw any firm conclusions on the impact of climate policies on the sector because of the lack of available data. Gathering data must be prioritised in order to avoid inappropriate and potentially damaging policy. A delay in mandatory policy may be negotiated as an incentive for firms to disclose verified emissions data.

**Pursue energy efficiency.** An aggressive energy efficiency programme must be pursued, and could be supported by the PCP or similar white certificate scheme, with the steep electricity price escalation acting as a natural stimulus, and technology standards supporting the adoption of mature and standardised energy efficiency technologies. Attention will need to be paid to potential carbon leakages from an indirect policy instrument like the PCP. The sector case studies indicated that negative or low cost energy efficiency options were available to most of the sectors. The relative abatement potential of energy efficiency options, however, varies widely between sectors. The evidence from the sector case studies does question the assumption used in the LTMS that energy efficiency options are negative cost options. In only 2 of the 7 sectors do negative cost energy efficiency measures (including more energy efficient industrial motors) make up more than 10% of identified abatement potential.

**Support technology development and adoption.** Subsidies and incentives for R&D in strategic low carbon areas are required in advance of the introduction of a carbon price to develop a competitive advantage for the country, and to ensure the development of suitable technologies for South Africa's low carbon future. The REFIT is a good example of an appropriately applied subsidy, although the issues surrounding policy in the energy sector need to be resolved to enable the REFIT to be implemented. There are no existing direct incentives for R&D in any specific low emissions technology in South Africa. Low emissions R&D is indirectly covered by general incentives. Given the prevalence of inherently risky abatement options (an indication that the technology has not matured yet – leaving scope for further R&D) with high abatement potential in the sector case studies, there appears to be sufficient justification for incentives which target the creation of a competitive advantage in a particular technology with a view to capturing the market for this technology internationally (eg. Centralised solar thermal power generation). It is unlikely that the fiscus has the resources to incentivise R&D in all of these opportunities, but should rather focus on one or two more likely candidates which offer the best immediate prospects for abatement. The current incentive package is strongly focused on energy, with no incentives in the transport sector at all, although transport will play an important role in medium to long term emission reductions. South Africa is developing a competency in the electric car, and has an automotive sector which may be able to support the creation of a competitive advantage in this mitigation technology. Incentives would be very appropriate to support this emerging industry. A second suggested use of R&D incentives is to adapt existing low emissions technology for application in the South African environment, such as fine-tuning solar water heater design for the country's climate, manufacturing skills and natural resources.

**Align climate and industrial policies.** Climate and industrial policies should be aligned, ensuring low carbon criteria are incorporated in all industrial policy projects and decisions, and that climate change opportunities are exploited directly, with environmental goods and services prioritised as a sector for development.

**Utilise voluntary measures.** Voluntary mechanisms like reporting or emissions reduction agreements can build consensus on upcoming mitigation policy, introduce firms to the idea of reporting and verifying emissions, and generate much-needed data to inform the policy design process. The systematic exploitation of CDM opportunities (particularly programmatic CDM) could also provide access to substantial amounts of funding for abatement activities in South Africa at very little cost to government (the cost of unlocking blockages). Sector case studies identified opportunities for CDM projects in all the focus sectors apart from Non-ferrous metals.

**Consider implementing a carbon price.** The sector case studies showed that a relatively low cost carbon price would incentivise the uptake of emissions reduction technologies and lead to significant GHG reductions in all but two sectors, namely the Electricity generation and supply and Mining sectors (these are the only sectors where low cost abatement options does not account for at least 60 percent of available abatement opportunities). The two economic instruments available to implement a broad-based carbon price in South Africa are a carbon tax and an ETS. Theoretically it is also possible to implement these two instruments together. A carbon tax could be gradually introduced, preceded by, or in parallel with a voluntary data disclosure scheme with an incentive such as tax rebates for the first few years as a reward for full disclosure. The impact of the tax will be optimal if it is aimed at emissions at source. The tax could generate significant fiscal revenues and could ensure that the overall bundle of climate change policies is revenue neutral (i.e. it could offset the cost of other climate change policies). Targeted government transfers could be used to offset the impact of a carbon tax on the poor. An ETS would benefit from an initial voluntary phase to generate data and familiarise participants with the mechanics of emissions trading. It should have broad coverage to maximise efficiency. Initially permits may be grandfathered, but a relatively fast move to full auctioning is suggested to ensure fiscal, environmental and economic efficiency and to address equity concerns and potential barriers to entry. Market power and a lack of liquidity are likely to significantly impact any local ETS as a result of South Africa's emissions profile. A local ETS should thus either be linked to an accredited international ETS, or be designed to minimize the risk of disproportionate market power. It is important to consider the effect that a reduction in coverage to address market power may have on the scheme's efficiency. If this is not taken into consideration, the rationale for having an ETS in the first place may not be adhered to. The benefits of design features to reduce price volatility must be considered against their impact on emissions reduction certainty and increased administrative complexity.

**Provide transitional assistance.** As carbon prices or international discrimination based on carbon intensiveness of exports is introduced, transitional incentives can be used to ease the transition for vulnerable or trade intensive sectors. These are best used temporarily, and not to support highly emissions intensive industries in the long term. At present there are no incentives in place to smooth the transition to a low carbon economy for vulnerable sectors. This is anticipated to be crucial for an economy which is so dependent on highly energy intensive exports, and has many vulnerable sectors which are currently drivers of economic growth and employment. Partial or full temporary exemption from policies that implement a carbon price may provide temporary room for industries to increase their carbon efficiency. Subsidies and soft loans for energy and carbon efficient technologies are likely to play a role in assisting these industries to increase their GHG-emission efficiency. The analysis in section indicated that, consistent with international experience, there is likely to be a minority of local sectors that will be disproportionately affected by climate change policies. The Non-ferrous metals and liquid fuel sectors, in particular, seem highly vulnerable to competitive concerns. The sector case studies also showed that the attractiveness of available abatement options vary significantly between sectors, and that there are a minority of sectors that will find it particularly difficult to reduce their GHG emissions. These two factors seem to indicate that

targeted transitional assistance will be justified in South Africa. Sectors which may benefit from this type of assistance include Non-ferrous metals, Liquid fuels and Mining

**Implement performance and technology standards.** Performance and technology standards in general are not economically efficient and do not lead to lowest cost abatement. In South Africa, however, there are 2 instances where standards seem warranted. Technology standards supporting the adoption of mature and standardised energy efficiency technologies can be useful to support energy efficiency – provided that the technologies mandated are expected to lead to cost benefits or only negligible cost increases. Furthermore, in order to meet the Peak, Plateau trajectory, performance standards may be an effective instrument to ensure the necessary shift in generation mix to achieve the zero carbon grid envisaged by the 2050 30%- 40% target, given that Eskom is a regulated monopoly.

**Consider transport emissions.** Transport has been specifically excluded from this study, but being a significant source of emissions in the future warrants careful attention. Appropriate policy instruments for transport will be particularly important.

### Sector actions

Based on the sector case studies a number of key actions can be highlighted that will enable focus sectors to engage constructively in the climate change debate and to assist them with moving towards low-carbon production (see section for more detail).

**Agro-processing.** There is a dearth of information regarding climate mitigation opportunities and emissions data in the Agro-processing sector. In addition, the study found that awareness of climate change issues and the particular risks and opportunities it poses for the Agro-processing industry need to be raised. Substantial research is required therefore to determine quantitative estimates of energy use and GHG emissions and to identify, quantify and consolidate the abatement potential offered by all potential abatement options in this sector.

**Electricity generation and supply.** The lack of implementation of policy in a co-ordinated fashion is currently hampering effective policy development and needs to be addressed. The cost profile of available abatement options means that this sector will need to find new ways of harnessing all potential energy sources in order to function effectively in a carbon constrained world. There are no low or no cost options available. Since electricity supply dominates carbon emissions and thus determines the carbon profile of most other industry, and given that assets in this sector are long lived and expensive, addressing the organisational issues in this sector should be a climate mitigation policy priority. Solar CSP appears to represent a potential source of competitive advantage for the country, and should be proposed for incentive funding. The way forward on nuclear needs to be clarified, with a plan for capturing technological competitive advantage (pebble bed modular reactor), or releasing funding for more promising technologies.

**Chemicals.** Reliable disaggregated GHG emissions data for the Chemicals sector needs to be generated. Electricity constitutes a significant proportion of the chemical industry's spend and energy efficient technologies are likely to become a significant source of competitive advantage in future. At an operational level, firms should identify high priority energy saving projects such as refraining from running equipment under no load, improving the Power Factor Correction (PFC), installing bearing technologies that are geared to reduce friction; improving the motor electrical efficiency by carefully assessing the practice of rewinding of motors; and exploring utilising smaller motors. Significant revenue growth for specialty chemical firms may be derived

from the development and marketing of chemical products which help to reduce energy consumption as well as materials for new energy technologies like solar photovoltaic cells and fuel cells). The Chemical sector is a potentially vulnerable sector to climate mitigation policies, and should therefore prioritise data collection and early action in energy efficiency to motivate for transitional subsidy protection in the future.

**Liquid fuels.** Plant level investigations of major sources of emissions should be undertaken to form a better understanding of the availability and cost of abatement technologies and potential GHG reductions. Emissions reduction information tends to be project specific, highly proprietary and un-transparent. The industry needs to be incentivised to share information dealing with climate change mitigation. Improvement in the local level of expertise in the usage of international protocols to quantify their GHG emissions would be beneficial for benchmarking purposes. The abatement potential and costs of emissions reduction in the South African liquid fuels sector will depend on the industry's ability to capture CHP, reduce flaring and implement energy-efficiency opportunities, as well as on the future feasibility of carbon capture and storage. Alternative fuel sources such as natural gas should be considered and supported. Strategically, improved planning is the key to improved implementation and operation. Given South Africa's current "lock-in" on CTL as a guarantor of national fuel security, further research to develop alternative processes to retrofit CTL should also be considered. The sector should promote CCS as a potential recipient of R&D incentive financing, with decision points identified for the viability of the technology.

**Iron and steel.** Driving towards more energy-efficient processes should remain one of the main focuses of the iron and steel industry. Technologies with a payback period of less than two years could generate savings in the order of 10 to 15% of total energy costs. The primary barriers to realising these opportunities are typically organisational and should be addressed. Increased steel recycling and shifting technology from the blast furnace route to the electric arc furnace offers the most significant mitigating potential. This shift is somewhat constrained by the availability of scrap metal required by the EAF. An important mitigation option is therefore to increase iron and steel recycling in the SA economy. As a sector potentially vulnerable to climate mitigation policies, this sector will need to justify the use of transitional subsidies, and early action on energy efficiency may stand the sector in good stead.

**Non-ferrous metals.** Sector specific data is almost non-existent on the costs and emission reduction potential of individual abatement options. Indications are that those options that have received attention, e.g. PFC reduction from aluminium, are relatively insignificant. To better be able to engage with government, there is a need for the industry to establish baselines in terms of both emissions and the costs and emission reduction potentials associated with various abatement technologies. Statistics on recycling are also poor and need to be improved to be able to assess the potentially its large abatement potential. As a particularly vulnerable sector to climate policies (highly traded and emissions intensive), it is strongly in the sector's interests to provide the data which justifies potential transitional subsidies.

**Mining.** Globally mitigation opportunities within the mining sector have tended to focus on coal mine methane projects. South African coal mines have relatively low concentrations of methane, and projects to capture and utilise the methane have generally been thought to be economically unviable. It is important to investigate technology advancements that could make methane projects feasible in low concentration mines given that fugitive emissions from coal mines are a significant source of GHG emissions in South Africa. It is important to gain a better understanding of methane project costs to confirm if costs really are prohibitive locally. Energy efficiency mitigation opportunities will yield relatively minor results, but their GHG savings are

still significant in absolute terms. It is important to investigate the reasons why many of these measures are not routinely implemented. Spontaneous combustion in coal mines is a significant issue. It also affects waste dumps and abandoned mines. Low technology mitigation measures are reasonably successful but fairly costly in avoiding coal fires arising from spontaneous combustion. The issue of spontaneous combustion in coal mines is largely overlooked and the reasons for this needs to be investigated and addressed. Similarly to metals and chemicals, mining is an emissions and trade intensive sector, and will have to justify the use of transitional subsidies.

# 1. INTRODUCTION

This report investigates the viability of using economic instruments to mitigate greenhouse gas (GHG) emissions in South Africa. The aim of this report is to gain a better understanding of the actual policy mechanisms which are available to achieve emission reductions, and their potential impacts on different South African sectors within the context of South Africa's industrial policy framework. The findings of the study will contribute to the national discourse around GHG emission reduction regulation, and empower industry to engage with government constructively to develop the most efficient and effective policy mechanisms to move South Africa to a low-carbon economy in the long term. In addition, the project will highlight what abatement options are available to individual sectors.

The report starts off with a short section outlining the methodology followed. It then proceeds to provide an overview of the economic instruments available to mitigate climate change and highlights important features of each with respect to their design and implementation. This section also looks at criteria for evaluating the suitability of the different instruments. Section provides a more practical analysis of the different instruments by evaluating the environmental, economic and fiscal efficiency of each instrument given the characteristics of the South African economy. The interplay between climate change and industrial policy is investigated in the section by evaluating what the impact of putting a price on carbon will be on the policy objectives identified in the National Industrial Policy Framework. Based on the preceding sections, a number of parameters that will be useful to inform the implementation of climate change policies in South Africa are provided in section .

In order to inform the implementation of climate policies in practice, an innovative framework that takes account of data limitations in South Africa is developed in section to provide case studies that assess available GHG emission mitigation/reduction actions in a number of focus sectors. The focus sectors are as follows: Agro-processing; Electricity generation and supply; Chemicals; Liquid fuels; Iron and steel; Non-ferrous metals; and Mining.

The case studies place the analysis of available mitigation options within a wider sector context by starting off with a definition of the relevant sector and an overview of any data issues that may complicate the analysis of the sector from a climate change perspective. They then proceeds to provide a general overview of the sector, the relevant sector's greenhouse gas (GHG) emissions profile and current climate change mitigation actions being undertaken by the sector. An indication of the relative attractiveness of potential measures to reduce carbon emissions in the sector is also provided, followed by a detailed description of each measure. The case studies conclude by identifying new opportunities arising from the implementation of climate change mitigation measures in order to identify opportunities that support the case for implementing climate change initiatives in a sector (or at least reduce the cost of complying with climate change regulations). For each sector, emissions reduction opportunities relating to scopes 1 and 2 of the Greenhouse Gas Protocol (on-site direct emissions, and indirect energy emissions) only will be formally included in the analysis. Section concludes by highlighting further actions required at a sectoral level to confirm and deepen the analysis and to contribute to the policy dialogue. The recommended actions will prepare the individual sectors to engage constructively with government in the climate change debate, while also generating the information government requires for policy-making.

Section considers the impact of climate change policies on individual sectors. A brief introduction is provided to frame the analysis that follows before a methodology to assess the vulnerability of individual sectors to climate change policies is developed. The methodology is then applied to the seven focus sectors.

Section looks in more detail at the types of incentive programmes that can be used to support greenhouse gas emissions reductions in South Africa. It aims to provide an overview of current government support programmes and incentives relating to greenhouse gas mitigation. A range of mechanisms are already in place to provide stimulus for investment in energy efficiency, renewable energy and clean technology and the report aims to catalogue and review these, as well as commenting on their likely effectiveness. This section provides insight into the rationale for using incentives to aid the transformation to a low carbon economy. South Africa's existing incentives are then discussed and evaluated. Recommendations will be made for further suitable incentive structures that could be introduced going forward. Finally, a brief section considers some of the incentives that are in place in other countries and whether these have any relevance for South Africa.

The report concludes by identifying possible policy options which could be considered for inclusion in the eventual suite of policies, and providing a summary of the key actions that will enable focus sectors to engage constructively in the climate change debate and to assist them with moving towards low-carbon production

## 2. METHODOLOGY

### 2.1. GENERAL

At its Lekgotla of July 2008, Cabinet indicated a „Peak, Plateau and Decline’ emissions trajectory and mitigation policy vision for the country (van Schalkwyk, 2008), aimed at meeting the 2050 GHG mitigation target of a 30-40% reduction from current emissions developed by the LTMS as the “required by science” scenario. This trajectory has been supported by the Governments conditional offer at the Copenhagen Conference of the Parties of a 34% emissions reduction from Business as Usual by 2020, and 42% by 2025 (Mundy, 2009). As of yet, there has been no formalisation of these targets or vision, and this project has been undertaken in the absence of either a firm set of national targets or sectoral targets. The division of effort between sectors is largely a strategic political process, and one which lies firmly outside of the remit of this project. However, the project has been undertaken with the „Peak, Plateau and Decline’ trajectory in mind, particularly the level of effort and timeframes that this will require.

The current report deals firstly with economic instruments to mitigate climate change. Because economic instruments are usually implemented within a broader package of policy options, other policy options are also addressed in this report. The focus is however on economic instruments, and other policy instruments are addressed in less detail. The project considers Scope 1 (direct emissions) and Scope 2 (indirect emissions from electricity) emissions only. Scope 3 emissions (non-electricity indirect emissions) are excluded from the analysis.

### 2.2. EVALUATION OF ABATEMENT OPTIONS: SECTOR CASE STUDIES

As a result of the data issues highlighted in Appendix (which will be further expanded upon in the sector case studies) it is not possible to create accurate standard abatement cost curves for the focus sectors in South African at present. As a result, a case study approach to the attractiveness of emissions reduction options that utilise “indicative abatement cost curves” was constructed with the strongest available data for each abatement option.

The implications of a case study approach are the following:

- Each sector is independently considered;
- Direct comparisons between sectors are not possible;
- No inferences about the distribution of the total cost curve for South Africa (including all sectors) can be made from the focus sectors.
- **The current approach serves as an information tool only.** It would need to incorporate much more detailed cost and emissions data (which does not currently exist in South Africa) before it can serve as the basis for policy decisions.

The strength of the current analysis is that it *builds a model that works in spite of all the data gaps that currently exist in South Africa*. Furthermore, by identifying the holes in the data at present, the study lays the groundwork for the further research that is required to move towards comprehensive abatement cost curves for different sectors in South Africa.

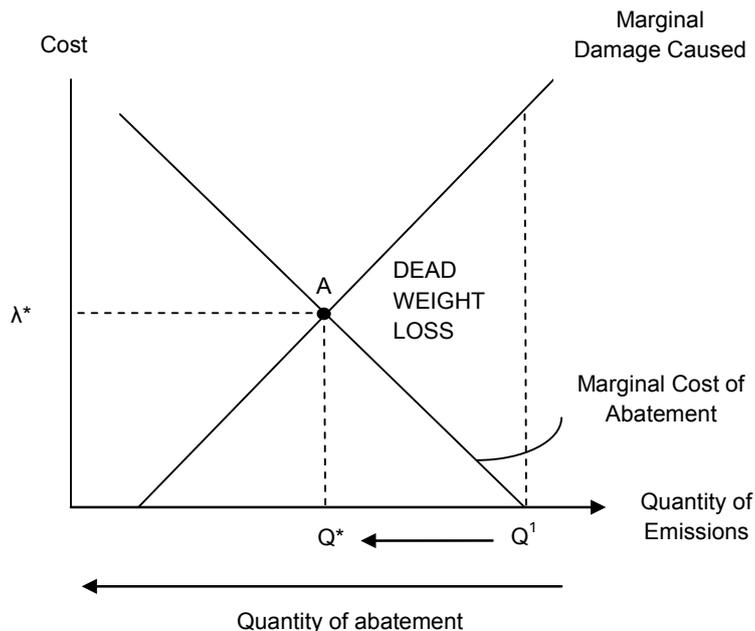
The framework aims to provide the maximum insight regarding the opportunities available for greenhouse gas (GHG) emissions mitigation in individual sectors given the substantial data issues that currently exist in South Africa by identifying and describing the main climate change mitigation measures available for consideration the seven focus sectors. This framework will assist all the relevant stakeholders to engage on the issue of greenhouse gas mitigation in a constructive way that optimizes outcomes for all parties and should thus *move the climate change policy debate in South Africa forward significantly*.

The sector case studies were presented to stakeholders at a stakeholder workshop and comments received from stakeholders were incorporated into the final version of the case studies.

### 3. INSTRUMENT OVERVIEW

#### 3.1. RATIONALE FOR INSTRUMENTS TO MITIGATE GHG EMISSIONS

Pollution and GHG emissions in particular, give rise to negative externalities. The firms that produce pollution as a by-product of the production process make their decisions of how much to produce, and consequently how much to pollute, based on the private returns they can generate from production. While polluting is costless to the individual firm, it holds significant cost from a societal point of view. In the absence of some form of government intervention, there will thus be a 'market failure' and firms will take decisions which are sub-optimal for society as a whole.



**Figure : GHG emissions as an externality**

Source: Genesis Analytics, 2010

This problem can be illustrated diagrammatically, as shown in Figure which plots the quantity of GHG emissions on the horizontal axis<sup>1</sup> against the cost per unit of the societal damage caused by the corresponding level of emissions, and firms' cost of reducing emissions at each level. The abatement of emissions is not costless since it requires firms either to reduce their level of production below their profit maximising point, or to adapt their technology and processes to emit less pollution for each unit of output. The 'Marginal Damage Caused' curve represents the cost of damage caused to the environment (and therefore society) of each extra unit of pollution. It is upward sloping since GHG emissions are a „stock' or cumulative variable, and build up in the atmosphere. The damage caused thus increases with each extra unit emitted. The „Marginal Cost of Abatement' curve represents the cost to firms of abating each extra unit of emissions. It is increasing in the level of abatement (or decreasing in the quantity of emissions) since the cost of abatement is generally lower to start and gets higher with each extra unit abated, since the easiest/least costly abatements are undertaken first.

In the absence of government interventions, the economy will be at point Q1, since producers would typically choose not to incur the costs of abatement and to pollute as much as is necessary to achieve their optimal production level. This outcome is sub-optimal for society as a whole since there is a cost of damage caused to society which is not reflected in the producers' costs and which is higher than the benefit gained by producers from polluting. The loss to society („dead weight loss') is determined by subtracting the cost of abatement from the cost of damage and is shown by the triangular area marked on the diagram.

The optimal point from a societal perspective is point A, where the cost of damage is exactly equal to the cost of abatement. At this point, abating one more unit of emissions would have a cost greater than the value of damage to the environment prevented. Conversely, abating one unit less would cause damage to the environment of a greater value than the cost of abating that unit. The rationale for interventions to mitigate GHG emissions is to reduce the dead weight loss to society by either compelling or incentivising producers to reduce their emissions and thereby move the economy leftwards towards point Q\*. Any movement in the direction of the arrow in Figure will reduce the deadweight loss to society – provided that the quantity of abatement does not exceed point Q\*. The main aim of any emissions reduction policy is thus to try and move the economy towards the socially optimal level of emissions.

### **3.2. DESCRIPTION OF INSTRUMENTS**

Various policy instruments can be employed to address market failures around GHG emissions. „Command and control' instruments use legislated emissions limits or technology standards with which firms must comply, whereas economic or market-based instruments try to force firms to internalise the full social cost of their activities by using the price mechanism. There are advantages and disadvantages of each instrument and they also differ in terms of their appropriateness for particular contexts, both at the economy and sectoral level. A thorough investigation and understanding of the implications of each instrument type is therefore an important component of carbon mitigation policy design.

Instruments to mitigate GHG emissions can be classified into four broad categories<sup>2</sup>: pure regulation, instruments that use the market, instruments which create a new market, and

<sup>1</sup> Note: the quantity of abatement is equal to the reduction in emissions, i.e. as illustrated in the diagram, the quantity of emissions increases to the right and the quantity of abatement increases to the left.

<sup>2</sup> Classifications suggested by National Treasury (2006) in the "Framework for environmental fiscal reform".

voluntary agreements. Within each of these categories are a range of instruments, all of which aim to reduce GHG emissions, but which vary substantially in the method they use to achieve this. Instruments generally focus on one of three tools: quantity, price or technology.

**Quantity-based instruments** are primarily concerned with achieving a given *level of emissions* and involve a target or cap at that level such that polluters are forced to abate their emissions. **Price-based mechanisms** on the other hand concentrate on regulating the *price signals* which are sent to polluters, aiming to set these at a level which forces polluters to internalise the full cost of their activities. Finally, **technology-based instruments** focus on promoting or legislating the *adoption of technologies* that reduce GHG emissions.

Table presents a description of the main instruments in each category and the way in which they aim to achieve reduced emissions.

Instrument category	Instrument name	Description	Mechanism to reduce emissions
<b>Regulation</b>	Performance standard	Regulator sets some kind of target for the level of emissions that producers must comply with or face penalties	Quantity
	Technology standards	Regulator determines minimum technological standards that producers must comply with or face penalties	Technology
	Information disclosure	Labelling requirements inform consumers about the carbon content of goods. This may lead to substitution towards less carbon-intensive goods.	Quantity/ Price
<b>Using markets</b>	Taxes	A tax is set on emissions to force producers to internalise the full cost of their activities	Price
	Subsidies	Incentives are provided to subsidise the cost to producers of reducing emissions or to encourage R&D in climate-friendly technologies. Subsidies can include public or private funding provided to science councils, universities etc to advance research focused on GHG mitigation.	Price
<b>Creating markets</b>	Cap and trade schemes	A certain cap on emissions quantities is determined and producers then face a decision to reduce emissions internally, or purchase emission reduction permits from those able to beat their caps more cost effectively.	Quantity
<b>Voluntary</b>	Voluntary commitments	Mitigation activities voluntarily agreed to by producers. Often used in the early stages of environmental policy consideration to aid adaptation before more stringent measures are introduced. Can include government-led initiatives such as consumer awareness campaigns.	Quantity/ Technology/ Price

**Table : GHG mitigation instruments**

Source: *Genesis Analytics, 2009*

### 3.3. GHG MITIGATION INSTRUMENTS: CROSS-CUTTING ISSUES

Before getting into an analysis of the different benefits and costs of each instrument, there are a few key issues common to all the instruments which are worth highlighting.

First of all, there are currently high **levels of uncertainty** around both the volume of GHG emissions from sectors and firms, and the cost of abating in each instance. GHG emissions have only recently been accepted to be a problem and have rarely been measured. Measurement and monitoring mechanisms are still under-development in many sectors and, even in developed nations they are rarely uniformly and accurately applied. Similarly, getting accurate data around the opportunities for and cost of abatement at a country, sector and firm level is extremely difficult. In this context it is impossible to know at what levels  $Q^*$  and  $\lambda^*$  in Figure 1 are in practice, and any price or quantity target that is set is unlikely to hit the socially optimal point straight off. The challenge is not to move too quickly to  $Q^*$  and in the process to shock the economy, nor to overshoot  $Q^*$  which will also result in unacceptable dead weight loss to society. The general lack of accurate data has implications for instrument choice.

Secondly, a strict and credible method of **enforcement** is necessary in order for any of the instruments to be effective. Otherwise, firms will face no real incentive to abate their emissions.

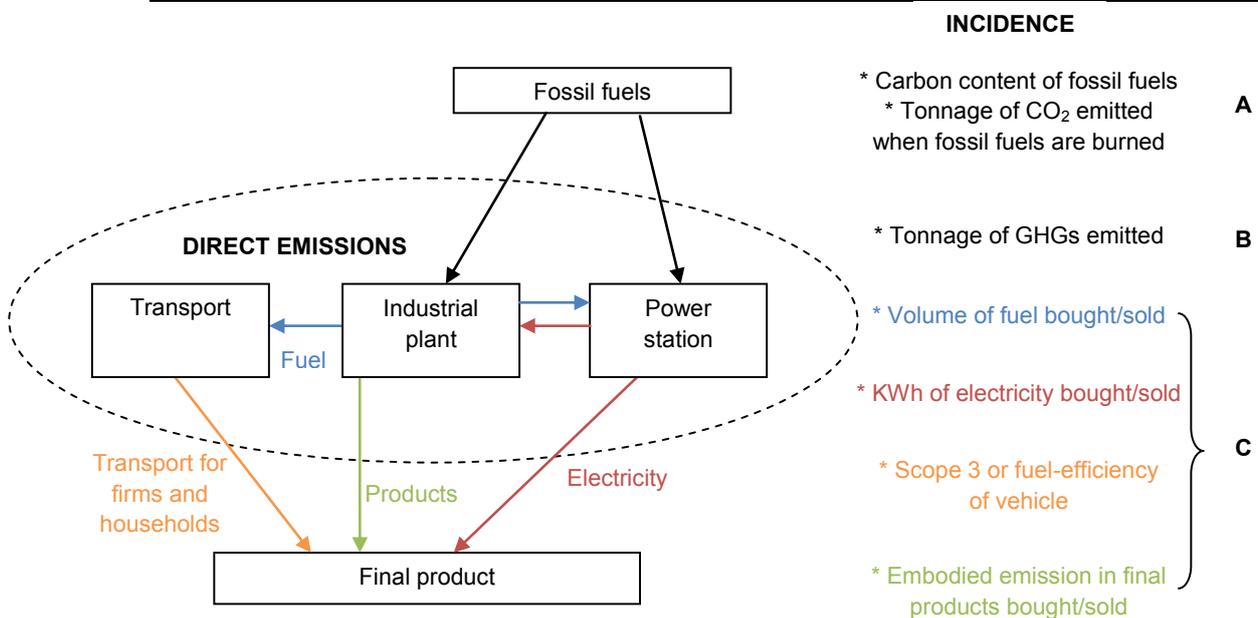
Thirdly, **context** is key to the choice of instruments. Theory has much to say about the relative effectiveness, efficiency, costs and benefits of the different instruments, but the final decision of what climate change policies to pursue must be guided by the relevant country context. Aspects such as economic structure, economic power derived from concentrations of firms within sectors, capacity to administer instruments, and experience with market mechanisms are all critical for effective policy design. This implies the need for a thorough analysis of the likely impact on different stakeholders and on the country as a whole, of different mitigation instruments. GHG emissions are a global pollutant, and as such local policy decisions will also need to fit in with the international context.

The final issue which needs to be considered with respect to any and all of the instruments is that of **incidence**. In general there are three points in the production value-chain which instruments can target to reduce GHG emissions. The key distinction between these is whether they target emissions directly or only indirectly.

1. *Upstream suppliers* or importers of fossil fuels or products containing carbon (point A in Figure 2). In general implementing measures upstream is the most administratively efficient, since there are typically fewer sources to target and there is no need for monitoring of emissions, since the target is simply the quantity of fossil fuels sold. The problem with targeting fossil fuels is that they are an imperfect proxy for GHG emissions; fossil fuels represent embodied emissions. As such, an instrument targeted at fossil fuels targets emissions only indirectly. Producers are only indirectly encouraged to emit less; their direct incentive is to use less fossil fuels. This ignores the option for reducing emissions whilst still using the same amount of fossil fuels, through carbon capture and storage (CCS) or co-generation, for instance.
2. *Downstream emitters* of greenhouse gasses (point B in Figure 2). This can include electricity generators and on-site power generation by industry, as well as emissions of other greenhouse gases at source (landfill sites, industrial gas emissions). This is the most economically efficient place to implement any instrument, since it is directly targeting the public "bad", GHG emissions, which provides the right incentives to polluters to change behaviour. Depending on

market structure and the price elasticity of demand, producers will pass on some or all of the cost of abating to consumers, which then provides an incentive for behaviour change at the consumer level as well. Downstream emitters generally have a greater number of abatement options available to them compared to their upstream counterparts which could makes targeting them more effective. However, monitoring and enforcement is more difficult at this level.

3. *Point of sale or use* of products containing embodied greenhouse gas emissions (point C in Figure 2) Product-focused instruments can target fuel, electricity, transport services or on any other final products, and can be at the level of the producer or consumer of the product. Regulation on electricity, fuel and transport emissions are more feasible from the perspective of measurement. Regulating other final products is significantly more complex due to the range of emissions direct and indirect which go into the production of all goods and services. It also presents major challenges in terms of double counting (so much so that this approach has been all but avoided in international GHG mitigation policy to date), due to complicated feedback loops in the value chains of the different products produced in the economy. One final product may also be an input into the production of another final product, in which case the emissions from the first product will be counted twice.



**Figure : Illustration of the potential incidence of GHG mitigation instruments<sup>3</sup>**

Source: Genesis Analytics, 2010

Targeting final products does not target emissions directly, and therefore there can be considerable “leakages” from a GHG perspective. Increasing the price of goods which embody GHG emissions will reduce demand for the goods and consequently producers will produce,

<sup>3</sup> Note: the diagram does not include agriculture or landfill emissions.

and emit, less. However, it does not provide producers with an incentive to find ways of abating whilst maintaining their level of output, unless instruments can be continually adjusted to take into account improvements in the emissions-efficiency of production

### **3.4. CRITERIA FOR INSTRUMENT CHOICE AND DESIGN**

In looking to arrive at a country or sector-wide strategy for reducing GHG emissions, it is not necessary to choose just one mechanism. Often a combination of instruments will represent the most appropriate solution. Nevertheless the instruments do differ substantially in terms of their benefits and costs, and it is therefore useful to weigh these as well as the applicability of the instrument to the specific context under consideration. From a design perspective there are a number of key considerations which are discussed below. For the purposes of the South African context, these are informed by and build on the criteria suggested by National Treasury (2006) in their "Framework for environmental fiscal reform".

#### **Environmental effectiveness**

The environmental effectiveness of an instrument depends on its ability to achieve reduced emissions. For all instruments this is obviously a function of the credibility of monitoring and enforcement mechanisms. Without good information, strict penalties and a means of monitoring emissions, no instrument will be effective. However, it is also dependant on instrument type. Instruments using a quantity tool, as opposed to price or technology tool to achieve reductions, have a much better chance of achieving a pre-identified volume of emissions reductions, as this is inherent in their design. For example, a cap on emissions with strict penalties for non-compliance is likely to achieve its target abatement. The volume of emissions abated using price or technology as a tool depends on the assumptions around mitigation costs, the price elasticity of demand for the end-product or technology performance. The volume of emissions reduction is indirectly targeted. The ability of these types of instruments to reduce emissions depends heavily on the availability of accurate baseline and recurrent data so that the price or technology standards can be set at a level where the desired level of emissions reduction will occur.

#### **Economic efficiency**

Consider Figure once more. Imagine that firms are polluting freely with no required abatement such that emissions are at the level  $Q_1$ . Requiring producers to abate a given amount will impose a cost on them depending on where they end up on the Marginal Cost of Abatement curve. However, as long as the Marginal Damage curve is above the Marginal Cost of Abatement curve, the result of any abatement intervention will be an efficiency improvement since the rest of society could afford to compensate producers for the cost of abatement, and still benefit from the reduction in emissions. In this situation no one is made worse off and society as a whole is better off (this is called „Pareto’ efficiency – the economic yardstick used to measure efficiency) Point A is the socially optimal point since at this point the benefit to society of the reduced emissions is exactly the amount necessary to compensate producers for the cost of abating to  $Q^*$

In order to reach the optimal point, every producer must abate to the point where an extra unit of abatement will hold a private cost for them which is greater than its benefit to society. Otherwise, society would be able to compensate the producer for the cost of abatement and still receive a benefit. Assuming that the benefit of each unit of abatement is equal, regardless

of who undertakes it, this means that the least costly abatement measure should be undertaken regardless of its distribution across producers; that is, those who have the lowest cost abatement options should be encouraged to abate first, either through regulation, price signals or incentives.

An instrument can be said to improve economic efficiency in a static way if it encourages a one-time improvement in the overall welfare of society. Instruments that encourage the implementation of least-cost abatement are likely to be economically efficient. Also important to consider in terms of economic efficiency is the impact which an instrument will have on the decision-making of producers over time: dynamic efficiency. In the real world countries do not move immediately to point A or even get there in the course of one year. This is particularly relevant in sectors where emissions mitigation requires significant investment in plant or processes, which are 'locked-in' for the lifetime of this plant (for example, power generating plant). In reality therefore, reducing emissions is an ongoing process, achieved over a number of years and decades through incremental tightening of whatever policy mechanism is chosen. In this context, instruments which require or incentivise firms only to adapt to a short-term target and then stop will be less efficient than instruments which provide continuous incentives for producers to find new ways to reduce emissions. This does not mean, however, that there is no place for interventions which achieve only static efficiency as these may also be important to eventually reaching a target emissions reduction.

### **Encouragement of substitution**

A key aim of any instrument aiming to mitigate GHG emissions must be to change the behaviour of both producers and consumers of GHG-intensive goods. The instrument must provide incentives for producers to switch inputs and production technologies, either through using those that already exist or by developing new alternatives themselves. It must also encourage consumers to substitute the consumption of GHG-intensive goods for those which are more emissions efficient.

### **Impact on technology development**

Instruments should also provide incentives to encourage ongoing investment in developing carbon-efficient technologies. The market failure which prevents polluters from facing the true social cost of GHG emissions works also to reduce the private incentive to innovate and improve emissions-efficiency. This makes it unattractive for firms to invest in new technology, particularly when this requires a big up-front investment for uncertain gain. If it is not to mean reduced output and economic activity, any emissions reduction target must be achieved by technological change in favour of more efficient methods of production; therefore the development of these technologies must be a priority.

### **Administrative requirements**

Some types of instrument have more complex and costly administrative requirements than others. It is important to a scheme's success that capacity exists to implement it effectively and that administrative costs are not prohibitively high.

### **Information requirements**

As discussed above, detailed and accurate data on historical, current and projected emissions and abatement opportunities and costs is often scarce. Therefore it is necessary to have an

understanding of how much information is required to efficiently implement each instrument and how the instrument performs under less-than-perfect information. Some instruments require data only on the total cost of abatement for the economy or a sector as a whole, whereas others need detailed data for every firm in order to achieve an optimal outcome for the economy. The choice of instrument will be influenced by the information available. The availability of information can be expected to improve with the maturity of the instrument, as long as there is adequate measuring, monitoring and verification. The long time frame under which climate change mitigation must be undertaken allows some flexibility in this regard.

### **Distribution**

Policies to reduce GHG emissions must eventually impose a cost on producers and/or users of emissions-intensive products in order to be effective. There may be some measures (energy-efficiency improvements for example) which provide a net gain for producers or at least no net loss, but these are not likely to provide all the necessary abatement. Any cost to firms will usually be felt by the end consumer as costs will be passed on wherever possible and the increase in price will incentivise households to shift consumption to less GHG-intensive products. How the costs of reaching climate change objectives are distributed in society will be important to ensure on-going political support for GHG mitigation in the long run.

Climate change policies can be regressive depending on the instrument chosen. For example a tax on electricity will tend to be regressive, since electricity is a basic need and makes up a larger proportion of total spending of poor households relative to richer households, reducing their disposable income<sup>4</sup>. On the other hand, a trading scheme based on the allocation of individual carbon quotas would prove inherently progressive, since rich households have a much higher carbon footprint than poor households once factors like travel, consumption patterns etc is included (UK Department for Environment and Rural Affairs, 2008). In addition to being progressive (with richer households paying proportionally more), such a scheme may even lead to welfare increasing transfers to poor households. Poor rural household may have such a low carbon footprint that they end up receiving significant sums in return for excess permits by high carbon consumers.

Distributional issues must be a key concern of policymakers when choosing an approach to reduce GHG emissions, especially in a country like South Africa where there are already major issues of inequality, poverty and unemployment. It should also be noted, however, that there are ways in which government can compensate households negatively affected by climate policies, such as reducing taxes or increasing social grants. This may enhance the attractiveness of instruments which generate revenue for government which can then be used to offset any negative distributional effects resulting from climate policy.

### **Support for the mechanism**

A wide variety of stakeholders, each with competing objectives, will be affected by any instrument choice and will therefore have a preference over which is chosen. Political economy considerations may influence which instruments can feasibly be introduced, or which are likely

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<sup>4</sup> An important point to note, however, is that it is often possible to mitigate at least some of the negative distributional characteristics of instruments through careful design (differentiated tax rates or a tax-exempts basic allowance, for instance, can reduce the regressivity inherent in electricity taxes).

to be able to be introduced in a form which will be effective. Again, this will be largely context-dependent but there are certain characteristics of different mechanisms which make them typically more or less attractive to the different constituents. Without taking cognisance of these issues, recommendations are likely to be unrealistic and face serious resistance. The process of policy development is a key mitigant to this risk.

### **Competitiveness**

Another key consideration when evaluating policies to reduce emissions is the effect that they could have on the competitiveness of traded industries. This could work both ways. The major developed countries which currently are subject to emission reduction targets under the Kyoto Protocol have indicated that at some stage in the future they may start imposing border adjustments<sup>5</sup> on products coming from developing countries with no emissions targets and which do not have sufficient emissions reduction policies in place. This suggests that there is a potential competitive advantage for any developing country which becomes a first-mover in this space in the long term when GHG emissions restrictions become more wide-spread, or change consumer preferences in favour of goods and services with a low carbon content. On the other hand, the increased cost imposed on firms who are forced to abate their emissions, may make them uncompetitive in other export markets. Climate policy must be designed to achieve a transition to a lower-carbon economy with the smallest possible cost to the competitiveness of domestic firms.

### **Interaction with other policies**

It is also important to consider the compatibility of each instrument with the broader policy environment and goals being pursued. Ideally instruments to mitigate GHG emissions would be designed to complement rather than detract from existing policy initiatives. In addition, the extent to which a sector or economic segment is already distorted through the presence of existing regulation will impact the effectiveness of any subsequent market mechanism in achieving its objectives. It is therefore important to analyse how each instrument is likely to interact with other policies, industrial policy in particular, before deciding on an emissions mitigation policy framework and instrument choice.

### **Fiscal affordability**

An important criterion in a developing country like South Africa with limited resources, is how costly an instrument will be for government to implement. Some instruments represent a cost to the fiscus, whereas others may actually generate revenue for government. The implementation and operational costs of each instrument will also differ. Interventions which generate revenue may be more attractive to government than those that cost them money, and this has another benefit which is that it provides funds which could be used to offset any negative distributional effects or to fund research into climate-friendly technologies. In South Africa, National Treasury is opposed to the idea of the “hard” earmarking of revenues – where funds generated by climate change mitigation instruments would go straight into an “off-budget” fund to be used for other climate change related activities – but is apparently open to the idea of the “on-budget” allocation of funding.

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<sup>5</sup> See footnote on page 45.

## **Flexibility**

In order to avoid potential negative consequences on the economy, it is important that there is an element of flexibility in any instrument, in order to give firms the space to adapt in the way which makes most sense for them. In particular, instruments which allow producers to vary their emissions over the economic cycle may be more desirable, since otherwise, abatement targets may act as a constraint on the economy's growth.

## **3.5. APPLICATION OF CRITERIA TO DIFFERENT INSTRUMENTS**

### **3.5.1. REGULATION**

Straight regulation or "command and control" approaches to emissions reductions are arguably the most straightforward way of achieving a given reduction target from a policymaker's perspective since they involve legislating the change that government wants to see, either in terms of direct emissions or adoption of less polluting technologies. However, these instruments have fallen out of favour internationally. Theory shows regulatory instruments to generate a less efficient outcome (as will be discussed in more detail below) and generally market-based interventions are proving more attractive to policymakers and industry around the world. Nevertheless regulation and technology standards in particular, may have a place as part of a comprehensive strategy to achieve emissions reductions as will be discussed below.

#### **Performance standard**

A regulation limiting emissions to a certain level is fairly certain of achieving the desired amount of abatement (environmentally effective), as long as monitoring mechanisms are strong and penalties for non-compliance impose a high enough cost on polluters. It may also be administratively simpler than other instrument options, especially if the enforcement mechanisms can be aligned with other regulations.

However, these instruments are unattractive from an economic efficiency point of view since they are unlikely to result in either static or dynamic efficiency. A blanket performance standard imposed on all firms to reduce emissions by a certain value or percentage below the baseline does not allow for the least cost abatement, since all firms must abate the same amount, regardless of their cost of abatement. Thus static efficiency is not achieved. There is also no incentive for firms to abate beyond the target set for them, even if it would be cheap and easy to do so. Firms are not encouraged to make ongoing investments in technology and process development to find more emissions-efficient ways of working. There is an initial level of substitution and potentially the adoption of more climate friendly technologies in order to reach the prescribed emission reduction target, but after that there is little impetus for further innovation and improvement. Thus the solution is also not dynamically efficient.

In order for a performance standard to be economically efficient, separate standards would need to be set for every firm, relating to their private cost of abatement and also to the total abatement needed for the economy as a whole to reach its optimal point. Government would need to understand not only the full costs and benefits of emissions reduction for the country as a whole, but also the cost structure related to emissions reduction for each individual producer. This implies a costly process of information gathering in order to design an efficient instrument. In reality this will be almost impossible to achieve since firms have little incentive to report their true cost of abatement as they want the most lenient target possible.

A performance standard may, however, be useful when there are few sources of emissions (or many homogenous emissions sources) and a high degree of information exists around these.

### **Technology standards**

The use of technology standards involves legislating the adoption of more emissions-efficient technologies (e.g. imposing energy efficiency standards on household appliances).

In some respects technology standards are very similar to other regulatory instruments. They are unlikely to be economically efficient unless government has a lot of information about firms and the industry as a whole. Moreover, they cannot deliver dynamic efficiency since the adjustment required is a one-time substitution of one technology for another (Perman et al, 1999). The key difference though from a cap or performance standard is that technology standards do not guarantee a certain emissions reduction, rather it is only clear ex-post what emissions reduction volume is achieved. However, the monitoring and enforcement of a technology standard is generally easier and less costly than monitoring actual emissions.

Technology standards can however be effective in terms of achieving large reductions in emissions quickly, particularly if a fairly low cost substitute technology exists but has not been widely adopted (Perman et al, 1999). They are potentially of benefit where a market failure exists; creating a barrier to the adoption of a technology that would actually give positive returns for firms over the long term. Examples include where firms lack information about the benefits of the technology, or where financing constraints prevent them from making the required up-front investment which would lead to a future payoff due to improved energy-efficiency for example (Jaffe et al, 1999). Under these circumstances technology standards are likely to provide a more economically efficient option than a performance standard but it is important that supportive policies and initiatives are put in place in order to ensure the standard's success. A problem associated with technology standards is that they can lead to an escalation in price of the technology, either due to scarcity or as suppliers realise that they can charge a premium. Therefore, it is important to ensure that the technology required is readily available at a reasonable price.

A further consideration is that this type of standard will tend to be harder for small firms to comply with than larger firms if the cost of adjustment is likely to have a greater relative impact on them financially. However, it is possible that special provision could be made for firms below a certain size or they could be assisted to adapt.

Technology standards can therefore be useful as part of a suite of measures aimed at achieving emissions reduction in specific circumstances where a market failure has been identified. However, evidence suggests that number of "win-win" (positive payoff) technologies may actually be quite small (Jaffe et al 1999).

### **Information disclosure**

Information disclosure rules will allow consumers to make informed purchasing decisions. Provided that consumers care about climate change and have a preference for relatively low carbon goods relative to relatively high carbon goods, this should decrease the demand for relatively high-carbon goods at a given price. Given that the effectiveness of information disclosure measures depends on consumer preferences, they may need to be implemented in conjunction with measures like public information campaigns that highlight the risks linked to climate change.

### **3.5.2. USING EXISTING MARKETS**

Mechanisms in this category aim to use the power of the market to induce the desired emissions reductions, through explicitly pricing the cost of emissions and thereby incorporating this cost into economic actor's decision making.

#### **Taxes**

A tax is a price-based instrument which achieves reduced emissions through imposing a cost on producers proportional to the level of pollution which they emit, in order to force them to face the full social cost of their activities. If set at the right level, a tax will lead to the optimal societal outcome since the externality of pollution will effectively be priced-in to producers' decision making such that they choose to reduce emissions to the socially optimal quantity. The dead weight loss caused by the externality is thus reduced to zero.

This occurs in a way which maximises static efficiency since all producers will reduce their emissions until the private marginal cost of abatement is equal to the social marginal benefit, regardless of the characteristics of their specific abatement curve. This is because they each make a decision of how much to abate by weighing the relative cost of abatement against the cost of the tax and abate to the point where abating one extra unit of pollution would cost them more than paying the tax on that unit.<sup>6</sup> If the tax is set to reflect the social benefit of abatement (or the social cost of pollution) then each producer abates until the point where to abate one more unit would have a cost greater than the benefit to society of abating that unit. This is the point previously defined as economically efficient; i.e. "least cost" abatement has been achieved. Put more simply, firms facing very heavy costs of abatement will prefer to abate only a small amount, or possibly not abate at all, since at all levels paying the tax will be cheaper for them than abating. Conversely, firms with a low cost of abatement will find it cheaper to abate than to pay the tax. Therefore the firms with the lowest cost of abatement will be the ones to abate. Taxes (and market-based instruments in general) are more attractive than Command and Control instruments, as the market achieves the economically efficient outcome without significant intervention from policymakers. Informational requirements are therefore also much less demanding. Government only needs to understand the abatement cost curve for the country or industry as a whole, not for every individual firm.

Taxes also have a strong dynamic efficiency component since they provide an enduring incentive to find cheap and effective ways of reducing emissions in order to reduce the firm's tax burden.

Climate change results from the slow build up of GHG emissions over time which means that emissions in a given year make up only a small proportion of the total problem. This means that in order to limit climate change, emissions must be reduced significantly over a long period of time but that precisely hitting the target in any given year is less important. By contrast the cost of abatement may vary quite substantially from year to year for a range of reasons such as the level of economic activity, energy market disruptions, and the availability of new low carbon technologies (US Congressional Budget Office, 2008). In this context, the tax

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<sup>6</sup> The analysis rests on the assumption that the cost of abatement increases with each extra unit abated. This is consistent with the idea that firms will undertake the easiest/least costly abatements first and thus abatement becomes more and more costly as over time the easiest gains are exhausted.

instrument is efficient, since it gives firms the flexibility to choose when they abate; they can emit more or less in one year and pay more or less tax. The optimal level of emissions will still be met in the long term but firms can respond appropriately to business cycle fluctuations and periods of high and low demand for their product by changing their level of emissions.

From a policymaker's perspective there are a few characteristics which make taxes less attractive. Firstly, if there is a lack of information about the shape of the abatement curve on a sector level, this means it is not possible to know for sure what level of tax will induce a required level of emissions reduction. However, there are effective mechanisms for improving the predictability of tax policy. Marquard and Winkler (2009) suggest a mechanism by which targets for emissions levels over a period of time are set and then the tax level is adjusted so that if emissions in a given year lie outside a pre-determined band around the target, they will be brought back within the target range. For example, if emissions are above the target band in a given year, this triggers a pre-determined upward adjustment of the tax in response which should bring emissions back into the band. This has a further benefit of providing transparency and certainty about future tax levels so that firms can plan effectively.

Secondly, there tends to be considerable resistance to the implementation of any kind of climate change tax; a notable example being the USA. An energy tax proposed early in the Clinton administration failed to gain the Senate support necessary to be passed and signed into law (Milne, 2008). This is justified to some extent, since if implemented in one country exclusively it will tend to harm the competitiveness of energy-intensive firms in that country. A number of European countries, including Denmark and Sweden, however, have successfully introduced broad-based carbon and energy taxes (Speck, 2008). In order to make it more appealing to business, a tax should be supported by other mechanisms which help firms to adapt as painlessly as possible to lower carbon methods of producing.

Thirdly, over time a carbon or energy tax can become regressive, as most of the cost of abatement, technology switching etc is passed on to consumers through higher prices. Since some of the products affected are goods like electricity, fuel and even food due to the impact on agriculture, this will have a negative effect on poor households which may be relatively greater than the effect on wealthier households. Although it desirable that the tax be passed through to consumers in higher product prices, as this will incentivise the switching of consumption to less emissions-intensive products, it is important that the distributional impact be carefully considered and measures taken to offset any negative impact on the poorest in society.

However, a final consideration when looking at the implications of a carbon or energy tax is the revenue which such an instrument would generate for government. A significant amount of money could be raised which could then be "recycled" or used in a number of ways; for example to compensate households bearing the greatest burden in terms of the cost of abatement, to fund incentives for the development of "green" technologies or to lower other taxes. This final example has been termed the "double dividend" effect, since it effectively reduces the dead weight loss to society twice; first from reducing the negative impact of the pollution externality as described above, and second by reducing the distortion caused by other taxes in the economy. A paper by Van Heerden et al (2005) uses a Computable General Equilibrium (CGE) model to look at the impact of a carbon or energy tax in South Africa when combined with a variety of schemes to redistribute the revenues from the tax to households. They find that there is a potential for a "triple dividend" in South Africa where emissions are reduced, GDP increases and poverty decreases. Such models abstract from the realities of transaction costs, however, and it is therefore unclear whether the cost of implementing a

carbon tax may outweigh some of the benefits. The key point is that a tax would not channel government funds away from spending priorities such as housing, education, healthcare etc, but would rather provide funds which could be used in a variety of ways.

### **Subsidies and incentives**

Subsidies or incentives aim to cause producers to reduce emissions by subsidising their abatement. A subsidy can achieve the same optimal quantity of emissions as a tax and similarly eliminate the deadweight loss associated with the externality if set at the right level. Furthermore, it can also achieve the least cost abatement since producers will abate until the subsidy they receive for abating is equal to the marginal cost of abatement. Abating one more unit will cost them more than the subsidy they will get for that unit whilst abating one unit less would leave them an opportunity to abate more and make a profit. This means that, just like a tax, firms with a high cost of abatement will abate less and those with a low cost will abate more.

An obvious advantage of subsidies over tax or regulation is that firms are able to abate emissions without any loss of competitiveness or profitability which is positive from the perspective of maintaining output and employment. This makes incentives popular from a business perspective. However, it is important to consider the fiscal burden which this type of instrument imposes. The payment of subsidies confers an opportunity cost on society, since government spending elsewhere will have to be reduced or else other taxes will have to rise in order to cover the cost.

Furthermore, over time subsidies are not as efficient as taxes. Firms are subsidised to abate so still do not face the full cost of their activities, and over time this means that more firms are attracted to join the industry than is optimal from a societal point of view. Thus, emissions will tend to grow despite the subsidy and the subsidy paid out by government will also grow. The burden of abatement falls on taxpayers rather than on the producers and consumers of polluting products which means that there is no incentive for consumers to reduce their consumption of the polluting good. This violates the polluter pays principle.

Investment tax credits are a more popular mitigation tool than straight environmental subsidies, since their costs are less transparent to public scrutiny and they give the impression of preserving competitiveness. In essence, however, they suffer from exactly the same flaws. They work by allowing firms to offset their taxable income by the amount of investment they made which means that the outcome is the same as if government subsidised a percentage of all investments equal to the corporate tax rate.

A separate category of subsidy encompasses those which are provided to positively incentivise activities which are beneficial to society, rather than to incentivise the mitigation of harmful behaviour. These can be introduced to promote certain strategic investment areas, for example in renewable electricity generation or in the development of energy-efficient technologies. These activities suffer from the opposite problem to GHG emissions, in that they provide a benefit to society which is not fully valued by the market. This provides a strong argument for government intervention to correct the market failure and make the activity more attractive to private firms. There is a particularly strong rationale for such interventions in areas where the initial investment required is high or where there is a lack of understanding in the market around the benefits and potential returns. The issue of opportunity cost still exists, however, and the cost of such incentives should always be weighed against alternative uses of government funds.

### **3.5.3. CREATING MARKETS**

This set of instruments also aims to use the power of the market and the incentives created by the price mechanism to elicit the abatement of GHG emissions. However, these instruments involve the creation of an entirely new market based on developing a new set of property rights for an environmental good or service (National Treasury, 2006). Tradable permits are generated by some kind of environmentally positive action; reducing emissions directly, reducing the use of a product which embodies emissions or producing a product which can substitute for an emissions-intensive product (e.g. producing renewable energy).

#### **Cap and trade**

An emissions trading scheme (ETS) is based on the allocation of allowances to emit pollutants, which in the case of climate change are greenhouse gases. Allowances analogous to a pre-defined target (emissions trading uses a quantity tool) are allocated to a defined set of emitters, who are required to hold sufficient allowances to cover their emissions at the end of a compliance period, or face penalties. Scarcity is created in the scheme through the allocation of fewer allowances than emissions, resulting in emitters having to choose between reducing their emissions in line with their allowance allocations or purchasing additional allowances to cover their excess emissions levels.

When government has perfect information about the cost and benefit of abatement, a cap and trade scheme will achieve exactly the same level of economic efficiency as a tax. If the quantity set is the optimal level of emissions, then the permit price which will result from trading is exactly equal to the tax rate that would achieve the optimal quantity target. Cap and trade also achieves least-cost abatement, since it allows firms for whom abatement is relatively cheap to abate extra, so that they can sell their excess permits to firms who cannot abate so cheaply. The ability to sell permits provides the incentive for all firms to abate until their marginal cost of one extra unit of abatement is equal to the price of a permit for that unit. Emissions trading schemes stimulate innovation in emissions mitigation technologies, as the potential to sell surplus credits provides an incentive for emitters to generate abatement to exceed their targets.

The economic gains mentioned above emanate from differences in the abatement costs of firms covered by the trading scheme (EC, 2000). The compliance cost of a trading scheme thus increases as the coverage of the scheme is reduced (Baron and Bygrave, 2002). In order to achieve economic efficiency, it is thus important that the coverage of a trading scheme (both in terms of firms/sectors and greenhouse gasses) is as broad as administratively feasible (EC, 2000; Reinaud and Philibert, 2007). Reinaud and Philibert (2007) also mention that it is advisable to for an ETS to have broad coverage in order to implement a carbon price that covers as much of the economy as possible. This will lead to the cost of carbon being internalised into decision-making throughout the economy, which in turn will ensure that the optimal amount of abatement is undertaken (see section ).

Although emissions trading can guarantee a given emissions reduction, there is uncertainty in terms of the price that will be set in the market for permits, and the impact on the economy that will result. There are a number of reasons why the price of permits may be volatile, for example uncertainty regarding future cap levels; an over- (or under-) allocation of permits due to inaccurate information or abatement technology developments; changes in the external economic conditions; or dynamics in underlying product markets. Price volatility causes uncertainty for firms and may cause them to delay investment in emissions-efficient technology

as future payoffs are unclear (Parry and Pizer, 2007). Therefore during the inception and operation of any emissions trading scheme it is extremely important that the process is credible and transparent and that cap reduction timelines are clearly laid out and visible to all participants. There are mechanisms which can be introduced to try and mitigate against excessive price volatility, such as setting price caps and floors which are maintained by government buying back permits or issuing extra permits, however, these mechanisms reduce the level of certainty about the emissions reduction that will be achieved.

An often-discussed way in which an ETS can be adapted to allow firms more flexibility is through the inter-temporal banking and borrowing of permits. Banking allows firms to hold onto permits which are unused in one year to be used to meet compliance targets in the following year(s). Conversely, borrowing allows firms to use part of the following year's permit allocation to meet the target in the current year. Generally banking is seen as more desirable, since borrowing may encourage firms to delay abatement. Too much borrowing in one period reduces the probability of being able to meet a future period's cap, and could cause many firms to meet their targets and incur penalties (UK Department for Environmental, Food and Rural Affairs, 2008). This could undermine the credibility of the scheme. These mechanisms complicate the design of an ETS somewhat, but this has to be weighed against their important anti-volatility effects. A price spike or crash can also undermine perceptions of the scheme.

An important aspect of trading scheme design is how the permits are allocated. Either government can distribute permits to firms based on historical emissions (called '*grandfathering*'), or they can be auctioned so that a market for scarce permits is immediately created and a permit price determined. The latter mechanism is the more attractive from the point of view of governments, since they receive revenue from the sale which they can then use as they would tax revenue, to cover the cost of the scheme, to offset any negative distributional outcomes or to provide incentives to invest in energy-efficient technology (or for any other objectives).

Grandfathering is more attractive to business, since it significantly reduces their cost of compliance. Under this arrangement firms receive a free allocation of allowances dependent on their past emissions. They only need to pay for allowances (by purchasing them from other scheme participants) if they exceed these historic levels. There are a number of arguments against this style of permit allocation. Firstly, grandfathering is less economically efficient since it reduces the incentive for innovation and investment in mitigation technologies. In a grandfathered scheme, rents belong to industry since there is a net transfer of assets from government to firms. This gives firms an incentive to keep the permit price high whereas under an auctioned scheme, firms would have to purchase all the permits they need, giving them an incentive to innovate and invest in abatement technology in order to achieve a reduction in the permit price (Cramton and Kerr, 1998). Furthermore, in a grandfathered scheme it takes longer for the price of permits to move to a price which reflects the scarcity of permits (i.e. reflecting the cap on emissions) which results in a market distortion. It is also much more administratively burdensome, since government must gather accurate data on the historical emissions and abatement opportunities of all participants in a situation of asymmetric information where firms have little incentive to reveal accurate data.

The distributional implications of grandfathering also make it less attractive than auctioning. In a grandfathered scheme benefits accrue to firms rather than tax-payers who fund the scheme and who also ultimately pay for any abatement that is undertaken if firms are able to pass on their costs. This has been shown to result in windfall profits for some firms since and increased prices to consumers, even though permits are distributed for free (Sjim et al. 2006). To

understand why this is so, consider the firm's production decision. At any point the firm could choose not to produce the next unit and sell a now unwanted emission permit. Therefore, the price the firm can command for each unit of output must be greater than the market price of permits, or the firm would rather sell the permit and reduce its production level. Thus, under a grandfathered scheme, the price faced by consumers will increase as much as under an auctioned scheme, and the rents accrue to firms rather than to government.

This feature of grandfathering has led to criticism of the EU ETS since power producers are perceived to have benefited unfairly under the scheme as they received free permits and power prices have increased significantly since the scheme's inception (Wettestad, 2007). A study by Sjim et al (2006) found that under the EU ETS firms who were allocated emissions permits had passed on between 60% and 100% of the opportunity cost of permits to their customers, resulting in significant windfall profits for polluting firms. An illustrative example is the case of the Netherlands where a CO<sub>2</sub> price of €20/tonne would result in windfall profits to power producers of €3 to €5 per MWh of electricity, which translates to €300 million to €600 million per year. A grandfathered ETS is therefore attractive to firms with inelastic demand for their products since they realise that under this type of scheme they will be able to pass on the price of permits to customers and make extra profit even if they engage in no abatement activities (Mendes and Santos, 2008).

Nevertheless, grandfathering may be necessary in the first phase of any cap and trade scheme in order to secure support for the introduction of the scheme. This was the case with the European Emissions Trading System which aims to phase out the use of grandfathered permits and move towards an auctioning system over the next few phases of the scheme.

A major consideration with regard to a cap and trade scheme is the set-up and administrative costs which accompany such an instrument. Experience suggests that the necessary institutions tend to spring up relatively quickly and cheaply (Parry and Pizer, 2008). However, international examples, and the European ETS in particular, suggest that even after all this is in place, it can take some time and significant trial and error before the right cap level and corresponding permit price is reached, potentially imposing real costs on the economy. In the mean time, as mentioned above, the price can be very volatile, undermining the effectiveness of the ETS as well as its credibility. For example, during the first phase of the EU ETS, the price of permits fell by more than 70% in one month due to new regulatory information being made public (Nordhaus, 2007). Nordhaus (2007) shows that in the US SO<sub>2</sub> trading scheme, the price of allowances from 1995 to 2006 was more than twice as volatile as the S&P500 index and almost as volatile as the oil price. Furthermore, the US NO<sub>x</sub> programme experienced a massive price spike over speculation about whether Maryland would enter the scheme on time (Parry and Pizer, 2008).

The high transaction costs associated with trading means that it is only viable for relatively large firms to take part, which means that coverage will not be 100%. A great deal of data is required to design the system, particularly if permits are grandfathered (informational requirements in a grandfathered ETS exceed that of either an auctioned ETS or a carbon tax). A voluntary phase prior to the introduction of a mandatory scheme is useful in terms of generating the necessary data, as well as allowing participants to get used to the idea and the mechanics of emissions trading. This makes implementing an ETS a lengthy process.

Market liquidity is very important in an ETS as a higher trading volume increases the frequency with which prices are observed which increases the volume and quality of information flowing to firms and government, allowing them to manage price risk more easily. It also makes the

market more efficient (Sin et al, 2005). An illiquid market makes issues of market concentration more likely since it will make it harder for firms to buy permits and enter the market whilst simultaneously making it easier for existing players to maintain high prices.

Finally, market power can be a problem in an emissions trading system, both while the scheme is being designed and set up, and during its operation (Muller and Mestelman, 1997, Stavins, 1997). If the landscape is dominated by one or two very big players in either the emissions allowance or underlying product market, then these firms could exercise too much influence, leading to inefficiencies in scheme design. Once in operation, excessive market power can allow firms to manipulate permit price for their own gain and at the cost of smaller players in the market. For example, firms may prevent entrants from joining by over-buying permits to push up the price, or they may reduce their cost of compliance by over-abating so that their demand for permits falls and the price falls. They could also buy up permits in advance to give themselves the option of not abating or just to control the market (Sin et al, 2005). In this way, permits can be used to further monopolise underlying product market.

Furthermore, a grandfathered ETS potentially creates high barriers to entry to the sectors covered by the scheme unless a quantity of permits is set aside for new entrants which would reduce the number of permits available to current participants (Stavins, 1997) Barriers to entry are removed when permits are fully auctioned every period since incumbent firms and new entrants face the same marginal cost of permits and have equal access to permits (EC, 2000).

One potential solution to these problems is the international linking of schemes, which is dealt with in more detail in section .

#### **Indirect market creation mechanisms: White/green certificate trading**

*White certificates* are documents awarded by an authorisation body to certify that a certain reduction in energy consumption has been obtained. From a greenhouse gas emissions reduction perspective, white certificate schemes are an indirect policy instrument, as their primary objective is energy efficiency. However, to the extent that the energy saved is generated from fossil fuels, a significant volume of greenhouse gas emissions reduction can be achieved. Reductions are usually defined relative to a certain baseline and are generated by producers and suppliers of electricity, oil and gas by assisting end users to implement energy efficiency measures in their homes. They usually face an obligation to reduce energy consumption by a certain percentage, and if trading of certificates is allowed, then firms who generate certificates in excess of their requirements can sell them on.

This type of trading scheme has the same benefit as an emissions trading scheme, in that it allows the necessary reduction in energy consumption to occur in the most efficient way possible, since reductions are transferable between firms. The existence of a price for certificates provides the necessary incentive to generate innovation in terms of how reductions are achieved. Oikonomou, Rietbergen and Patel (2006) find the main benefit of white certificate schemes to be in overcoming the “efficiency gap” which manifests in the unwillingness of consumers to invest in energy-efficient goods, even though it may generate cost savings. This may be due to a lack of information or lack of willingness or ability to pay the upfront cost of such measures. The scheme can exist alongside and interact with other mitigation instruments, in particular an emissions trading scheme, as long as the two are designed to be compatible. There is, however, a risk of double-counting if there is fungibility between the two schemes.

A major benefit of white certificate trading has been found to be the measurement, tracking and accounting of energy efficiency activities (Oikonomou, 2004). Furthermore, European experience has shown that a WCS can be successfully implemented in both monopolistic and liberalised energy markets, and that it can also develop with the energy sector as it transitions from one to the other (Lees, 2007).

Much like emissions trading, white certificates and the trading thereof necessitate the introduction of effective monitoring and verification infrastructure. Ensuring that energy efficiency activities are additional (in addition to those that would have occurred in the absence of the WCS) is critical to ensuring environmental effectiveness. This is more difficult in an environment where there are numerous interacting energy policy instruments to be accounted for. It is also important that the correct baseline is set, so that firms are not over-compensated for their efforts. However this must be balanced, since overly cumbersome additionality and baseline rules will deter participation in the scheme, and reduce the incentive to overachieve targets (Capozza, 2006). Finally, since GHG emissions are targeted only indirectly, it is necessary to design a white certificate scheme carefully in order to ensure that there are no "leakages" from an emissions perspective. This issue is dealt with in more detail in section .

*Green certificates*, also known as Renewable Energy Certificates, are granted to certify that a renewable energy source was used in the generation of a certain amount of electricity. By design, the certificates are separated from the underlying electrons enabling them to be sold to different purchasers to that of the electricity, which is mostly fed into the national grid and mixed uniformly with electricity generated from non-renewable sources. If the scheme is mandatory, electricity producers, suppliers or consumers are obliged to purchase a minimum share of renewable energy with penalties for non-compliance and are able to purchase green certificates in order to meet their obligations. Alternatively the scheme could be voluntary, with firms purchasing green certificates for reputational reasons. Such schemes have been implemented in a number of countries internationally, including various European countries, the United States and Australia.

The payment for green certificates to renewable energy generators provides an increased incentive for investment in renewable electricity generation and can fund the expansion of the renewable generation industry. The mechanism has a similar impact to subsidies provided by government for green energy generation; the only difference here is that the market determines the extent of the subsidy. It is also cheaper for government, since they are not the ones paying the subsidy. Green certificate trading is also a useful mechanism for building confidence in green energy and the credibility of commitment to increasing the share of renewable energy. Like white certificate trading, green certificate trading only targets emissions indirectly but if an increase in renewable generation capacity is achieved, this will lead to reduced GHG emissions as less of the electricity required by the economy will come from fossil fuel-based generation.

#### **3.5.4. VOLUNTARY MECHANISMS**

##### **Voluntary commitments**

Voluntary commitments are intended to encourage producers to reduce emissions even though they are not legally obliged to do so. This is often in return for a delay in formal regulation. There are various types of voluntary programmes encompassing the range of tools for emission reduction already discussed. The introduction of voluntary commitments enables firms to gradually reduce their aggregate emissions before legislated mandatory caps or taxes

are introduced, and they facilitate learning about and a focus on reduction activities. Importantly, voluntary schemes can generate a significant amount of data on emissions volumes and abatement costs. There are several types of voluntary schemes as described below (Lyon, 2003 and Thalmann and Baranzini, 2007).

*Self-regulation* refers to abatement efforts initiated by firms voluntarily, where there is no formal compulsion to do so. The firms are generally not bound to any targets. However, the threat of regulation or taxation serves as an incentive for firms to comply. Self-regulation can avoid the costly process of passing legislation, implementing policy and monitoring compliance. It gives firms flexibility to meet environmental goals in a cost-efficient manner since they generally have the best information on how to control their carbon emissions, information which may be costly for government to acquire. Self-regulation initiatives can be found in most European countries.

*Negotiated agreements* are contracts negotiated on a case-by-case basis between the government and individual firms or a group of firms, which define targets and timetables for pollution reduction, rewards and penalties. The rewards are usually exemptions from taxes and regulation, thus offering an incentive for firms to comply with emission reductions.

*Public voluntary programmes* are government provisions of technical assistance (subsidies, research and development funding, technical assistance and marketing opportunities) to help firms to meet environmental goals. The government or an agency administers the programme by defining performance, technology and organisational standards and invites companies to participate. Firms are then expected to make an effort to meet environmental goals.

*Early reduction credits* (ERCs) are a special case of voluntary commitment programmes which are popular in the US. They are usually awarded to firms that implement projects to reduce GHG emissions. The early reduction credits are then exchanged for tradable permits if and when a mandatory cap-and-trade programme is created. Since they do not use a price system, incentives for reducing GHG emissions are not fully transmitted throughout the economy and thus they provide weaker incentives than an immediate move to a cap and trade system. They are also more costly to implement since potential future income from permits is sacrificed.

In theory, voluntary commitments are flexible, inexpensive instruments to reduce GHG emissions. However, since participation is voluntary, incentives tend to be insufficient to induce optimal emissions reductions. Thus, unlike the market-based economic instruments discussed previously, voluntary commitments do not lead firms to fully internalise pollution costs and emissions reductions are likely to be relatively small. The voluntary nature of these schemes also reduces the likely market size, making it difficult for voluntary mitigants to realise the benefit of their actions. Furthermore, in order for agreements to be credible, there needs to be external monitoring of compliance which is often lacking.

Nevertheless, voluntary programmes can be a useful option when political resistance blocks the implementation of more powerful mandatory controls. They are also a useful first step towards a mandatory regime, as they generate data on emissions levels and abatement opportunities and costs, which can then be used in its design of mandatory schemes. They allow all stakeholders to adapt to the concept and requirements of emissions reduction without imposing a sudden shock and in a much less confrontational environment. This may be helpful in terms of gaining support for the idea of emissions reduction and for regimes to be implemented later on.

## 4. EFFICIENCY OF INSTRUMENTS: SA PERSPECTIVE

### 4.1. SOUTH AFRICA'S EMISSIONS PROFILE AND CONTEXT

#### 4.1.1. OVERVIEW

The structure of South Africa's GHG emissions has major implications for the design of an effective policy regime to meet emissions reduction targets. South Africa emitted 495 Mt CO<sub>2</sub>e in 2007 (Energy Research Centre, 2008) making it one of the world's highest emitters on a per capita basis.

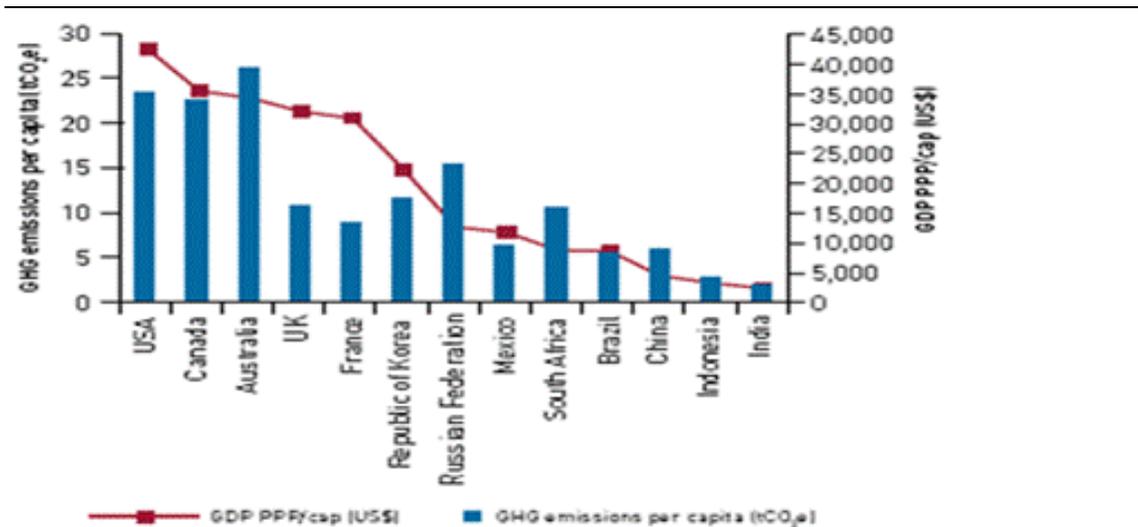
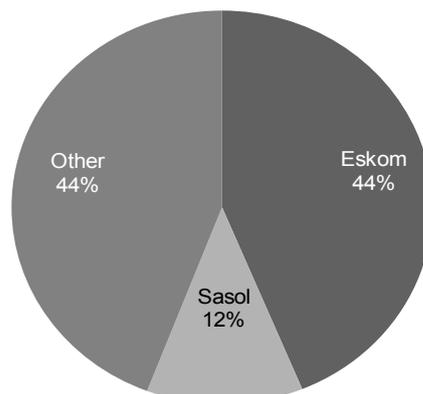


Figure : Per capita emissions and income in selected countries in 2006

Source: UK Department of Energy and Climate Change (2009)

79% of the country's emissions profile is made up of emissions associated with energy (Energy Research Centre, 2009), with the remainder being industry process emissions, and methane from waste management and agriculture. The high contribution of energy is largely due to the country's reliance on coal for electricity generation. In fact coal burned for electricity generation makes up around 40% of all emissions (Energy Research Centre, 2009).



**Figure : Institutional profile of South Africa's GHG emissions in 2008<sup>7</sup>**

Source: Source: Genesis Analytics, 2010

From an institutional perspective, two organisations dominate South Africa's GHG emissions, accounting for 56% of total emissions. 12% of emissions are attributable to liquid fuel manufacturing (Sasol) and 44% to the country's electricity supply (Eskom). This poses particular challenges for any climate change mitigation regime. Furthermore it suggests that strategic decisions made by these two firms will have the potential to influence South Africa's GHG emissions more than any other factor. Government therefore needs to engage with Eskom and Sasol to find ways of balancing alternative policy objectives (like energy security) with mitigation priorities. Research into the development of Carbon Capture and Storage facilities will be very important in this regard, for Sasol in particular

#### **4.1.2. THE SOUTH AFRICA ELECTRICITY MARKET AND CLIMATE CHANGE**

South Africa's emissions profile and the work done under the LTMS modelling suggest that electricity generation and energy efficiency are priorities of any mitigation strategy. From this perspective, recent developments in the electricity generation market could prove to be complementary to the goal of reducing emissions, and should be considered in the development of any greenhouse gas mitigation policy package.

The structure of the electricity generation market (Eskom is a state-owned monopoly) and the prominence of developmental goals have combined to keep the price of electricity artificially low in South Africa. This has caused a number of problems, not least the decreased incentive for investment in new power generation capacity which resulted in the recent capacity shortfall experienced by Eskom, and power cuts and power rationing to consumers. It has also meant that industrial, commercial and household users of electricity have had little incentive to use it efficiently or to invest in more efficient alternatives. Inexpensive electricity has historically been instrumental in attracting energy-intensive firms to South Africa, and large capital investments then caused the economy to become "locked-in" to a pattern of high energy consumption (Marquard and Winkler, 2009).

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<sup>7</sup> Calculated by comparing individual firm emissions from 2008 CDP report with the projected total emissions in South Africa for 2008 from the LTMS data. LTMS projections data set was provided to Genesis Analytics by the ERC.

In recognition of these issues, Government has already indicated a move to liberalise the electricity sector, having mandated that in future 30% of new capacity must be generated by private suppliers or Independent Power Producers (IPPs) (Eskom, 2009). Draft legislation put forward for public comment on 30 January 2009 confirms that Eskom will be the single buyer of electricity produced by new power generators and the electricity will then be transmitted to Eskom customers (and other licensed supply areas) via the main grid. Policy in this area has proven to be extremely fluid, and it is possible that in the longer term IPPs may be allowed to sell directly to customers with Eskom or the municipalities acting only as the distributor of that electricity. At present, however, it seems that firms will sell to Eskom under a long term (25 year) Power Purchase Agreement (Eskom 2009).

Also in response to the electricity crisis, and as part of the Power Conservation Programme of the National Demand Management Strategy, an Energy Conservation Scheme (ECS) is under development to reduce electricity used nationally by 10%. This scheme is currently being implemented by Eskom on a voluntary basis whilst the regulatory framework is being prepared for it to become mandatory. According to the draft guidelines published by the National Energy Regulator in December 2008<sup>8</sup>, the ECS will cover Eskom's biggest customers (private and municipal) based on volume of electricity used (the draft guidelines suggest firms consuming more than 25GW per annum) and will include penalties for missing targets. The guidelines suggest that there will be differential targets depending on the efficiency opportunities in different sectors. Those sectors which compete internationally and may be disadvantaged by the scheme could be protected with less stringent and graduated targets. Targets are to be allocated according to a baseline period of October 2006 to September 2007.

Furthermore, substantial increases in the price of electricity are expected over the next few years as the price is aligned with the real cost of generation, provided that the National Energy Regulator of South Africa allows electricity prices to rise to cost-reflective levels. This should act as a natural stimulus for the adoption of more efficient practices and technologies. Eskom has signalled its intention to move towards cost-reflective tariffs over the next 5 years with some analysts suggesting that tariffs will need to rise by as much as 80% in order to secure sufficient funds for Eskom's proposed investment programme (Business Day, 2009). This year alone a price rise of around 25% is expected. Increasing the cost of electricity so that it reflects the full cost of production is important in order to reduce the distortion in the electricity market as well as to incentivise energy efficiency.

From a climate change perspective, increases in the efficiency of electricity use and an overall reduction in electricity use can be seen as a "win-win" for the country, since it can, if well designed, simultaneously provide a solution to the power crisis, contribute to GHG mitigation efforts and provide cost reductions to firms and households. This is confirmed by the LTMS modelling which found that both commercial and industrial energy efficiency are "net negative cost options" when considered within a systems context; i.e. the upfront costs of improving efficiency are more than offset by the energy cost savings over time.

However, it is important to note that climate change mitigation is not the primary goal of the PCP and other responses to the supply crisis. The PCP is primarily being designed to reduce the burden of demand on Eskom's power generation capacity, and the staggered increase in tariffs aims to avert future power crises by increasing tariffs to a cost-reflective level. This

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<sup>8</sup> These guidelines are currently subject to discussion by stakeholders and the final draft is likely to be changed in a number of respects from the current draft. At the time of writing it was not clear what changes would be made.

means that any climate change impact of these policies will be indirect, simply a potential positive side-effect and is certainly not a given. Indeed the interaction between the different policies, each with different goals and mostly not climate change-related, may actually result in perverse incentives and negative outcomes, as is illustrated below, if not carefully managed.

Similar considerations apply to renewable energy policy. South Africa has identified an increase in the generation of renewable energy as a policy objective. Feed-in tariffs for renewable energy<sup>9</sup> offering a substantial subsidy to renewable electricity generation have been announced by the National Energy Regulator of South Africa (NERSA) in the hope that these will encourage the adoption of renewable technology enabling the country to meet its target of 10,000GWh of renewable capacity in the generation mix by 2013 (DME, 2003). A system of tradable renewable energy certificates is also being considered by the Department of Minerals and Energy to achieve this.

The Government has been subsidising the development of nuclear technology, with the intent of positioning the country as a leader in the application of the pebble bed modular reactor. Nuclear power does not emit greenhouse gases in its generation, and is a key component of Eskom's own climate change strategy. The development of pebble bed plants are still likely to be some years away, but in the meantime Eskom planned to build a number of convention pressurised water reactor plants. However, there is strong opposition to the expansion of nuclear from the environmental lobby, and Eskom recently announced that it was postponing the development of its new build nuclear programme due to affordability issues (World Nuclear News, 2008).

These developments in the South African electricity market introduce a complex range of incentives into the energy economy, as depicted in Table . Penalties for not meeting electricity savings targets under the PCP could encourage firms to find ways of using less electricity through efficiency drives and process innovations. However, it may prove cheaper for them to invest in on-site electricity generation capacity instead. The effects of electricity price increases are even more ambiguous. Firms and households will probably try to cut down electricity usage to some extent, but at a certain level, demand for electricity becomes inelastic and they may choose to rather pay the higher price and reduce their expenditures in other areas instead. Otherwise, depending on the price differentials, they may also choose to generate some or all of their power privately.

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<sup>9</sup> These are: R1.25/KWh for wind, R0.94/KWh for Hydro, R0.9/KWh for Landfill gas and R2.10/KWh for concentrated solar.

Development	Aim	Incentive
Power Conservation Programme	Reduce electricity used from the main grid by 10%	Find ways of producing that use less electricity OR Find alternative source of energy (e.g. burn more fuels) OR Invest in own generation capacity
Cost-reflective tariffs	Move to increase electricity prices over next 5 years	Find ways of producing that use less electricity OR Find alternative source of energy (e.g. burn more fuels) OR Invest in own generation capacity OR Reduce costs elsewhere in the organisation to make up for increase in electricity cost
Feed-in tariffs for renewable technology	Eskom will buy electricity from renewable generators at a price which subsidises the cost of production	Invest in and develop renewable power generation capacity in South Africa <i>to feed into main grid</i>
Proposed carbon tax	2c/KWh levy on electricity generated from non-renewable sources	Buy renewable power if available OR Reduce electricity usage as per cost-reflective tariffs

**Table : Developments in the electricity generation market and their potential incentive effects**

Source: Genesis Analytics, 2010

Renewable feed-in tariffs provide an incentive for investment in renewable electricity generation capacity, but at present only if the electricity is bought and distributed by Eskom. Producers cannot choose to sell their power directly to customers. Finally, a carbon tax such as the 2c/KWh proposed by National Treasury, if levied on or passed on to consumers, could incentivise the purchase of renewable power if it becomes possible to purchase power directly from renewable IPPs rather than through Eskom. Otherwise, it will have exactly the same effect on behaviour as a tariff increase.

This suggests that there could easily be “leakages” from a climate change perspective, for example if firms switch to burning more fuel on-site to avoid grid electricity consumption, instead of finding more energy-efficient ways of production. Big industrial users of electricity may invest in private power generation capacity (indeed some have already done so) which would not be fed into the grid but go straight to their installations. In the absence of appropriate incentives, this would be likely to be diesel or gas based due to the lower costs associated with these technologies. Firms are free to produce up to 10MW, a substantial amount, before they are required to conduct an environmental impact assessment.

The 2c/KWh levy identified in the mid-term budget speech in 2008 could also create perverse incentives for similar reasons and is unlikely to influence behaviour of consumers, particularly in the context of a potential 80% increase in tariffs over the next 5 years.

In conclusion, it is imperative that any climate change policy be designed to align with the suite of energy policy instruments aimed at conserving electricity use and encouraging renewable and nuclear which are currently under development. Given the dominance of energy emissions in the South African emissions profile, all possible points of alignment between the two policy objectives should be exploited. In the short term, policies being pursued from an energy security perspective present an opportunity for climate change mitigation, but in order for reduced emissions to be realised, the combination of incentives facing electricity users must be carefully considered, and climate policy focused on preventing carbon leakages from this system. In the long-term it will be important to consider what happens after the PCP when there is no longer an independent imperative to improve energy efficiency. The fluidity of policy in this area presents a challenge, as it makes it more difficult to anticipate where these leakages will occur, and the situation is likely to remain this way for some time. A detailed consideration of the present and likely future electricity context is therefore vital to designing effective policy.

#### **4.1.3. THE PROPOSED PEAK, PLATEAU AND DECLINE TRAJECTORY**

Government has declared its intention to develop a comprehensive response to climate change and transition to a “climate resilient and low-carbon economy and society”<sup>10</sup>. Cabinet’s Peak, Plateau and Decline trajectory is based on the modelling undertaken in the Long Term Mitigation Scenario (LTMS) process and accepts that in order to reach the “required by science” emissions level by 2050, emissions must peak by 2020 - 2025, plateau and then decline. Four scenarios were modelled, none of which go far enough to align with the Cabinet’s trajectory in the long term. It appears that aggressive energy efficiency will be sufficient to meet the Peak (aligned with the 34% reduction from baseline emissions by 2020 and 42% by 2025 offered at Copenhagen), but substantial progress will need to be made in laying the groundwork for the reductions from the remaining technologies modelled in the LTMS (renewables, nuclear, electric cars, passenger modal shift, carbon capture and storage etc) and more, post 2020. The „Use the Market’ scenario, modelling the imposition of an escalating carbon price comes closest to the medium and long term ambitions of Peak, Plateau and Decline, seeming to indicate that a price mechanism is likely to provide the heart of the long term mitigation policy suite. This is aligned to international climate mitigation policy thinking and direction.

There is still a need for actions which go beyond those so far implemented by government. By far the biggest emissions reduction “wedge”<sup>11</sup> was found in the LTMS to come from the imposition of a carbon price. In the LTMS this was modelled through the levying of an escalating carbon tax but it could conceivably also come from an emissions trading scheme. This implies that some form of market-related mechanism is could be important to achieving the ambitious target of a 40% reduction from 1998 levels by 2050. In fact, the LTMS modelling

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<sup>10</sup> DEET presentation to the WWF Renewable Energy Conference, November 2008

<sup>11</sup> In the LTMS “wedges” were used to show the emissions reduction potential of various abatement opportunities over time. The larger the wedge, the higher the potential abatement.

found that South Africa would need a carbon price, a significant expansion of renewable and nuclear electricity generation, achievement of energy-efficiency improvements *and more* in order to reach the target.

However, they face a number of other conflicting challenges. South Africa is still a developing country with high levels of poverty and unemployment, so any climate policies must be balanced against the need to grow the economy, create jobs and limit the impact of policies on the poor. In this context, the choice of instruments to mitigate emissions will prove critical and must be carefully considered with the complexities of the South African context in mind. In the next sections the various available instruments are weighed against one another in terms of the environmental, economic and fiscal efficiency criteria from a South African perspective.

## 4.2. INSTRUMENT COMPARISON

Environmental efficiency	Economic efficiency	Fiscal efficiency
How effective is the instrument in reducing emissions?	What will the instrument do to the economy?	Is the instrument affordable and is it an efficient way of raising revenue?
Environmental effectiveness	Competitiveness	Fiscal affordability
Encouragement of substitution	Distributional outcome	Administrative requirements
Impact on technology development	Economic efficiency	Information requirements
Support for the mechanism	Flexibility	
	Interaction with other policies	

**Table : Grouping of instrument choice criteria into themes**

*Source: Genesis Analytics, 2008*

The criteria for instrument choice used in section to evaluate the various instruments can be broadly grouped into three themes: environmental, economic and fiscal efficiency. This is illustrated in Table . Environmental efficiency encompasses all the criteria which determine whether or not a given instrument will be able to achieve a targeted level of emissions reduction, taking account of the country context. The economic efficiency of instruments is concerned with the effect that a given instrument will have on the South African economy through a variety of channels. Finally, fiscal efficiency deals with the cost and affordability of each instrument from government's perspective.

In reality, a single economic instrument to mitigate emissions may not be desirable and in fact a bouquet of instruments is likely to be more appropriate. This suite of instruments may also include non-market-based instruments like regulation and voluntary schemes. In the sections that follow, the report aims to analyse the various instruments in terms of their environmental, economic and fiscal efficiency in order to get an idea of what suite of instruments might be desirable for South Africa.

### 4.2.1. REGULATION

South African government has signalled its intention to move away from regulation as a tool to reduce emissions (National Treasury, 2006). This is largely due to its failure to meet the *economic efficiency* criteria, and market-based instruments are currently favoured over regulation as least-cost policy measures.

### **Performance standards**

As noted in Section , performance standards can be *environmentally efficient*. The fact that emissions are concentrated so heavily in two institutions in South Africa (two firms are the source of 56% of emissions) fits the condition under which regulation can be effective as there are relatively few sources to regulate, however it is likely to be politically difficult to impose such an inflexible regime and this detracts from the likely environmental effectiveness of regulation in practice. It is also unlikely that economic efficiency would be achieved in either the short run (as a result of a lack of information about cost structures in the wider economy) or in the long run (no incentives to continue abating once standards are implemented).

From a *fiscal efficiency* point of view, a performance standard generates no revenue for government (unless firms are incurring penalties for non-compliance, in which case the environmental efficiency criteria is not being met) and faces the same monitoring costs as other instruments. As far as South Africa is concerned, a further barrier to the design of a pollution cap or performance standard is lack of accurate information. In order to be efficient, such mechanisms are very data-intensive and the paucity of available data in South Africa makes it unlikely that government would have the information it needs in order to design the instrument efficiently. Gathering the necessary data will be an expensive and time-consuming process in itself.

### **Technology standards**

Technology standards share some of the characteristics of performance standards, but have some extra advantages of their own as detailed in Section . They can be very *environmentally efficient* in a situation where a technology exists that is proven to reduce emissions but that has not yet been widely adopted. From an *economic efficiency* point of view, technology standards may be positive in certain circumstances. Like a performance standard, a technology standard will not raise revenue for government, but it is less costly from an informational and monitoring requirements perspective, and therefore has a higher degree of *fiscal efficiency*.

Technology standards could therefore be an appropriate instrument to help South Africa achieve its mitigation goals as part of policy package which also includes a range of other mechanisms. For example, energy efficiency standards could be imposed on new buildings or fuel efficiency standards on new cars. This form of product specification will force consumers to

### **Information disclosure**

Information disclosure rules are *fiscally* and *economically* efficient given that they can encourage substitution at low cost to government. Their level of *environmental efficiency*, however, depends crucially on consumer preferences. Given the current socio-economic challenges in South Africa it is unclear whether consumers would have a strong preference for low carbon goods and services. Information disclosure rules may be useful to support voluntary measures like 'green' public procurement policies.

## 4.2.2. USING EXISTING MARKETS

### Taxes

The idea of using a tax to achieve emissions reduction in South Africa has been considered in a number of studies. The most sophisticated of these, the LTMS modelling exercise, considered a “use the market” approach as one of the strategic options to reach the “required by science” 30 to 40% reduction from 2003 levels by 2050. An escalating carbon tax is introduced starting at R100/tonne (around the level seen in international carbon trading markets to-date) and increasing to R750/tonne in the last decade. The model finds that this level of tax is able to drive the diversification of the electricity supply away from coal and towards renewables and nuclear. However, the tax alone does not provide enough impetus to take the economy all the way to the target since, in the model at least, it does not generate enough behaviour change from firms and consumers. In reality this is likely to be because there are too many unknowns in later years in terms of the discovery of new technologies and interaction of these technologies with human behaviour for the model to predict their effects with accuracy. Nevertheless, the “use the market” option generates a “wedge” of emissions reduction twice the size of any other alternative. In 2050 it reduces emissions by more than 600 Mt CO<sub>2</sub> equivalent. This suggests that a tax could prove very *environmentally efficient*.

As noted in section , carbon taxes have proven difficult to implement in some countries, thanks to entrenched interest groups who have vigorously opposed the use of such an instrument. In the South African context this may also be the case, especially given the country’s high concentration of energy-intensive industries. However, as discussed in Section , a tax provides price certainty which may prove attractive to business and outweigh this effect to some extent. A tax also has the benefit of providing a perception of equity, since producers are directly charged for their negative behaviour, which may appeal to consumers and to government. Thus it should be possible to build support for a tax amongst the various stakeholders.

In terms of the effect on the economy, taxes can also prove beneficial. Van Heerden et al (2006) show that with a suitable mechanism for redistribution of the tax revenues, the full negative effects of a range of potential environmental taxes can be offset, and a net positive impact on the economy can even be obtained, the so-called “triple-dividend” effect of environmental taxes. The LTMS modelling work found a similar result for relatively low tax levels. The “breakpoint” of the economic effects is shown to occur between a level of R100 and R200 per ton of GHG equivalent. For example, in the case of recycling of revenues through a subsidisation of basic food prices, employment changes stay positive up to the R100 level for semi-skilled workers, and up to R200 for unskilled workers. After that changes become negative (Marquard and Winkler, 2009)

It is argued in section that a tax can offer flexibility to adapt at an optimal pace over the business cycle at the same time as providing cost certainty for firms, as long as government sets out a long term path for the tax rate, which allows them to plan more accurately and may prevent them from sinking money into investments which may later prove expensive as the carbon price rises. This may be an important factor in South Africa, since there are already a number of issues which impair its attractiveness to business, so another source of uncertainty would be unwelcome. A carbon tax therefore also has significant advantages in terms of *economic efficiency*.

Under the final theme of fiscal efficiency, there are a number of considerations. The revenue generating aspect of a tax makes it attractive, as it provides funds for offsetting any negative

distributional effects. These are of even higher importance in South Africa where poverty levels are already high and policy cannot afford to exacerbate these conditions.

National Treasury is against the idea of earmarking tax revenues in general, arguing that it goes against the principles of sound fiscal management. However, they have indicated that they are open to the idea of “soft” earmarking such that revenues generated by an environmental tax could be allocated “on-budget” with special consideration to be given to redistribution mechanisms in favour of the poor, and to targeted incentives for positive environmental activities (National Treasury, 2006). From a political perspective this may be important, as there likely to be less resistance to the idea of a tax if taxpayers can see that the money is going to be put to good use.

Finally, in terms of the administrative costs of the policy, the institutions necessary to levy a tax are already in place and the South African Revenue Services which would be responsible for administering the tax is one of the most capacitated and efficient of government departments. However, there will be a cost attached to creating the infrastructure to monitor emissions at a plant level, if a direct tax on emissions is chosen. These costs need not be prohibitive if the systems are built up over time in a graduated way. Therefore, the tax can certainly prove to be *fiscally efficiency*.

A final concern in this section is the potential design of a tax in South Africa. In terms of the incidence of a tax, van Heerden et al (2006) consider the effects of a range of environmental taxes on the South African economy. They compare a tax on GHG emissions, a fuel tax, an electricity tax and an energy tax (a combination of the fuel and electricity taxes) to see, for a given level of emissions reduction, which type of tax has the smallest negative impact on the economy. The tax on emissions is found to be the most efficient in terms of providing the smallest drop in GDP for each unit of emissions reduction; however, the fuel tax causes the smallest increase in poverty, since it does not directly increase the price of electricity which is an important item for the poor. Assuming that the revenues from the tax can be used to some extent to offset the distributional implications of the tax, the emissions tax is certainly the best option from an environmental and economic efficiency point of view.

This analysis abstracts from the cost of administering such a tax, however, and it should be noted that a tax directly on emissions is likely to be quite expensive to monitor whereas National Treasury and SARS already have the systems in place to implement taxes on fuel and electricity. In fact there is already a tax on fuel of 150 cents per litre for petrol of 135 cents per litre of diesel and in the 2009 budget a tax of 2 cents per kWh on electricity generated from non-renewable sources was introduced.

Energy-intensive industries will be particularly heavily affected by a tax. Internationally this problem has sometimes been addressed by giving exemptions for energy-intensive industries. However, these reduce the impact of the tax on emissions reduction and, if done on an ad hoc basis can make the system very complex and significantly less efficient. They also have competitive implications since they tend to benefit some firms at the expense of others (Marquard and Winkler, 2009). In general it is more advisable to put in place measures complementary to a tax, to support energy-intensive firms in the transition to lower emissions-intensity. In addition, depending on the nature of completion and the structure of an industry, firms may in some cases be able to pass on most or all of the cost of compliance with climate policies to end-users. This has been found to be the case for power generation firms under the European Emissions Trading Scheme. (Sjimm et al, 2006).

## Subsidies

From an *environmental efficiency* perspective, subsidies are also effective, particularly as they are more attractive to business and therefore should be easier to implement.

Subsidies to incentivise investment in the development of green technologies are *economically efficient* as they encourage an activity which would be under-provided relative to its social benefit if left to the market. Recently agreed feed-in tariffs for renewable energy can be seen as a kind of subsidy to promote a social good, although it does not flow directly from the fiscus (although to the extent that government is providing cheap funding to Eskom and underwriting the institution's other borrowing for operational and investment purposes, tax payers' money is indirectly supporting the policy). Producers of electricity using wind, solar, landfill gas or hydro technologies will now benefit from a selling price higher than the economy-wide price of electricity. This is anticipated to encourage significant investment in green power generation over the next few years. There is also a strong argument for other kinds of subsidies and tax-based incentives such as more generous depreciation allowances to stimulate environmentally positive behaviour like investment in energy-efficiency technology.

Subsidies aimed at polluting firms in order to help them to abate are not as economically efficient. This is since they tend to provide the wrong dynamic incentives in the long term, preventing industries which present a high cost to society from shrinking as they would under a tax or trading regime. They also suffer from more negative perception issues, since the producer no longer pays the full cost of abatement themselves. However, there can be occasions where such subsidies can be efficient, if for example the up-front cost of financing a particular abatement technology is prohibitive relative to firms' ability to borrow. In South Africa, where there are a high proportion of energy-intensive firms, it may be necessary to support a mandatory tax or trading scheme with some subsidies in order to reduce the burden on firms in some targeted areas where abatement technology is very expensive.

Subsidies are obviously less *fiscally efficient* than a tax, since they represent expenditure for government rather than revenue. For this reason, and because of economic efficiency concerns highlighted above, subsidies and incentives should not form the centre-piece of a strategy to reduce GHG emissions, but rather should be used in a targeted way to provide support to a tax or trading scheme.

### 4.2.3. CREATING MARKETS

#### Cap and trade

Emissions trading schemes are the most popular form of greenhouse gas mitigation policy instruments in effect globally, with the Kyoto Protocol establishing an ETS at a global level and a number of countries and regions implementing their own schemes. As outlined above, they are generally popular with business since they are typically grandfathered, at least to begin with. The attractions of such a scheme for South Africa are the same as the general benefits described in Section ; however, there are a number of issues which raise problems for the implementation of an ETS in the South African context.

The *environmental efficiency* of an emissions trading scheme can be high if it is well-designed and the cap on emissions is not set too high. However, there are some other concerns in this respect. First of all, there is a growing perception, fuelled by international experience, of ETS as an inequitable means of addressing the problem of mitigation, since polluters have been seen to make windfall profits from the scheme in a number of cases, as detailed in Section . These experiences have undermined confidence in ETS and may make it a harder sell in South Africa. There are ways of avoiding such an outcome, however. Making sure that the initial allocation of permits is not too high should ensure that real abatement takes place, and this in turn can be aided by the gathering of accurate emissions and abatement cost data which could be facilitated by the introduction of a voluntary scheme prior to it becoming mandatory. Moreover, a relatively swift (the EU ETS aims to phase out the free allocation of permits for most industries by 2020) move away from grandfathering towards the auctioning of permits could be specified. This obviously needs to be balanced against the goal of ensuring a smooth transition which allows firms time to adapt.

In South Africa, market power is also an important issue to consider. Eskom and Sasol's emissions contributions could potentially give them too much influence over both scheme design and the eventual price of permits. The two represent 44% and 12% respectively of the country's total emissions but would make up an even greater proportion of the permit market as there are a number of emissions sources which would not be covered by an ETS due to measurement issues. For example, transport emissions (except emissions from aviation) are typically excluded from trading schemes due to the huge number of emissions sources. Transport emissions make up 11% of the South Africa's total emissions (Energy Research Centre 2008). If transport is excluded from a potential South African cap and trade scheme, Eskom and Sasol's contributions increase to 49.3% and 13.5% respectively. The analysis in Section suggests that this would have negative consequences for the effectiveness and efficiency of the ETS. Potential market power in the market for emissions certificates could lead to wider competition concerns by strengthening Eskom and Sasol's overall positions in their respective industries by creating extra barriers to entry. Sin et al (2005), suggest that in order to avoid the strategic manipulation of an ETS, no single market participant should hold more than 20% of permits. This would obviously be impossible in any scheme involving Eskom. Depending on the specification of a potential ETS in South Africa (for example, if the scheme started off like the EU ETS by only including electricity generators and large industrial emitters), Sasol's share of emissions covered in the scheme could also easily be more than 20%. Stavins (1997) mentions that market power may become an issue once individual firms hold more than 10% of permits. See Appendix for a discussion on possible ways to overcome market power and liquidity issues.

In terms of the barriers to entry question, however, there are ways of alleviating this problem, such as keeping permits aside in reserve for new firms or fully auctioning permits every period. Liquidity in the market is however still likely to be a problem which will make the scheme less environmentally and economically efficient<sup>12</sup>.

With respect to *economic efficiency* it is important that an ETS covers as large a proportion of emissions as possible (see section ). As mentioned above, market structure is likely to reduce the economic efficiency of an emissions trading scheme in South Africa as a result of low liquidity and market power issues. While it may theoretically possible to implement a trading scheme downstream that excludes Eskom and potentially Sasol's process emissions (potentially combined with other instruments like green or white certificate trading schemes and performance or technology standards) that will reduce liquidity and market power issues, this will significantly reduce the coverage of an ETS and reduce economic efficiency (also see section for a discussion for why implementing economic instruments on down-stream emitters is less efficient than implementing them on upstream emitters). Given the large upfront fixed costs of establishing a trading scheme, reducing the coverage of an ETS will also increase the cost of implementing such a scheme relative to the amount of emissions reduction achieved (the cost of the scheme will be split over fewer GHG emissions reduction units).

The distributional impact varies depending on whether the scheme is grandfathered or auctioned. Schemes are more efficient if auctioned and the distributional implications of an auctioned ETS in South Africa would be much the same as those of a carbon tax. The revenue generated from auctioning can be used in the same way as tax revenue could to offset any negative effects. A grandfathered scheme, however, will result in gains for some firms and potential losses for others, depending on how easy it is for them to abate and what proportion of costs they can pass on to consumers. No revenue is generated for government, which limits their ability to mitigate any impact on households and firms. Grandfathering is more business-friendly since it imposes a lower cost on firms. Overall therefore, the economic efficiency of trading schemes is mixed but generally higher if an auctioned scheme is chosen.

The *fiscal efficiency* of an ETS is also partly dependent on its design. A grandfathered trading scheme would generate no revenue for government but would involve substantial set-up and operational costs. If permits can be fully auctioned from early on, then a trading scheme could generate similar revenue to a tax but there are no international examples of schemes beginning with fully auctioned permits or even moving quickly in this direction. Under a grandfathered scheme, it would be more difficult to find space to support other environmental incentives or measures to offset any negative distributional impact. South Africa is a relatively small economy and a developing one. A revenue raising scheme is therefore attractive, since it would not divert any resources from other developmental goals towards climate policies. This suggests auctioning is more appropriate for the South African context.

Two other considerations which have a bearing on the fiscal efficiency of an ETS in South Africa are data requirements for the effective design of an ETS, and the level of sophistication of infrastructure required. On the first point, it has been noted more than once in the foregoing discussion that South Africa is in a particularly poor position in terms of having detailed and accurate data on historical emissions and abatement opportunities and costs. This is a problem for ETS (and other mitigation instruments) which could be offset to some extent by the

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<sup>12</sup> See Section for a more detailed discussion of market liquidity issues

implementation of a pilot, voluntary or otherwise. In general, an auctioned ETS would not be more information-intensive to establish than a tax on emissions, but grandfathered schemes require significantly more information to implement. The level of sophistication is a more serious problem. ETS are highly complex in terms of design and implementation and require an ongoing and robust process of review and adjustment. The skills shortage in South Africa which is particularly acute in the public sector, has led a number of commentators to question whether or not government would realistically be able to implement such a scheme effectively. This is certainly a cause for concern, although the establishment of a white or green certificate scheme (both are currently under consideration) or an initial voluntary phase in an ETS could prove useful from a capacity-building perspective.

A final note on the potential for ETS in South Africa is related to the international policy context. If a South African scheme could be linked with international trading schemes, this would have a number of positive implications for the prospects for ETS in South Africa. It could resolve the problems of liquidity and market power, since South African firms would make up a smaller proportion of the total market. The number of compliance options for firms would increase, which should give them greater flexibility and reduce costs. On the other hand, a linkage of this nature would reduce the autonomy of South African authorities to make decisions unilaterally about the operation of the scheme and force them to align their objectives with those of any partner countries. As a small country South Africa would possibly find itself subject to decisions taken by trading partners. Finally, monitoring and verification mechanisms would have to be very robust on both sides in order for schemes to be successfully integrated. Furthermore, if the opportunity presents itself for a local ETS to link to an international ETS, it is important that the international ETS be an accredited international mechanism. This is required to ensure that the scheme does not interfere with SA international commitments (i.e. permits bought by South African firms need to count towards any binding emissions reduction targets that South Africa may have). International permit trading is not currently a reality (except between EU member states participating in the European ETS) and so any arguments around South Africa's potential to benefit from it must be purely theoretical. However, it is worth noting as an area for further consideration and is discussed further in Appendix .

### **White certificate trading**

Given the huge contribution of energy to South Africa's GHG emissions, a white certificate scheme could be an appropriate and effective instrument for the country. In fact, the aforementioned Energy Conservation Scheme which aims to reduce electricity consumption by the biggest consumers (currently those using above 25GWh per year, anyone using more than 100MWh per year in the second phase) by 10% is a first step towards exactly that. The scheme is voluntary currently but is scheduled to become mandatory once the regulatory regime has been finalised, and draft guidelines published by the National Energy Regulator (NERSA 2008) suggest that trading will form part of the scheme.

Although introduced as a measure to address the power shortage, the ECS can also be seen as a GHG mitigation instrument. It represents a WCS in a fairly advanced stage of design, and with significant government and industry stakeholder backing which increases its chances of being effective. This is a key advantage of a WCS for South Africa, especially in the short term. If carefully designed, it could serve a dual purpose and also be an effective mechanism for reducing emissions.

However the issue of using a proxy for emissions (electricity usage in this case) rather than emissions themselves as the target of policy has implications for the overall *environmental*

*efficiency* of the scheme, as leakages could occur. For example, electricity supply could easily be substituted with quick-fix solutions (like diesel generators) which are more GHG emissions intensive. If the scheme is intended as a GHG mitigation instrument, not just as a means of reducing demand for electricity, methods of guarding against leakages must be explored. One example of such a mechanism could be investment tax incentives, such as accelerated depreciation for equipment that enhances energy efficiency. This could be effective in influencing the portion of electricity which is substituted with fossil fuel generated power (e.g. diesel), as opposed to energy efficiency measures or renewable sources. However, these interventions may also have side-effects; in the example of accelerated depreciation, this tool is generally viewed as a source of market distortion with hidden and potentially large costs of its own.

As noted in section , white certificate schemes achieve the goal of reduced energy consumption relative to a baseline in the most *economically efficient* way possible, since firms which can most cheaply conserve power will do so and sell permits to firms for which it is more costly. The provision for flexibility for those sectors least able to conserve power gives the potential to safeguard against competitiveness concerns. Distributional implications are not too serious since at first at least the target will be big industrial users of power, and energy efficiency can have positive payoffs for firms in terms of reduced costs.

In terms of *fiscal efficiency*, again a WCS would not raise any revenue, except in the event that firms incur penalties for non-compliance. Capacity is important to a WCS in terms of the effective design and implementation of a scheme (Lees, 2007), and as previously mentioned, this is an area where South Africa is generally weak. However, the financial sector is well advanced which may mitigate this concern to some extent. Accurate and timely monitoring and compliance evaluation will be critical, but South Africa's experience in the Demand Side Management Programme run by Eskom to subsidise the capital costs of energy efficiency to users provides it with some capacity in this regard. Technical knowledge, administrative capacity, and monitoring and verification challenges are not held to be insurmountable, and are considerably less onerous for a WCS than a full ETS (Lees, 2007). In sum, it is a relatively low-cost option for government although it would not generate any revenue.

### **Green certificate trading**

Green certificate schemes are an efficient way of stimulating the renewable electricity market and subsidising investment in renewables which are a public good and undervalued by the market. Since coal emissions from electricity generation are the number one cause of emissions in South Africa, there is a need for a systematic decarbonisation of electricity generation and a move towards more sustainable sources of power. In recognition of this government has set a target that 10 000 GWh of power generated in South Africa by 2013 be from renewable sources, but as yet not much progress has been made towards the target due to distortions in the electricity market. A green certificate scheme is one mechanism under consideration to help move the economy towards this target.

A GCS could be *environmentally effective* in South Africa since under a GCS, the "green" attributes of renewable energy are separated from the underlying electricity, which means that the problem of market power is circumvented. Anyone can buy a green certificate and thus support the development of renewable electricity, regardless of the fact that the actual electricity they use comes from the grid and cannot be traced back to any particular power producer. This yields the additional benefit of a green certificate scheme, which is that it

provides a credible platform which allows all kinds of electricity consumers to demonstrate their commitment to renewable power directly (Brick, 2009).

The same as a white certificate scheme, the trading aspect of a green certificate scheme makes it *economically efficient*, and allows support to be provided to renewable energy generators at least cost. It is also a *fiscally efficient* way of supporting green energy producers, since the incentives for renewable generation come from users of electricity rather than from government's budget. There would of course be set-up costs, but these would not be prohibitive.

In theory therefore, there are benefits to a GCS for South Africa. In practice, however, it is not clear that they are immediately necessary. The recently announced feed-in tariffs for certain kinds of renewable electricity have been widely hailed as sizeable enough to encourage investment in renewables in South Africa. Feed-in tariffs have been effective internationally in generating the right environment for investment in renewables to take place and for the industry to grow (Brick, 2009), and a wide range of studies on European experience have concluded that feed-in tariffs are more effective than green certificate trading for promoting renewable energy (Toke, 2008). So in the short-term at least the country is moving in the right direction. In the longer term it will be necessary to consider whether the tariffs go far enough to encourage the level of substitution required, and whether a GCS might be a valuable addition to policy. At present, government seems to be considering implementing a GCS on top of the feed-in tariffs, but there is still a lot of confusion around how this could work and whether the benefits derived from the scheme will outweigh the costs.

#### **4.2.4. VOLUNTARY MECHANISMS**

The main downside of voluntary mechanisms as a long term policy instrument is that they are unlikely to be very efficient at reducing emissions. However, in the short run they have a number of benefits which are very relevant to South Africa<sup>13</sup>, as the country is at an early stage of developing its policy response to climate change. The use of voluntary mechanisms in the short run will substantially increase the likelihood of designing effective, low-cost instruments for abatement in the longer term.

Firstly, South Africa needs to generate much more detailed and accurate data around emissions and abatement opportunities as a vital step towards developing effective policy. This suggests that voluntary reporting mechanisms, perhaps with incentives for compliance could be very useful in South Africa. Such schemes have been used with good effect internationally and have elicited information from firms on Scope 1, 2 and 3 emissions. This approach would also give government time to establish the infrastructure required to monitor and verify firms' emissions.

Furthermore, South Africa is just beginning to think about a climate change strategy, and so the various stakeholders may not be well-informed about the potential impact of mitigation policies on their business or household. A voluntary pilot scheme to encourage firms to reduce emissions could prove helpful in terms of building awareness and consensus, and easing firms

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<sup>13</sup> There are already a number of voluntary initiatives in place in South Africa that concern GHG emissions, these include: The Chemical Industry's Responsible Care initiative, the Energy Efficiency Accord, the Carbon Disclosure Project, the Global Reporting Initiative and voluntary input into the creation of South Africa's Carbon Inventory.

into the idea of climate policies. In essence, both of these approaches lay the groundwork for more effective mitigation policy later on.

A final point to note under the voluntary section is the huge opportunities offered by the UN's Clean Development Mechanism (CDM). Through the CDM, developed countries which face mandatory emissions targets under the Kyoto protocol, can generate credits towards their targets by financing emissions reduction activities in developing countries. There has been relatively little uptake of CDM funding in South Africa (see section ). There needs to be much greater exploitation of this instrument going forward, as it can provide significant funding for abatement opportunities in South Africa which will cushion the effect on the economy and reduce the amount of government revenue which has to be put into funding mitigation (Sangena Investments, 2004).

An approach being considered internationally is the negotiation of sector targets for developing countries. The United Kingdom in particular is in favour of the mechanism, which would see developing countries agreeing to sector specific "no lose" targets whereby no penalties would be levied for non-compliance but where countries would qualify for carbon credits if sectors are able to abate below the specified target. (UK Department of Climate Change, 2009). Countries would then be free to choose which instruments to use to get the sectors to achieve these targets. There are a broad range of models in terms of spreading the risks (too little abatement) and the potential rewards (income from carbon credits sold) between government and the sectors involved. The proponents of this mechanism believe that a sectoral approach will make it easier to reach consensus in Copenhagen, paving the way for a broad global climate agreement.

## **5. CLIMATE CHANGE AND INDUSTRIAL POLICY**

### **5.1. INDUSTRIAL POLICY IN SA: AN OVERVIEW**

#### **5.1.1. DEFINITION AND PURPOSE**

The main purpose of industrial policy is to "speed up the process of structural change towards higher productivity activities" (Hausmann, Rodrik and Sabel (2007:1). It can be defined as different points along a continuum (Chang, 1998). The broadest definition includes all government policy that influences industrial performance, while the narrowest definition of industrial policy includes only specific policy measures aimed at developing specific sectors (referred to as „sector targeting' or „picking winners'). A third definition, which essentially is a compromise between the very broad and very narrow definitions of industrial policy, sees industrial policy as consisting of "core" policies targeting specific priority sectors supported by "general", non-sector specific policies (like broad support for research and development) aimed at increasing the competitiveness of all industries.

The National Industrial Policy Framework (NIPF) and the accompanying Industrial Policy Action Plan (IPAP) (dti, 2007a and 2007b), which sets out the South African government's approach to industrial policy, indicate that the third definition of industrial policy is currently favoured in South Africa. The NIPF (dti, 2007a:10) identifies the need to "identify and act upon

critical constraints and opportunities at *both the cross-cutting and the sectoral levels* of the industrial economy [emphasis added].

The main objectives of the NIPF are (dti, 2007a:10-11 and 2007b:2):

- To facilitate diversification of the South African economy beyond its current reliance on traditional commodities and non-tradable services;
- To intensify the industrialisation process in South Africa in the long term and to steer it towards a knowledge economy;
- To promote more labour-intensive industrialisation in South Africa;
- To promote broader-based industrialisation that offers increased economic opportunities to historically disadvantaged individuals and marginalised regions; and
- To support industrial development on the African continent.

### **5.1.2. INSTITUTIONAL FRAMEWORK**

The Accelerated and Shared Growth Initiative (AsgiSA) suggested that South Africa embrace a more active industrial policy approach in order to move the economy to a more „inclusive’ growth path (dti, 2007a; Presidency, 2009). AsgiSA identified cross-cutting issues that industrial policy needs to address, as well as a number of priority sectors for industrial policy purposes (shown below as the 13 strategic themes highlighted in the NIPF) (Mlambo-Ngcuka, 2006). AsgiSA endeavoured to focus the energy of government and important stakeholders on industrial policy while a national industrial policy framework for South Africa was being prepared. The NIPF and the accompanying IPAP was finalised in 2007. These two documents set the scene for industrial policy at the national level (MEDS, 2007). Through the provision of principles, processes and strategic direction, the NIPF aims to provide a “framework rather than a blueprint” to guide South Africa’s industrialisation and to facilitate structural change in the economy (dti, 2007a:9). The NIPF thus provides the broad framework guiding industrial policy, while the IPAP sets out a prioritisation of key actions that need to be undertaken within a 3-year Medium Term Expenditure Framework term.

The NIPF emphasises the “inherent intra-governmental nature of industrial policy” (dti, 2007a:11). In order for industrial policy to be successful, the NIPF stresses that it needs to be supported by a set of four complementary policies. These complementary policies deal with (dti, 2007:11):

- A supportive macroeconomic and regulatory environment;
- Skills and education;
- Traditional and modern infrastructure; and
- Support for technological effort.

The NIPF provides a point of intersection between industrial policy and complementary policies and programmes within government. This is particularly true within the Economic, Investment and Employment Cluster (EIEC) (dti, 2007a). The NIPF also calls for greater coordination between various government clusters to facilitate greater coherence in economic planning. In particular, greater coordination between industrial policy and issues of service delivery and spatial development (the location of housing, water, electricity, telecommunications and

transport infrastructure), international relations and trade and investment is needed to create an environment conducive to industrial development. The role of an effective justice system, security and crime prevention in creating an enabling investment climate must also not be underestimated.

The effective implementation of industrial policy involves the commitment and coordination of a wide range of government departments and agencies. Even “narrow industrial policy”, requires departments other than the dti (which is tasked with implementing industrial policy and sector strategies) to play an important role. Kaplan (2008) highlights the role of Public Enterprises, for instance, in supporting very selective interventions that favour certain sectors or activities like direct state support to the armaments industry, support for the development of the Pebble Bed Modular Reactor (PBMR) and subsidised infrastructure and energy to the Coega industrial development zone. Kaplan (2008:37) refers to very selective industrial interventions like the ones listed above as “hidden industrial policy” since they are often initiated and managed by departments other than the dti and presented by government outside of an industrial policy framework.

### **5.1.3. SECTOR STRATEGIES**

#### **Selection criteria and policy instruments**

The NIPF focuses on providing a set of “*principles and processes* through which sector strategies are to be developed, strengthened and prioritised [emphasis in original]” rather than providing a “definitive prioritisation of sectors” (dti, 2007a:33). This is done in order to accommodate changes in economic structure over time and allow for further sector analysis. The NIPF prescribes that all sector development work undertaken by the South African government should be based on (dti, 2007a:34):

- A detailed economic analysis of the sector that is both realistic and based on verifiable evidence. The important factors to take account of are the relative size and growth prospects of the sector as well as the potential impact of the sector with respect to employment creation, additional value-added, diversification of exports and production, development of new technologies and broad based empowerment.
- A serious „self-discovery’ process<sup>14</sup> that aims to identify the constraints and opportunities in the sector that may justify government intervention.
- An analysis of the viability and sustainability of the sector in the medium to long term.
- An economic cost-benefit analysis of the alternative policy responses available to address identified constraints and opportunities within the sector.
- An assessment of institutional arrangements that influence both the sector’s ability to engage with government and assist in implementing policy measures, and government’s capacity to implement identified suitable policy measures in the relevant sector. Government capacity is especially important in cases where the implementation of a sector strategy will require inputs from various government departments.

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<sup>14</sup> Self-discovery processes can take many forms, but essentially involves a robust consultation between the firms in a sector, government, labour, civil society and other relevant stakeholders (dti, 2007a). The process should be informed by extensive research into the sector and analysis of relevant issues and opportunities facing the sector (dti, 2007s).

The NIPF advocates the prioritisation of roughly 5 high-impact priority sectors for sector development purposes within every MTEF period (dti, 2007:34-35). In accordance with AsgiSA growth and employment objectives, the NIPF suggests prioritising sectors that can generate *significant employment and growth, especially in non-traditional tradable activities*. Emphasis should also be placed on *sectors that can support South Africa's structural transition to a "technology sophisticated and knowledge-driven economy"* (dti, 2007a:35). In addition, sector development activities should focus on sectors that will generate "significant positive external economies" if their growth constraints are addressed or development opportunities are exploited, that have made significant progress in 'self-discovery' and where substantial knowledge about the sector has been generated. The institutional ability of both the sector and government to implement proposed sector strategies, and the scale of the economic benefits expected from government support relative to the cost of providing the support, should also be taken into consideration when sectors are prioritised for development activities.

The IPAP indicates that government will prioritise sectors for development based on significant (dti, 2007b:3):

- Growth and employment potential;
- Potential for the diversification and growth of exports; and
- Research and self-discovery process having been completed.

The IPAP mentions that the following policy instruments will be of particular relevance to support identified sectors (dti, 2007:3):

- Appropriate targeting and scale to support investment in updated machinery and equipment to replace ageing capital stock;
- Support for industrial upgrading to deepen manufacturing capacity;
- Support for industry- and cluster-specific infrastructure; and
- Addressing monopoly pricing in input markets.

### **Priority Sectors**

Based on existing research, the NIPF identified 5 broad sector groupings where it believes the greatest potential for diversification opportunities lie. The 5 sector groupings, and examples of sectors explicitly mentioned within each in the NIPF, are as follows (dti, 2007a:36-38):

- Natural resource based sectors
- Medium technology sectors (including downstream mineral beneficiation): Metals fabrication; Machinery and equipment; Chemicals and Plastics; Paper and Pulp; Oil and Gas; Jewellery.
- Advanced manufacturing sectors: Automotives; Aerospace; Electronics; Nuclear energy; Capital goods.
- Labour-intensive sectors: Agriculture; Forestry; Fishing; Certain mining activities; Clothing and Textiles; Footwear; Food; Beverages; Furniture.
- Tradable services sectors: business process outsourcing; ICT services; engineering; construction and mining services; film.

The IPAP identifies 4 lead sectors with respect to the implementation of the NIPF, namely (dti, 2007b:3): *Capital/transport equipment and Metals; Automotive assembly and Components; Chemicals, Plastic fabrication and Pharmaceuticals; and Forestry, Pulp and Paper and Furniture*. The IPAP also seeks to maintain momentum with respect to supporting the 3 key sectors identified in AsgiSA (dti, 2007b:3), namely: *Business Process Outsourcing and Offshoring; Tourism; and Biofuels*. In addition, significant sectoral interventions are also put forward in the following sectors (dti, 2007b:20-28): *Clothing and Textiles; Diamond beneficiation and jewellery; Agro-processing; Film and Television; and Crafts*. The IPAP further endeavours to develop more wide-ranging sector strategies and design interventions for the following sectors (dti, 2007b:30): *Mining and mineral beneficiation; Agriculture/Agri-processing; ICT services and products; and Creative industries*. Finally, the IPAP mentions that “perspectives” need to be developed on the *White goods, Retail and Community/Social services sectors* (dti, 2007b:30).

## **5.2. ALIGNMENT OF CLIMATE CHANGE AND INDUSTRIAL POLICY OBJECTIVES**

Although the NIPF and the IPAP do not address climate change mitigation, there are significant overlaps between the objectives of industrial policy (mentioned above) and climate change policies.

### **5.2.1. STRUCTURAL CHANGES TO THE SOUTH AFRICAN ECONOMY**

Hausmann, Rodrik and Sabel (2008:2) mention that “self-discovery externalities” are ubiquitous in emerging markets. The process of learning how to produce new products profitably, and which products to produce in a specific economy, is under-supplied since it is a risky endeavour and the social value of success exceeds the private return. By forcing the private sector to consider the implications of climate change and GHG emissions on their activities, climate change policy can assist the „self-discovery’ process that is one of the cornerstones of industrial policy in South Africa. In a relatively new area like climate change the social value of successful self-discovery is very high, given that new opportunities for global growth are opening up as new markets for environmental goods and services<sup>15</sup> are created (Demaillly, 2009; dti, 2007a). Countries and firms that identify and act upon these opportunities relatively quickly will have a significant first-mover advantage and enjoy a competitive advantage as the demand for these goods and services grow in the long term<sup>16</sup> (Demaillly, 2008; dti, 2007a; MEDS, 2007). Becker and Shadbegian (2009) found that environmental products manufacturing firms in the US are more likely to be exporters than general manufacturers.

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<sup>15</sup> Environmental goods and services “measure, prevent, limit, minimise or correct environmental damage”, and include activities as diverse as renewable energy generation, environmental consulting, environmentally friendly construction techniques and energy efficiency (European Commission, 2008:9).

<sup>16</sup> The impact of climate change policies on industrial activities have to date been relatively small, and are currently dwarfed by factors like trade barriers, transport costs, existing customer relationships, exchange rate fluctuations, investment climate factors, etc for most sectors (Desmaillly, 2008; Oikonomou, Neuhoff and Mathes, 2008). This is, however, largely a function of carbon commitments internationally being relatively generous to date. As international commitments become more onerous, and developing countries start being party to these commitments (as is general expected to happen in the near future), the first-mover advantage in environmental goods and services linked to climate change will increasingly be translated into a competitive advantage.

Blueprint (2006) identifies climate change as one of the key factors expected to drive growth in the environmental goods and services sector in South Africa, and identifies 3 main areas of opportunity linked to climate change, namely analytical and consulting services (eg. data generation and interpretation); commercialisation of new technologies (eg. carbon capture and storage technologies); and renewable energy (eg. wind farm and solar energy). One possible outcome of climate change measures may be to incentivise the creation of new areas of low-carbon competitive advantage within the economy based on local resource endowments (Winkler and Marquard, 2007). One potential such area of competitive advantage in South Africa may be the solar energy industry, given that South Africa has some of the best conditions for solar energy generation in the world (Winkler and Marquard, 2007). Furthermore, by favouring less energy- and carbon-intensive sectors, climate change policy will assist in diversifying the South African economy away from its historical reliance on energy- and capital-intensive upstream resource-based manufacturing (dti, 2007a; Winkler & Marquard, 2007).

In addition to developing new tradable goods and services, well conceived and implemented climate change policies could play an important role in supporting the NIPF objective of moving the South African economy towards non-traditional tradable goods and services in the medium to long term by facilitating continued access to current export markets in developed countries (dti, 2007a). Developed countries that implement relatively stringent climate change policies are increasingly concerned with the issue of “carbon leakage”. Carbon leakage refers to a relocation of production activities to jurisdictions with less stringent climate change policies as a result of, for instance, a shift in consumption of carbon-intensive goods from local production to cheaper imported products (Van Asselt, Brewer and Mehling, 2009). Carbon leakage thus refers to a situation where the competitiveness of firms are reduced as a result of a price on carbon existing in some countries, but not in others (Garnaut, 2008)<sup>17</sup>. Carbon leakage can, inter alia, be addressed by border adjustment measures<sup>18</sup> or using labelling and product specifications to allow local consumers to differentiate between more and less environmentally damaging goods. The US is currently considering the implementation of broad border adjustment measures (potentially covering energy-intensive products and all other final products), while the EU is in favour of sub-sector-specific trade measures to address carbon leakage (targeting energy-intensive products) (Van Asselt, Brewer and Mehling, 2009). The EU has already adopted environmental labelling regulations and minimum requirements on energy-related products (European Commission, 2008).

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<sup>17</sup> As is clearly stated in Reinaud (2008), the issue addressed in the carbon leakage literature is the artificial competitiveness disadvantage experienced by industries in countries where carbon is priced into the production process relative to carbon “unconstrained” producers in countries where carbon does not have a price. Gradual changes in the comparative advantage of countries as a result of the cost of carbon being internalised into the production process should thus not be viewed as carbon leakage.

<sup>18</sup> Border adjustment measures aim to remove the cost advantage of imported goods produced under less stringent climate change policies by levying a tariff on imported goods equal to the differential between the local price of carbon and the price on carbon in the country where the imports originated, or by requiring importers to buy permits equal to the value of the carbon embodied in imports (Frankel, 2009; Van Asselt, Brewer and Mehling, 2009). Given that there is a precedent of allowing trade measures to combat global externalities (trade restrictions relating to products linked to CFC emissions under the Montreal Protocol, for instance), Frankel (2009) and Bordoff (2009) believe that border adjustment measures linked to GHGs may well be WTO compliant, depending on how they are designed and implemented. Frankel (2009) and Bordoff (2009), however, both mention the possibility that border adjustment measures may be implemented as protectionist tools given the discretion that individual governments will have to define whether trade partners are meeting their carbon responsibilities, how to measure the carbon content of manufactures, what sectors are susceptible to border adjustment measures etc.

If adequate local climate change policies are not in place, and border adjustment measures are applied to South African goods, it could significantly affect the ability of South Africa to grow (or even sustain) exports to its main export markets, namely the EU and US.

### **5.2.2. KNOWLEDGE-BASED INDUSTRIALISATION**

Climate change mitigation offers significant opportunities for technology development, innovation and adoption. European Commission (2008:2) states that efforts to increase sustainability and global pressures to increase resource efficiency “could become an important source of innovation and ... asset for industry’s competitiveness”. The extent of the opportunity is highlighted by the fact that MEDS (2007) places climate change mitigation and adaptation at the centre of the Western Cape’s innovation strategy. An environment that incentivises low-carbon production technologies (for example through internalising the price of carbon into production) may also lead to significant technology spill-over effects as new low-carbon technologies available internationally are adopted and adapted locally (Demailly, 2008).

Knowledge industries are often established in response to market signals and other incentives like government support for specific technologies and their implementation (MEDS, 2007). A regulatory environment where climate change considerations are incorporated into investment and policy decisions, underpinned by appropriate public sector support programmes, would thus create the right incentives for private sector players to exploit the opportunities offered by climate change (MEDS, 2007; Winkler & Marquard, 2007). Winkler and Marquard (2007) believe that, with the right support measures, South Africa could become a “world leader” in solar thermal energy in a similar way that Denmark became the leading developer and exporter of wind technology. In addition to solar energy, DEAT (2009) believes investment in research and development related to electric and hybrid vehicles, carbon capture and storage, and clean coal technologies should be prioritised.

An opportunity to secure international funding for the development of new environmental goods and services, and to facilitate technological spill-over effects, which has been underutilised in South Africa, is the Kyoto Protocol’s Clean Development Mechanism (CDM) (Sangena Investments, 2004). In 2006 the value of trade in CDM credits was €6bn while only 12 out of the 839 CDM projects registered internationally, were registered in South Africa (Van den Berg, 2008). The CDM is only available to South African firms for a limited period of time (until South Africa enters into binding international commitments to reduce its GHG emissions), and measures should thus be put in place speedily to assist South African firms to make the most of this opportunity while it is still available (Sangena Investments, 2004; Van den Berg, 2008). According to the UNFCCC CDM registry, as at the 12th of November 2009, only 17 out of a total of 1895 (0.9%) CDM projects were registered in South Africa. In contrast, 165 projects were registered in Brazil, 467 in India and 663 in China (<http://cdm.unfccc.int>).

### **5.2.3. LABOUR-INTENSIVE AND BROAD-BASED INDUSTRIALISATION**

A move towards a low-carbon economy has the potential to create a number of “green jobs”<sup>19</sup>. For example, Winkler (2007b) mentions that a growing body of literature indicates that energy

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<sup>19</sup> UNEP (2008:3) defines “green jobs as work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute substantially to preserving or restoring environmental quality[emphasis added]”.

efficiency measures generate significant employment opportunities. Not only are people employed directly in energy efficiency initiatives, but savings on energy expenditures enables greater expenditure on non-energy goods and services (the production of which is generally more labour-intensive than the energy sector) which leads to employment gains throughout the economy (Geller, DeCicco and Laitner, 1992; UNEP, 2008, Winkler, 2007b). UNEP (2009) mentions that opportunities for employment creation linked to energy efficiency are particularly significant in developing countries as a result of large stocks of energy inefficient buildings that will require retrofiting<sup>20</sup>. In addition, Winkler (2007a) mentions that renewable energy technologies are more labour intensive than non-renewal technologies. AGAMA (2003)<sup>21</sup> calculated that adding renewable energy to the generation mix to meet energy demand in 2020 (70% of the estimated 62TWh additional supply provided from renewable sources) will lead to an 21% increase in the number of direct jobs created in the electricity supply industry compared to a situation where all additional capacity is generated from coal-fired power stations (52 000 new jobs versus 43 000). If the new capacity is generated exclusively from renewable sources, the increase in direct jobs jumps to 33% (57 000 jobs versus 43 000). In the last scenario where all new generation is provided by renewable sources, renewables would provide 15% of total generation in 2020.

On the whole, the European Trade Union Confederation (EUTC, 2007) believes that climate change mitigation actions will have a modest positive impact on employment. Furthermore, not only will the additional jobs include a significant number of un-skilled and semi-skilled labour<sup>22</sup> (mainly in the biofuels, biogas and solar water heaters sectors), but the distribution of jobs will also support the NIPF's stated objective of greater regional equity in employment creation. The jobs created by renewable sources will be more decentralised than will be the case with gas, nuclear and coal generation and will largely be located in rural areas (AGAMA, 2003). The provision of off-grid electricity to remote areas could also stimulate rural economic activity (AGAMA, 2003).

#### **5.2.4. INDUSTRIAL COMPETITIVENESS**

##### **Overview**

While climate change creates many opportunities for firms in the medium to long term through the development of new markets for low-carbon environmental goods and services, and may even lead to increased competitiveness as firms are forced to audit their production process for unexploited efficiencies, there is a concern that having to internalise the cost of GHG emissions may reduce the *international competitiveness* of sectors (MEDS, 2007; Demailly, 2008). In addition, fears also abound that carbon leakage could lead to a reduction in employment and tax revenues (Demailly, 2008; Neuhoff, 2008).

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<sup>20</sup> For examples of employment creation linked to energy efficiency initiatives, see UNEP (2008).

<sup>21</sup> The results of this study is consistent with that of the European Commission's MITRE project that found that employment creation in the renewable energy sector more than compensates for employment losses elsewhere in an economy, and that "pro-active encouragement of renewables give rise to significant net employment gains" (EC, 2004:13).

<sup>22</sup> For a detailed assessment of the types of skills required for individual renewable energy technologies, see AGAMA (2003). These results are consistent with EC (2004), which found a split between skilled and unskilled employment creation for renewables of 30/70. The unskilled definition used in EC (2004) would most likely refer to semi-and unskilled labour in South Africa.

Different sectors within a country have different comparative advantages, and are often faced with different regulatory regimes. In terms of international competitiveness, the emphasis should thus be on the sectors or even firms within countries that compete in international markets, rather than the competitiveness of a country (Krugman, 1994). Climate change policies will reduce the competitiveness of carbon-intensive sectors relative to less carbon-intensive sectors within an economy. They may also reduce the competitiveness of carbon-intensive sectors in a country relative to carbon-intensive sectors in countries with less stringent climate change policies since the sectors will experience asymmetric increases in production costs (Demailly, 2008). Only the relative competitiveness of tradable sectors in countries with different levels of climate change policies in place will be affected (Demailly, 2008). In practice, however, climate change (and other environmental) policies are only one of many factors influencing competitiveness.

The impact of climate change policies have to date been relatively small, and are currently dwarfed by factors like trade barriers, transport costs, existing customer relationships, exchange rate fluctuations, investment climate factors, etc for most sectors (Desmally, 2008; Oikonomou, Neuhoff and Mathes, 2008; Patel and Worell, 2006)<sup>23</sup>. Factors like sunk costs also limit the ability of firms to relocate (Desmally, 2008). Firms that wish to relocate also run the risk that climate change policies may become stricter in the jurisdiction that they are contemplating relocating to during the pay-back period on their new investment as a result of international pressure, border measures in export markets etc. (Neuhoff and Mathes, 2008). Sijm et al (2006), in a survey of the empirical literature, and Barker et al (2007:20), based on an econometric assessment of carbon leakage within the European union, both find that environmental policy has to date not generally had a significant effect on either the competitiveness or investment/relocation decisions of firms in energy-intensive industries. Evidence from the broad literature surrounding carbon leakage suggest that the reason for the relatively insignificant leakage impact in practice is that carbon leakage effects are to a large extent offset by technology spillover effects (Desmally, 2008; Barket et al 2007).

A number of studies have shown that the cost impacts of climate change policies do, however, vary widely between sectors, and that there are usually a minority of sectors in a country that are significantly affected by climate change policies (Neuhoff and Mathes, 2008). This point is illustrated by Figure . It shows which sectors in the UK economy are expected to experience an increase of more than 2% in their production costs (relative to gross value added [GVA] – this measure is referred to as “value at stake”) as a result of a carbon price of €20/t and a €10/MWh increase in the price of electricity (Houcade et al (2008). The figure shows that sectors accounting for just more than 1% of economic activity in the UK will experience an increase of 2% or more. These sectors also contribute 11% of the UK’s total GHG emissions and 0.5% of its employment. Even within the sample of sectors potentially heavily affected by climate change policies, the impact of these policies vary significant between sectors. It is clear that there is a small sub-set of sectors that are disproportionately affected. Neuhoff and Mathes (2008) mention that the results obtained in Houcade et al (2008) are very similar to results from other studies dealing with OECD countries.

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<sup>23</sup> This may however change as climate change commitments become more ambitious internationally.

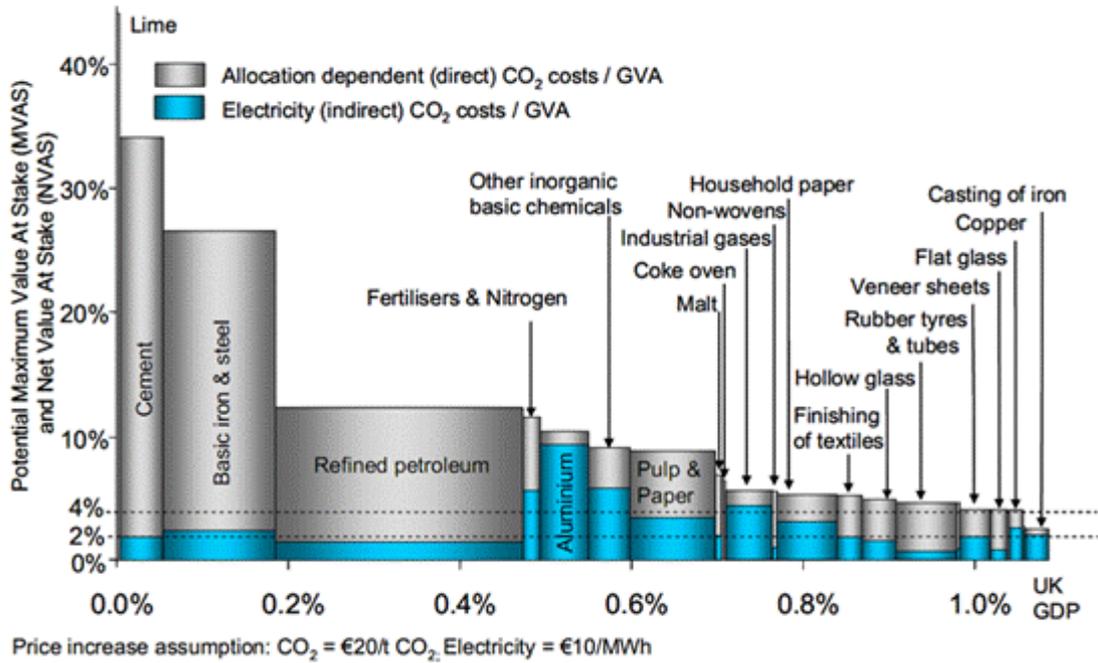


Figure : Sectors potentially exposed to significant CO<sub>2</sub> price effects (UK 2004 data)  
Source: Houcade et al (2008)

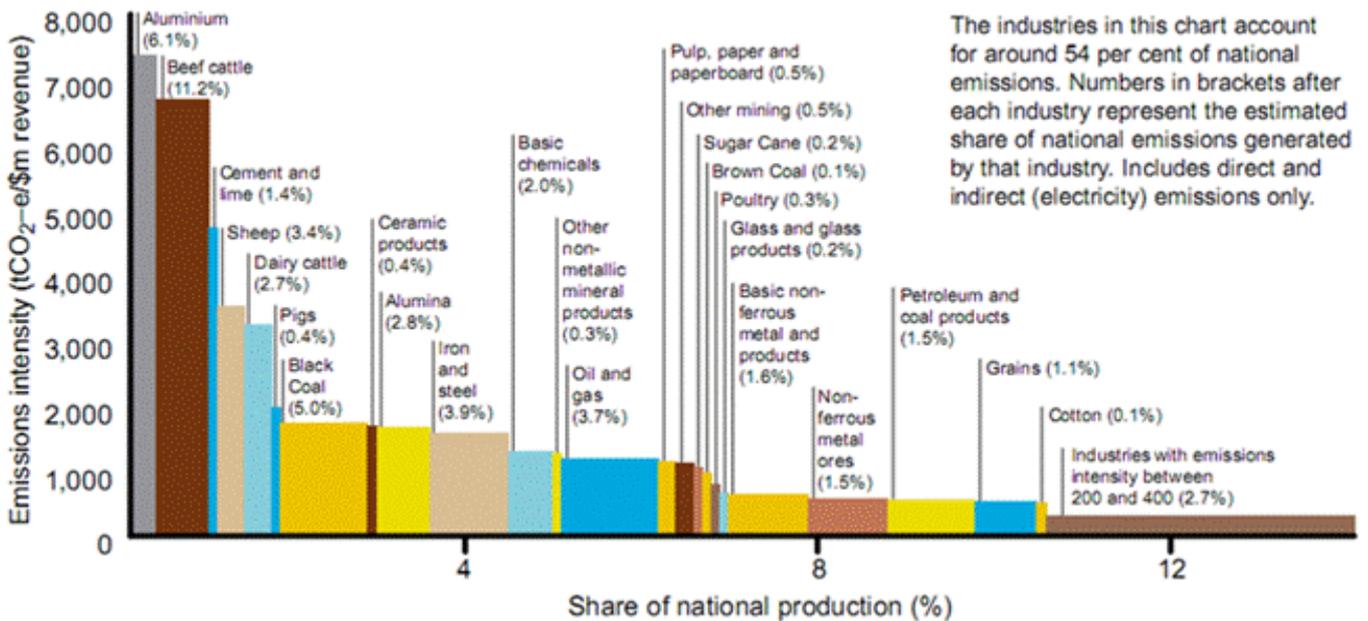


Figure : Emission intensity of traded sectors in the Australian economy (2001-2002)  
Source: Australian Government (2008)

Figure (above) shows that 5 Australian traded goods and services sectors stand out as very emissions-intensive in comparison with the rest of the economy, namely: aluminium, beef cattle; cement and lime; sheep; and dairy cattle (Australian Government, 2008). The 10 industries with the highest emissions-intensity accounted for 37% of Australia's total emissions, around 4% of GDP, 3% of total employment and 15% of total exports in 2001-2002. For the 5 most emissions intensive industries, an indicative carbon price of about \$20/t CO<sub>2</sub> would increase production costs by 10–15% (Australian Government, 2008). The moderately emissions-intensive sectors (the sectors preceding the second step-down in Figure 6), would experience a production costs increase of 3-8%. Sectors that would experience a production cost increase of 4% or more as a result of a \$20/t carbon price contributed 25% of Australia's national emissions, and around 2% of GDP and employment in 2001-2002 (Australian Government, 2008).

A significant increase in production costs as a result of climate change policy in a region, however, only translates into a reduction in competitiveness in a sector if the firms in the sector are not able to pass on cost increases to consumers (Neuhoff and Mathes, 2008). The most important factor that constrains the ability of firms to pass on cost increases is competition from foreign imports (often from areas with less stringent environmental policies in place) (Neuhoff and Mathes, 2008). The trade intensity of a sector (which can be measured in a number of ways) is thus an important indicator in identifying sectors that are vulnerable to climate change policies (Neuhoff and Mathes, 2008). It is, however, not a perfect indicator and can change over time in response to large price movements that allow exporters to target new markets (Demailly, 2008). A low trade intensity, however, usually indicates that there are significant local trade barriers like transport costs, shipping time, congested infrastructure or some other measure shielding the sector from foreign competition (Demailly, 2008). The ability of a firm to pass on costs will also depend on its market power, which may be linked to issues like concentration within the sector, product differentiation, relationships with customers and government policies (Gerald, Keeney and Scott, 2007; Neuhoff and Mathes, 2007). The availability and cost of abatement technology is also an important factor in determining a sector's vulnerability to carbon pricing (Gerald, Keeney and Scott, 2007). Technology that allows firms to abate cheaply will have a significant impact on the competitiveness of a sector (Gerald, Keeney and Scott, 2007).

Figure shows an assessment of 5 UK sectors to a carbon price based on their energy intensity (as a proxy for carbon intensity), ability to pass on cost increases, and the availability of energy efficiency technology to the sectors. Gerald, Keeney and Scott (2007) mention that Basic metals is the sector most vulnerable to a carbon price, since it is relatively energy intensive, has few energy efficiency technologies available to it, and the ability of firms in this sector to pass on cost increases is severely constrained by price competition from imports. The chemicals sector is more energy intensive than Basic metals, but has more discretion in setting prices and has more energy efficiency options available to it. As a result, Chemicals is deemed to be less vulnerable to a lack of competitiveness due to a carbon price than Basic metals.

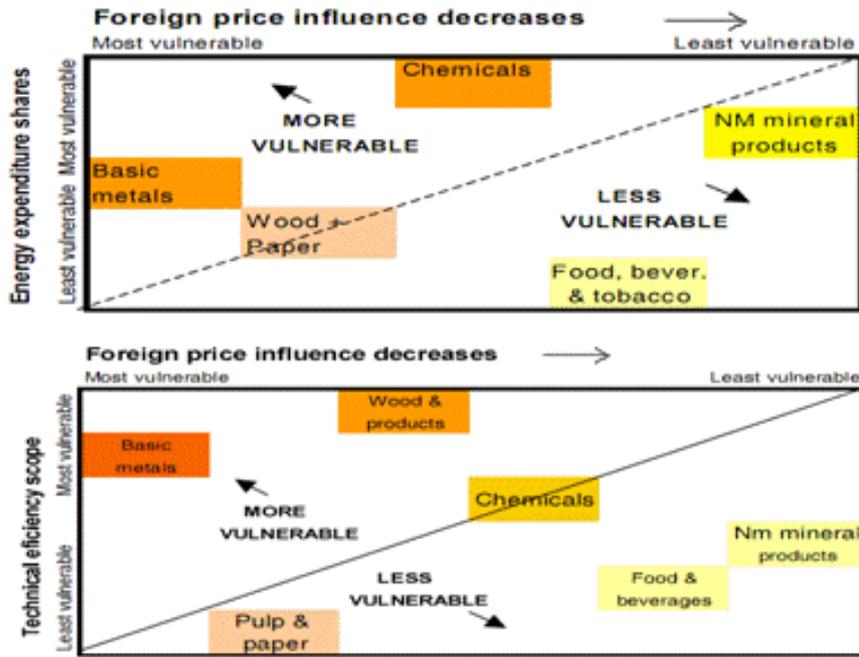
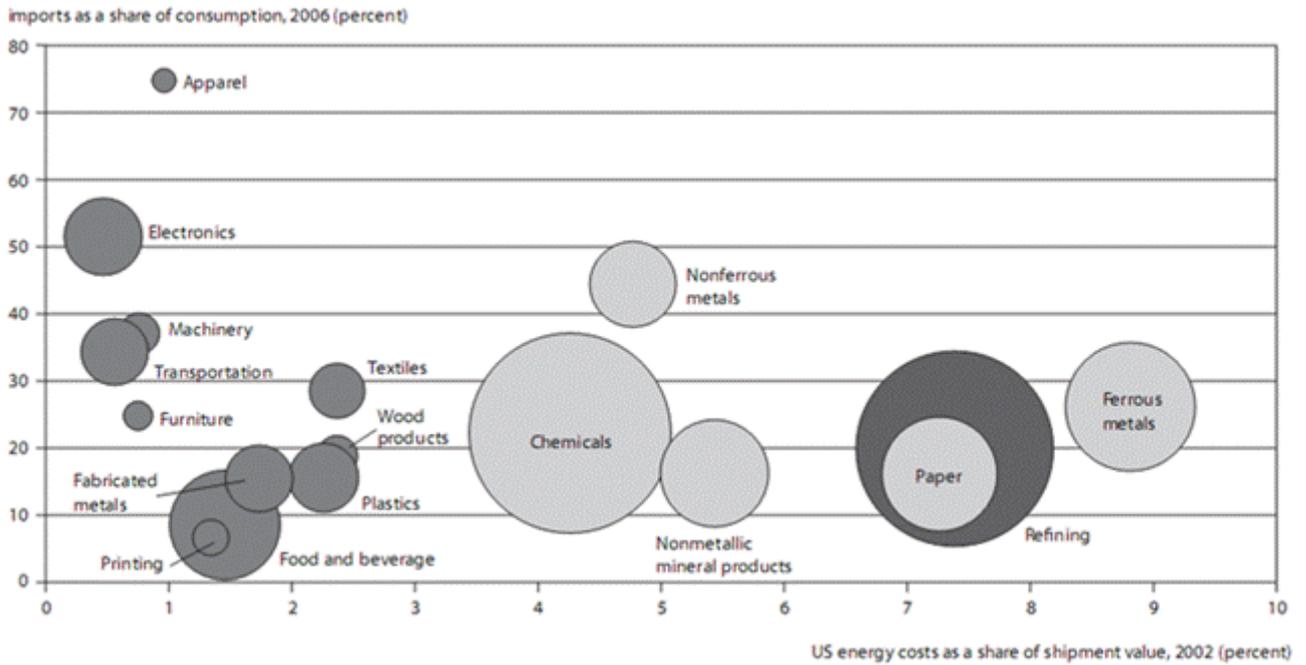


Figure : Assessing vulnerability of UK sectors to carbon prices  
 Source: Gerald, Keeney and Scott, 2007



Note: The size of the bubbles indicates the total CO<sub>2</sub> emissions from the industry in 2002.

Figure : Assessing vulnerability of US sectors to carbon price based on trade and energy intensity  
 Source: WRI, 2008

Figure (above) shows imports as a share of local consumption (as a proxy for the tradability of a sector and hence the ability of firms in a sector to pass on cost increase) relative to the energy intensity (as a proxy for carbon intensity) for a number of sectors in the US (WRI, 2008). The figure indicates that the most energy intensive sectors in the US (with the exception of Non ferrous metals) are relatively shielded from international cost pressures. As a result, the Non ferrous metals sector is likely to be much more constrained in its ability to pass on cost increases due to climate change policy than a sector like Ferrous metals. Thus, despite the fact that the Ferrous metals sector in the US is much more energy intensive than the Non ferrous metal sector, the competitiveness of the Non ferrous sector is likely to be more vulnerable to climate change policies than is the case with Ferrous metals. However, this analysis does not take into account the availability and cost of abatement options open to the Non ferrous metal industry in the US. The Ferrous metal sector will be less vulnerable to competitiveness issues if it has a number of relatively low-cost abatement measures available to it.

### **South African context**

Neuhoff and Mathes (2008) reveal that sectors that are likely to be significantly impacted by carbon pricing tend to be upstream sub-sectors using energy and CO<sub>2</sub>-intensive processes to produce low value-added products. Hourcade et al (2008) mention that highly affected sectors tend to contribute relatively small shares of GDP and employment. The focus on a few specific subsectors of limited size allow for customised technical solutions to address valid competitiveness and leakage concerns, thus supporting robust economic performance while still addressing climate change concerns (Hourcade et al, 2008). This is important since these sectors may play an important role in supplying downstream sectors.

The socio-economic challenges that face South Africa mean that climate change mitigation needs to be balanced with the need for sustained economic growth (DEAT, 2009). Thus, while industrial policy endeavours to diversify the South African economy away from its current over-reliance on energy- and capital-intensive upstream resource-based manufacturing (which based on international experience is likely to include the sectors that will be most vulnerable to climate change policies), these sectors are currently one of the key areas of South Africa's international competitiveness. Energy-intensive upstream resource-based manufacturing currently constitutes a large part of the economy, attracts significant local and foreign investment, and contributes disproportionately to exports (Winkler and Marquard, 2007).

In the long run, it is quite possible that the introduction of a price on carbon emissions will mean that some industrial activities<sup>24</sup> will no longer be viable in South Africa and these activities should be allowed to migrate to other parts of the world. In the short- to medium-term, however, it is important to identify the extent to which particular sectors are exposed to

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<sup>24</sup> The best example of an industry that may be unviable in South Africa in a carbon-constrained world is aluminium smelting. Winkler and Marquard (2007) mention that this industry is based in South Africa primarily as a result of very low electricity prices historically since the industry imports its feedstock and exports most of its production. This stands in contrast to other mineral beneficiation industries like coal, iron and steel, ferrochrome etc, that beneficiate minerals that are mined locally and of which a large proportion of production is consumed locally. Winkler and Marquard (2007:20) contend that "aluminium smelting in South Africa is thus really another form of coal beneficiation or electricity export". In a world where the cost of carbon is fully priced into the production of goods and services, it is likely that the production of aluminium will concentrate in countries like Canada (where on average 200g of CO<sub>2</sub> is emitted per kilowatt-hour of electricity generated) rather than South Africa (where on average 960g of CO<sub>2</sub> is emitted per kilowatt-hour of electricity generated) (Winkler, 2008).

competitiveness issues as a result of climate change policies. In order to reduce the adjustment costs to the South African economy of moving to a towards a more environmentally sustainable growth path (built around higher value-added and knowledge-based production), vulnerable sectors should receive support in order to move towards production processes that produce fewer GHG emissions and address any industrial competitiveness issues that may arise while the adjustment process is ongoing. The support should be linked to technical measures to reduce their carbon emissions so as to not interfere with the overall structural adjustment path of the economy. The particular measures will differ from industry to industry and depend on factors like the abatement technologies and options available to the industry, but in general should include measures linked to support for research and development, industrial upgrading, the adoption of new technologies, energy efficiency etc. These measures coincide with many of the cross-cutting issues identified in the NIPF, and should thus be relatively easy to implement within the current industrial policy framework in South Africa.

## 6. CLIMATE POLICY: GENERAL POINTERS

### 6.1. POLICY OBJECTIVES

The objectives for climate change policy in South Africa need to balance both a short and long term view. In the **long term** South Africa will obviously need to reduce emissions substantially and is highly likely to be subject to targets (and penalties for missing these targets) negotiated with the international community.

In the **short term**, however, South Africa is designated as a developing country under the current international climate regime, and hence is not yet subject to a mandatory emissions reduction target. This affords policymakers some degree of time to optimise policy design. First and foremost, South Africa needs to take advantage of the fact that it does not face an immediate imperative to reduce emissions and *generate detailed information* that is necessary to design and implement successful GHG mitigation instruments. At present data is scarce in South Africa, both around emissions themselves and their sectoral and sub-sectoral makeup, and around mitigation opportunities and costs. If an effective and coherent policy framework is to be designed, *accurate data* needs to be gathered as quickly as possible.

Secondly the short term response needs to focus on gaining *credibility in international negotiations*. Although South Africa does not face mandatory reduction targets yet, developed countries will be looking for developing countries, especially emerging market countries like South Africa with heavy emissions profiles, to show commitment to the goal of reducing emissions. This will influence the rigor of the targets that developed countries are prepared to commit to, and will also determine the extent to which they will assist developing countries to reduce their emissions. There could also be negative consequences for South Africa in the medium term if significant progress is not made with respect to climate change mitigation. South Africa may find itself economically isolated as the globe moves towards a carbon constrained economic system.

A final short term consideration from the South African perspective is how best the country can capitalise on the opportunities offered by GHG mitigation in order to *build international competitiveness*. There may well be a first-mover advantage for developing countries that are quick to adopt a strategy to combat climate change in terms of access to international markets and the development of environmental goods and services. In the shorter term, if South African

firms and industries can brand themselves as a “green” alternative, this could prove a substantial competitive advantage in developed country markets where consumers are much more discerning on sustainability issues.

## 6.2. GENERAL POLICY GUIDELINES

„Best practice’ policy guidelines for climate change mitigation policy recommended to ensure that instruments are as effective as possible include<sup>25</sup>:

- The policy response should take a **strategic and holistic** approach. A detailed regulatory impact assessment should be carried out before any measure is implemented to avoid unintended consequences.
- **Policy coherence**, both in terms of new and pre-existing policies, is required to make the response effective. There is potential for climate change policies to align with, or to work in opposition to, policies aimed at reaching other development goals. These overlaps need to be explicitly addressed in order to ensure that all incentives in the economy are well aligned. It is also important to consider where climate policies overlap in order to avoid double-counting of emissions or emissions reductions.
- **Transparency** is vital to building consensus and support for the instruments chosen. Without this, it may prove politically difficult to implement the selected policies.
- In order to enable a smooth adjustment by the private sector to a low-carbon economy, and to minimise losses to society, a **long-term approach** which provides **certainty** around the direction of future policy is very important. Otherwise, investment decisions taken by firms in the short-run will not reflect the emissions reality which they will face in a few years time. Firms need to be able to adjust slowly to what is required of them and to plan for what the price of carbon might be in the future. This is particularly difficult when data is not readily available to determine future carbon price levels or the extent of feasible mitigation in the economy, but a balance must be struck.
- Finally, international experience has shown that it takes time to design and implement effective climate change policy. In terms of timeframes, emphasis in South Africa should be on getting policy right, not on jumping to a conclusion in order to implement quickly. It is more important that the right mechanisms are ultimately chosen than that emissions are substantially reduced right away. This suggests that in the short-term, interventions aimed at gathering data and building awareness and consensus around proposed policies may be more useful than jumping straight in to a tax or cap on emissions. Under the Peak, Plateau and Decline emissions trajectory and Copenhagen offer, emissions must only plateau by 2020 – 2025 in order to reach a 30%-40% reduction target by 2050. According to the LTMS modelling, the peak is achievable largely through energy efficiency, and some diversification of electricity generation. Apart from moving quickly in these key areas, so South Africa can afford to take the time to **implement policy slowly, but do it right**. This may also entail changing policies which do not prove to be as effective as expected

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<sup>25</sup> These have been partly informed by the Better Regulation Commission’s “Seven tests for better climate change regulation”. BRC 2007, *Regulating to mitigate climate change: A response to the Stern Review*

## **6.3. POLICY OPTIONS**

The implementation of a number of policy options simultaneously is likely to lead to lowest-cost abatement. As a result, a bouquet of possible policy options is provided. It is suggested that the first policy option implemented should focus on the cross-cutting issue of data availability, which will be important for government to consider no matter what instruments are ultimately chosen.

Policy measures should, as far as possible, explicitly be linked to GHG mitigation activities and should not take the form of production incentives (which will only reduce the impact of the overall climate change policy package by providing an offsetting revenue stream and will not provide an incentive to change firm behaviour). In cases where government wants to support the development of green industries like renewable energy technologies, for instance, general incentives in the form of production incentives may be acceptable. The guiding principle with respect to supporting mechanisms should thus be that wherever incentives are provided to firms, these should be closely targeted on the activity which government wants to encourage and on the understanding that a commensurate or greater effort is required from firms themselves towards meeting any eventual target. Funding should be tied to some outcome on the part of the firm and should be of limited and clearly stated duration. Monitoring and evaluation mechanisms need to be of sufficient calibre to enable accurate information to be generated on the impact of the various measures implemented

### **6.3.1. GENERATE DATA**

Data around GHG emissions and abatement opportunities is not readily available in South Africa but this information is vital to the design and implementation of climate change policies. Therefore, a key recommendation of this paper is that action should be taken to generate the relevant data as a matter of urgency. The order of magnitude of data error may well exceed any emission reduction targets which can be feasibly implemented initially, and so this objective may well supersede that of getting mitigation policy in place in terms of environmental impact. In addition to a lack of emissions and mitigation cost information, there is also a difficulty relating to the form in which existing data is available. To date data has been generated for the purposes of compliance with the national inventory requirements of the United Nations Framework Convention of Climate Change, or for economy level modelling in the LTMS. However, data for the purposes of policy development is required at an individual process and SIC code level in order to consider issues of alignment with other policies and industrial strategies.

Some specific ways in which this problem could be addressed are suggested in the recommendations to follow. For example a delay in mandatory emissions mitigation regulation may act as an incentive for firms to accelerate reporting on emissions. Funding could also be made available for more detailed primary research needs to be done on the mitigation opportunities available to the country. In addition, incorporating climate change considerations into industrial policy mechanisms could assist in generating information about specific industries.

### **6.3.2. PURSUE ENERGY EFFICIENCY**

The climate change policy with the biggest immediate wins for the economy is the uptake of energy efficiency interventions among all energy users and particularly industrial users who

make up the bulk of Scope 2 energy emissions in the country. In the short-term this involves seeking to align the proposed PCP with climate change objectives, or finding some way of capturing any potential “leakages” from the programme given that the PCP is an indirect as opposed to direct emission reduction tool. In the longer term it will mean designing a mechanism to provide ongoing incentives for reductions in energy use, after the PCP comes to an end. A white certificate trading scheme could prove effective in this regard, and indeed the infrastructure may already be in place to support such the instrument if, as proposed, some element of trading is allowed under the PCP. Draft income tax legislation published in February 2009 provided incentives for the adoption of energy efficiency measures in the form of nominal deductions for income tax purposes for energy efficiency savings certificates issued by the National Energy Efficiency Agency. These savings will be measured from certified baselines.

Measures should also be taken to encourage energy efficiency at the individual or household level. These include the amendment of building standards<sup>26</sup> to make higher levels of energy efficiency mandatory in residential developments, restrictions on the sale of energy inefficient appliances (some of which are already in place), and educational initiatives to inform the public about potential savings from adopting energy efficient practices and technologies. It may also include providing incentives for the adoption of energy efficient technologies at a household level, such as for example the energy-efficient light bulb exchange and solar water heater subsidy programmes run by Eskom, while electricity prices move to cost-reflective levels. Once these levels are reached, however, the rationale for incentives will be diminished.

### **6.3.3. SUBSIDIES FOR TECHNOLOGY DEVELOPMENT AND ADOPTION**

As discussed in sections and , investment in the development of low-carbon technologies is an activity which is undervalued by the market relative to its true value to society. This provides a rationale for government intervention to encourage, or even drive, the research process in both the public and private sectors. Subsidies and incentives for technology development will be an important means of eventually providing firms and consumers with abatement options which will reduce the burden of the carbon policy on the economy. In a perfect world, the prospect of the introduction of a carbon price alone should be enough to incentivise the optimal level of investment in green technologies. However, in the real world firms may face financing constraints which prevent them from sinking money into technology development even if it has a payoff later on, or they may lack sufficient information to make an informed investment decision. Therefore, there is a need for targeted government subsidies to initiate the development of options for South Africa in strategic areas, such as renewable electricity generation. The feed-in tariffs recently announced for renewable electricity (and expanded to cover most renewable generation methods in July 2009) are an example of this kind of subsidy, aiming to increase the attractiveness of an investment in green technology. According to FRIDGE Chemical Sector Summit Project (2005), support currently offered for pilot development and the commercialisation of new technologies is inadequate; an area of particular concern for environmental technologies. This and other available subsidies will need to be reviewed for alignment with climate change goals. The Department of Science and Technology’s Innovation Fund has recently indicated its intention to fund the development of renewable energy technologies.

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<sup>26</sup> The Green Building Council of South Africa was established in 2007 to further this aim, and has recently introduced the Green Star SA rating tool to set standards and benchmarks for green buildings (Van der Merwe, 2009).

#### **6.3.4. ALIGN INDUSTRIAL AND CLIMATE CHANGE POLICIES**

In order to start moving South Africa towards a low-carbon economy, Industrial policy needs to start favouring less GHG-intensive industries in the medium to long term (DEAT, 2009). Incorporating climate change issues into the NIPF and IPAP<sup>27</sup>, can be done in two ways:

Firstly, climate change considerations need to inform all industrial policy actions (DEAT, 2009). The climate change implications of every industrial policy project supported, be it general incentive programmes, industrial financing by the IDC, industrial upgrading or “hidden industrial policy” need to be assessed (Winkler and Marquard, 2007). Where there are trade-offs between environmental and growth objectives, these trade-offs should be considered explicitly (MEDS, 2007). The recently published draft regulations relating to tax incentives for large industrial projects (to replace the expired Strategic Investment Programme) which incorporates energy efficiency criteria in the qualifying criteria is a step in the right direction. Environmental and energy efficiency standards should now be applied to all incentives. Climate change considerations should also inform the selection and prioritisation of sectors to support in the medium to long term. Sector strategies should include a mandatory climate change section to provide baseline information, and to facilitate self-discovery of climate change opportunities and the range and cost of mitigation technologies available. The provision of information about a firm’s carbon footprint should become a necessary step to qualify for government support (MEDS, 2007). Within cross-cutting areas like industrial upgrading, support for research and development etc, special attention should be paid to financial and technical support for the adoption and adaptation of GHG mitigation technologies. Government should reconsider its beneficiation strategy to focus on high value-added products. Additional value-add can outweigh additional energy use and help to reduce the energy intensity of the economy (Winkler and Marquard, 2007). The European Union’s example should be followed and energy efficiency and environmental standards for public procurement should be specified to move towards a “Green Public Procurement” paradigm (European Commission, 2008:7).

Secondly, climate change opportunities should be exploited directly and environmental goods and services should be prioritised as a sector for development. This would be consistent with the European Union’s new policy direction of undertaking a comprehensive screening of regulatory barriers and market failures in environmental industries that hamper their uptake and competitiveness. The self-discovery process underlying industrial policy sector interactions in South Africa will help to identify potential new areas of advantage in “climate-friendly” technologies. Government should seek to support firms to build new competitive advantages in the identified areas and aim to become market leaders in new technologies like solar energy or carbon capture and storage (DEAT, 2009). Given the overlap with current industrial policy objectives, the renewable energy sector should be identified as a key growth sub-sector within environmental goods and services (DEAT, 2009).

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<sup>27</sup> It is believed that climate change considerations will be present in the new IPAP that is due to be completed early in 2010. In particular, the environmental goods and services („green”) industry will be singled-out for support (SA TO FOCUS ON TRADE AS GOLBAL CRISIS RECEDES, 2009)

### 6.3.5. UTILISE VOLUNTARY MEASURES

Voluntary reporting or emissions reduction agreements can build consensus on climate policy between the various stakeholders, introduce firms to the idea of reporting and verifying emissions, and generate much-needed data to inform the policy design process. In South Africa this approach could prove very useful in the short term while there are no carbon commitments in place for the country as a whole, and while policies elsewhere (in the energy arena in particular) are already providing the impetus for development of climate solutions in some parts of the economy. Data generation is the top priority for policy in the short term as effective policy cannot be designed without it.

#### *Using the Clean Development Mechanism to South Africa's advantage*

An important voluntary mechanism that has been underutilised in South Africa (given the absence of binding international commitments on South Africa to reduce its GHG emissions) is the Clean Development Mechanism under the Kyoto Protocol (see section ). The CDM presents access to funding for the transition to low-carbon production and has the potential to provide substantial amounts of funding for abatement activities in South Africa at very little cost to government.

Currently uptake of CDM projects in South Africa is constrained by high costs related to the packaging and implementation of projects (Sangena Investments, 2004)<sup>28</sup>. However, a more active approach from government to promote the use of the CDM, for example through the establishment of a dedicated unit<sup>29</sup> to source potential projects, advise firms, and package projects before they are put before the relevant international authorities may assist in reducing these barriers. Certified Emission Reductions will be exempted from income tax in South Africa in future based on draft income tax legislation published in February 2009.

Programmatic CDM provides a particularly interesting opportunity for supporting low carbon policy by focussing on the development of a programme covering a number of similar activities (NBI, 2009). This approach allows energy efficiency and renewable energy projects, for example, that would be too small individually to justify the high transaction costs involved in developing and registering a CDM project to be package into viable programmes. Given the „common good’ nature of programmes, together with the very new status of the mechanism, assistance from government in covering upfront costs and risks would be required.

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<sup>28</sup> Sangena Investments (2004) identify significant costs as costs related to: the establishment of baseline estimates; the creation of monitoring frameworks, the validation of entities implementing projects, the registration of projects, environmental impact assessments, and supporting the development of local project implementers (Sangena Investments, 2004).

<sup>29</sup> The Designated National Authority for Clean Development Mechanism in South Africa (DNA) is tasked with providing support to CDM project developers locally and to promote South Africa as an attractive location for CDM projects (DME, undated). The DNA’s main purpose, however, is to assess whether potential CDM projects will assist South Africa in meeting its sustainable development goals, and to issue formal host nation approval to the United Nations Framework convention on Climate Change and the Kyoto Protocol. The new unit should have project finance expertise and assist with the identification, development and packaging of projects, something the DNA does not actively do at present. In addition to providing its financial and project development expertise, it should work together closely with the DNA to also cover the technical aspects relating to specific CDM requirements. The IDC recently established an Environmental Finance function t in its Wood, Paper and Other strategic business unit to specialise in the funding of CDM projects (IDC, 2009).

Management of these programmes could be undertaken at a sector level, and aligned with particular capital subsidies, such as those proposed in the area of energy efficiency. Initiatives are already underway in the low income housing and solar water heater sectors to establish CDM programmes on this basis<sup>30</sup>. CDM programmes have the added advantage of generating data, and can form formal components of the South African negotiating position in the international climate change negotiations.

### **6.3.6. CONSIDER IMPLEMENTING A CARBON PRICE**

The LTMS modelling indicated that a broad-based price-based mechanism takes the economy the closest to the “required by science” scenario indicating the effectiveness of utilising an economic instrument for carbon mitigation in the long term. An economic instrument is most effective when broad based, enabling access to many emission reduction opportunities with different cost and timing profiles. Therefore, a White Certificate Scheme on its own is not optimal. Based on the policy guidelines laid out in the previous section, it would be prudent to only implement a market-based instrument at any significant level once sufficient information has been generated about South Africa’s emission profile (at a sector level or below), policy certainty has been established, and a number of other policy measures have been put in place to make firms more competitive by enabling them to implement GHG mitigation measures at the lowest possible cost.

The analysis in Sections , and Appendix indicates while the balance of arguments concerning which economic instrument would deliver abatement at the least overall cost to society in South Africa seems to lean towards a carbon tax at present (at least in the short to medium term) the debate is ongoing. As a result design considerations relating to both instruments are provided below.

#### **6.3.6.1. TIMING**

The question of timing is important for the effectiveness of an economic instrument. In the absence of a hard cap on South African emissions and in the context of current developments in the electricity market and the drive for energy efficiency, it may be counter-productive to impose an economic instrument right away. In the short run it will be more useful if policy focuses on capturing the potential leakages from policies already in the process of being implemented, and on generating data and support for the later implementation of an economic instrument to reduce GHG emissions.

#### **6.3.6.2. ISSUES TO CONSIDER WHEN DESIGNING A CARBON TAX**

##### **Incidence**

When designing a carbon tax, government must take into account all aspects of the country context. In the light of an extremely distorted electricity market, high expected tariff increases, and the drive to reduce energy consumption by 10% economy-wide, the efficacy of the current proposed 2c/KWh tax on electricity generated from fossil fuels seems questionable from a climate change mitigation perspective. However, it does at least provide a credible indicator to

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<sup>30</sup> Eskom’s solar water heater programme and the National Sustainable Housing Initiative supported by the Department of Housing.

consumers and firms that government is taking climate change seriously, and that they can expect some form of carbon price to be imposed in the economy in due course. The question is how to achieve this at the lowest possible cost to society.

As discussed in section , the most efficient place to impose a tax from both an environmental and an economic efficiency point of view is directly on emissions at their source in order to minimise “leakages”. A tax imposed anywhere else will result in the abatement of emissions only indirectly, and therefore will not provide full coverage. Taxing emissions directly involves a potentially high cost of monitoring firms and installations where emissions take place, but there are ways of reducing this cost by phasing in the tax slowly, and exempting those with emissions below a certain threshold.

For example, it could be useful to introduce mandatory reporting of emissions a couple of years prior to the implementation of a tax. There could then be penalties for non-compliance as well as incentives for full compliance such as a tax reduction in the first year or two that the carbon tax is levied. This would also have the advantage of generating detailed emissions data which could then be used to help set the appropriate tax level. Working on the 80:20 principle, the biggest emitters (say the top 100 firms from an emissions perspective) could be covered first, followed later by the remaining firms as systems are able to be put in place to capture the emissions of those firms. There is international precedent for the monitoring of emissions; in the UK for example, firms are mandated to report Scope 1, 2 and 3 emissions. The top 100 listed South Africa firms have been requested to provide similar data through the Carbon Disclosure Project, a voluntary initiative, but steps are underway to make this mandatory.

### **Exceptions**

A final consideration for the design of a carbon tax is whether it will be necessary or desirable to exempt any industries or groups of firms from the tax. In general, it is not efficient to do so. However, it may not be practical to have complete coverage from the start. Some potential candidates for separate regulation are the transport and agriculture industries, as well as the residential sector. The proportion of emissions generated by transport is set to grow in the future, according to the LTMS. However, it would be difficult to include the sector in a carbon tax as set out above. There will therefore need to be some kind of alternative solution for this sector. The sector is explicitly excluded from consideration in this study, so it is merely noted here that it warrants further consideration. Agriculture, also excluded from this study, is also more complicated from a monitoring perspective, which suggests there may also need to be specific policy solution for that sector. Finally, households will face some incentives to change their behaviour if electricity prices increase at the rate expected. Furthermore, as described in section , there may be other ways of encouraging household energy efficiency. Further consideration will need to be given to the treatment of any other emissions-intensive goods used by consumers that are not able to be covered by the carbon tax, but care must be taken not to double-tax any items. Temporary exemptions for energy-intensive sectors that are likely to suffer a deteriorating in their competitiveness as a result of the carbon tax may be considered, but the emphasis should be on technical solutions to try and maintain the competitiveness of vulnerable sectors.

### 6.3.6.3. ISSUES TO CONSIDER WHEN DESIGNING A CAP-AND-TRADE SCHEME

#### Coverage

As a result of transaction costs, the coverage of an ETS will never be 100% and initially only larger emitters will be included. In order to ensure economic and environmental efficiency, however, it is important that the coverage of an ETS is as broad as administratively feasible. Rather than exempting emissions intensive sectors and firms from an ETS, it may be more efficient to provide them with a declining free allocation of permits for a limited time while they adjust their production processes. Given that it will not be feasible to include all sectors in an ETS (for instance sectors that are difficult to monitor like Agriculture and transport), the points raised about the need to incentivise behaviour change in sectors not covered by a single economic instrument in Section also apply here.

As with a carbon tax, imposing an ETS on emissions directly will ensure environmental and economic efficiency. Because of the level of information needed to design an ETS (particularly one in which permits are grandfathered), a voluntary phase prior to the introduction of a mandatory scheme may be useful to generate data. It would also allow participants to get used to the idea and the mechanics of emissions trading. In practice, however, this makes implementing an ETS a lengthy process.

#### Allocation of permits

Auctioning permits rather than giving them away in relation to past emissions („grandfathering“) requires less information to implement. It is also more economically efficient since it provides stronger incentives to innovate and invest in mitigation technologies. Auctioned schemes also generate government revenue that can be used to counteract any negative distributional effects that may emerge as a result of a price on carbon. Grandfathering, in contrast, often give rise to equity concerns as windfall profits often materialise when ETS participants pass on the cost of permits they received for free to their customers. Grandfathering is however attractive to the private sector and may thus be useful to generate support for a prospective ETS. If a grandfathered ETS is implemented, a relatively fast move to the auctioning of permits could maximise fiscal, environmental and economic efficiency and address equity concerns. A move to auctioning of permits would also remove potential barriers to entry created by grandfathered schemes (although this could also be addressed by setting aside permits for new entrants). The efficiency gains inherent in a move to auctioning obviously need to be balanced against the goal of ensuring a smooth transition which allows firms time to adapt to the presence of a carbon price. In order to ensure that real abatement takes place, it is important to sure that the initial allocation of permits is not too high. This can be aided by the gathering of accurate emissions and abatement cost data which could be facilitated by the introduction of a voluntary scheme prior to it becoming mandatory.

#### Market power and liquidity considerations

In the South African context the concentration of GHG emissions implies that market power and a lack of liquidity are important issues to consider. A local ETS would thus need to link to an international ETS, or the ETS would need to be designed in a way that overcomes market power and liquidity concerns (see Appendix ). If the opportunity presents itself for a local ETS to link to an international ETS, it is important that it is an accredited international mechanism. This is required to ensure that the scheme does not interfere with SA international commitments (i.e. permits bought by South African firms need to count towards any binding

emissions reduction targets that South Africa may have). When an ETS is designed to overcome market power and liquidity issues, it is important to consider the effect that a reduction in coverage may have on the environmental and economic efficiency of the scheme. If this is not done the rationale for having an ETS in the first place may be lost.

### **Volatility**

Price volatility causes uncertainty for firms and may cause them to delay investment in emissions-efficient technology as future payoffs are unclear. Therefore during the inception and operation of any emissions trading scheme it is extremely important that the process is credible and transparent and that cap reduction timelines are clearly laid out and visible to all participants. There are mechanisms which can be introduced to try and reduce excessive price volatility, such as setting price caps and floors which are maintained by government buying back permits or issuing extra permits, and the inter-temporal banking and borrowing of permits. These mechanisms, however, reduce the level of certainty about the emissions reduction that will be achieved. They also complicate the design of an ETS somewhat, and this has to be weighed against their important anti-volatility effects.

### **6.3.7. CONSIDER TRANSITIONAL ASSISTANCE**

In general, it is not efficient to subsidise firms to abate as it prevents producers and consumers from internalising the cost of carbon. However, it may be useful in the short term to provide incentives for the adoption of certain technologies in order to help firms adapt to the introduction of price on carbon with a minimum of disruption to the economy (see section 9.4). These types of incentives should not be provided in industries where there are relatively inexpensive and effective ways of reducing emissions, but rather in industries where technology options for abatement require such a big up-front investment as to make it very difficult for firms to fund these activities individually. There may well be sectors or firms for whom there are simply no viable abatement options in the medium term. Unless suitable technologies are developed in these areas, these activities may prove too costly from a climate change perspective for the economy to bear and it may be in South Africa's best interest that they shrink in the long term.

## 7. SECTOR CASE STUDIES

### 7.1. METHODOLOGY

The methodology for looking at the abatement options available to each sector is in two parts. First a summary is provided of the abatement options available in the form of an Indicative Abatement Cost Curve and then each abatement option/technology is described in detail. The methodologies behind the indicative abatement cost curves, and the risk indicators that feed into them, are outlined below.

#### 7.1.1. INDICATIVE ABATEMENT COST CURVE (IACC)

The IACC provides a summary of the main mitigation options available to the sector, how easy it will be to implement each (based on the risk assessment undertaken in the second part of this section), how costly they will be to implement, and how effective each will be in relation to the other options available to reduce GHG emissions.

The IACC is represented in the form of a column chart. The *vertical axis (Y-axis) indicates the indicative cost of implementing the options*. It is important to note here that the *cost rating reflects only the cost to firms of implementing the option once the technology is established, not the cost of developing the technology*. The cost of development is accounted for in the risk assessment below (see Table ). The indicative cost will be grouped in one of 4 categories, the definitions of which are as follows:

- **Cost offset.** The benefits of implementing the option will outweigh the costs. As part of an overall package of abatement options, this option would reduce the total cost of the package. Implementing an „cost offset” option is thus not expected to reduce the competitiveness of a sector significantly. It will not necessarily increase the sector’s competitiveness since there may be other investment options available which provide greater benefits at the same cost. It is thus not assumed that an option in this category will necessary provide a return that is higher than the sector’s hurdle rate required for new investments, only that there is not a net positive cost associated with implementing the option.
- **Low cost.** Low cost options are defined as leading to an increase in costs in the sector that causes limited disruption to the way the sector functions. Business as usual will continue with this level of cost increase. In fact, there may be very little disruption (if any at all) if the abatement option also has significant co-benefits. The implementation of any of the low cost options will thus not cause a disruption more significant than normal business cycle variations. The low cost category also includes „No cost’ options. No cost options will be expected to generate sufficient operational benefits to offset their implementation costs. No cost options will thus not affect the competitiveness of a sector as investments in these options will „break even’.
- **Medium cost.** Options that fall in this category are expected to increase costs to a level that causes a medium disruption to the way the sector does business. The sector will survive in something close to its current form, but it may have to move to new technologies, production processes or inputs; it may have to shrink in size; or it may have to reconsider the mix of products it supplies.

- **High cost.** High cost options will lead to a significant increase in product cost which, if it cannot be passed on to consumers, will necessitate a fundamental reorganisation of the sector. The sector will not be able to continue functioning in its current form. Some industries may be forced to shut down, while other industries will have to reinvent themselves in order to continue producing.

*The horizontal axis (X-axis) indicates the relative amount of CO<sub>2</sub>-e reduction an abatement option is expected to provide in comparison with the other identified abatement technologies/options included in the IACC.* The sum along the X-axis is thus a reduction equal to 100% of the identified abatement options. The abatement options identified (included in the IACC and in the descriptions which follow) together aim to capture 80% of the total amount of abatement deemed possible in sector at present given the technologies either currently available or under development. If estimates of the total amount of abatement possible in a sector (from a specific option, or from all options together) are available, they have been included in the description of the abatement option. From a methodological perspective, however, the X-axis only provides a comparison between identified abatement options.

The height of the column associated with an abatement option thus indicates its relative cost, while the width indicates its relative effectiveness in relation to other identified abatement options in the sector. The scale of width used is guided by the relative impact of the abatement options with the smallest and largest expected impact. So while the height of the column associated with a specific abatement opportunity varies from -1 to 3, the relative width of the columns is sector-specific.

A final piece of information provided in the IACC is risk associated with each abatement option. The *risk associated with each option is classified as Low, Medium or High* according to the criteria laid out in the next section. The risk rating is indicated in the IACC by a colour associated with each of the 3 risk categories. High-risk options are red, medium-risk options yellow and low-risk options green. The risk rating provides an indication of the ease with which each of the abatement options can be implemented, and thus provides a reality check of the weight that should be attached to each option in the sector's GHG mitigation planning. A note on how to read the IACC and identify each abatement option is provided in footnote in section .

### **7.1.2. RISK INDICATORS**

Four risk indicators are used to assign a risk rating to the available abatement options. Each option is rated against each indicator and receives a score of between 1 (low risk) and 4 (very high risk). The sum of the four risk indicators for each abatement option is then used to attach a composite risk rating to the relevant abatement option. The composite risk rating falls in one of three broad risk categories:

- **Low risk:** Composite risk rating of 1-6
- **Medium risk:** Composite risk rating of 7-11
- **High risk:** Composite risk rating of 12-16

As noted above, each of the three risk ratings is associated with a colour in order to show the risk rating of a specific abatement option graphically in the IACC. The various risk scores for each option are also shown graphically using a spider diagram. This diagram has four axes,

each representing one of the risk indicators, and the score for each option on each risk indicator is marked on the appropriate axis. A line is then drawn to connect the points. The larger the area of the resulting shape, the more risky the abatement option.

The 4 risk indicators used to assign a risk rating to each abatement option are:

**Technology risk.** A high score on this measure indicates that a technology is still relatively risky, at an early stage of development, or only expected to only be commercially viable far in the future. Technology risk ratings will be assigned according to the following criteria:

Rating criteria – technology risk	Risk rating
Technology has not moved beyond theory	4
Technology has moved to pilot phase	3
Technology has been commercially proven internationally	2
Technology has been commercially proven in South Africa	1

**Table : Technology risk categories**

*Source: Genesis Analytics, 2010*

#### Implementation timeframe.

Rating criteria – implementation timeframe	Risk rating
More than 10 years to implement	4
5 to 10 years to implement	3
2 to 5 years to implement	2
Less than 2 years to implement	1

**Table : Implementation timeframe risk categories**

*Source: Genesis Analytics, 2010*

A high score indicates that the technology/abatement option may require a long lead time to implement. This reduces the usefulness of the abatement option for GHG reduction in a sector in the short to medium term. A sector that is heavily reliant on abatement options which will take a long time to implement will find it more difficult to adapt to the need to reduce GHG emissions than a sector that has more options with relatively short implementation timeframes available to it. Sectors heavily reliant on abatement options with relatively long implementation timeframes may also be at a competitive disadvantage to international competitors that have already started moving towards reducing their GHG emissions

**Development costs.** R&D and other development costs may stand in the way of promising technologies being adopted in a sector. The higher the development costs related to an abatement option, the higher the risk that the option will never be implemented by firms.

Rating criteria – development costs	Risk rating
Exceptional investment required (requires public funding)	4
Substantial investment required (multiple firms or sector level involvement required)	3
Individual firm should be able to bear development costs	2
No development costs required (technology/option ready to implement)	1

**Table : Development cost risk categories**

*Source: Genesis Analytics, 2010*

**Other risks.** This risk indicator provides a reality check on the viability of an abatement option in practice. It aims to capture all other risks that may stop an abatement option/technology from fulfilling its expected role in reducing the GHG emissions in a sector. Examples of risks covered by this indicator will include political risk (an abatement option may have distributional effects that will not be tolerated by government), security of supply (it may be difficult to guarantee the supply of electricity originating in politically unstable countries or regions), perception risk (the belief that the risks associated with nuclear power may outweigh the benefits) and so forth.

Rating criteria – other risks	Risk rating
High probability that technology/option will not be widely adopted	4
Medium probability that technology/option will not be widely adopted	3
Low probability that technology/option will not be widely adopted	2
No risk that external factors will complicate adoption of technology/option	1

**Table : Other risk categories**

Source: Genesis Analytics, 2010

The description of the risk indicators for each abatement option will start with the radar diagram. This will be followed by a table explaining the score for each risk indicator.

### 7.1.3. LIMITATIONS OF INDICATIVE ABATEMENT COST METHODOLOGY

It is important to note that while the methodology developed in this sector aims to provide the maximum insight regarding the opportunities available for greenhouse gas (GHG) emissions mitigation in individual sectors given current data limitations, and thus contributes significantly to the climate change policy debate in South Africa, it does have limitations that reduce its usefulness to inform policy decisions directly.

The volume on the horizontal axis of the IACCs indicates the percentage GHG emission reductions that can be achieved by an abatement options relative to the other identified available abatement options. There is thus no indication of the absolute value of emissions that an abatement option can reduce. Because the total emissions related to every current production technology or process is not known, no inferences can be made about the amount of emissions that an option can abate relative to the total emissions in a specific sector. It is thus *not possible to calculate what percentage of the total emissions in a sector can be reduced by say „low cost’ options*. The IACCs on their own can thus not be used to evaluate the impact of a carbon price on a sector because it is not clear what proportion of the sector’s total emissions is covered by the identified abatement options (an methodology to investigate the likely impact of a carbon price on individual sectors is developed in section ).

The methodology can however be used to flag sectors that are expected to experience difficulty in reducing their GHG emissions. Sectors where the bulk of identified abatement options are relatively costly or risky are likely to struggle to reduce their GHG emissions. The flip side of this argument is however not true. The bulk of a sector’s available options being low cost or well proven does not mean the sector will easily be able to meet a given reduction in their emissions since it not known what the total amount of emissions reduction is that the bundle of identified options can achieve.

The limitations of the current methodology highlight the importance of generating detailed emissions data for individual sectors, as well as detailed information regarding the cost and abatement potential of abatement options, to underpin the policy development process.

## **7.2. AGRO-PROCESSING CASE STUDY**

### **7.2.1. SECTOR DEFINITION AND DATA ISSUES**

Many definitions for the Agro-processing sector were encountered in the literature reviewed ranging from the all encompassing definition that includes input supply, raw materials and value adding to definitions that only focus on value adding. The National Department of Trade and Industry (dti) defines Agro-processing as a “set of activities involved in the transformation of primary agricultural products into value added products” which includes processes that do not necessarily change the form of the product but improves its value (Makhongwana, 2009). This is furthermore broadly understood as post-harvest activities involved in the transformation, preservation and preparation of agricultural products for intermediary or final consumption. It is generally taken to include food, beverages, textiles, leather and pharmaceutical products.

Statistics South Africa (SA) uses the standard industry classifications (SIC) codes to categorise key economic data for sectors. SIC codes 301 to 304 includes the manufacturing, processing and preservation of meat, fish, fruit, vegetables, oils and fats (301); manufacture of dairy products (302); manufacture of grain mill products, starches and starch products and prepared animal feeds (303); manufacture of other food products (e.g. bread, sugar, chocolate, pasta, coffee, nuts and spices) (304); and the manufacture of beverages (305). The description of SIC codes 301 to 305 is not perfectly aligned to the definition of Agro-processing used by the DTI but it is used for the purposes of the study since it corresponds to the available sources of GHG emissions and abatement information.

As discussed in Appendix , there is no accurate emissions data available for the Agro-processing sector in South Africa and an extensive search revealed that there is no information currently available locally on potential GHG emissions reductions and capital costs of mitigation options for specific sub sectors.

In terms of energy efficiency, the low percentage that energy contributes to total costs in South Africa due to the low cost of electricity is the main reason for the lack of reporting on energy use compared to detailed energy use data collected in American and European Agro-processing firms. For example, in 2006 the US Department of Energy revised General and Technical Guidelines for voluntary reporting of greenhouse gas (GHG) emissions, sequestration and reduction. This is known as the 1605(b) program since section 1605(b) of the US Energy Policy Act of 1992 established a voluntary reporting mechanism for GHG emissions and reductions. Since the programme guidelines were issued in 1994, approximately 200 utilities, industries, institutions and other entities have reported annually. This information is used to develop comprehensive programmes to reduce energy use. (United States Department of Agriculture, 2009)

The implications of these data issues for this report are as follows:

- The report relied exclusively on data from international best practices to identify GHG mitigation options due as there was no data available locally;
- The report also relied exclusively on international best practices for quantitative cost and emission reduction estimates as there was no data available locally; and
- The sector Indicative Abatement Cost Curve that is provided is based on these international examples of best practice for a specific sub-sector in that country.

A desktop review of international studies revealed a number of studies on energy and cost savings potential in Agro-processing sub-sectors mainly for the USA. These studies do not explicitly link potential GHG emission reductions to energy savings. Hence the GHG emissions reduction potential for mitigation options identified from these studies were computed from energy savings using relevant factors.

The lack of availability of data suggests that a review of GHG emissions on a sector-wide and sub-sector wide basis is an imperative for the Agro-processing sector to meaningfully engage in any debate on GHG mitigation and to provide input on GHG mitigation strategies for this sector.

## **7.2.2. SECTOR CONTEXT**

Agro-processing, as defined above, is an important component of South Africa's manufacturing economy and the National Industrial Policy Framework that provides a framework for South Africa's industrialisation process, identified Agro-processing as a key sector for economic growth. Agro-processing, as defined by the dti, contributes 10% of South Africa's GDP and is the third largest manufacturing sector (Ohiokpehai et al, 2009). For the three months to January 2009 the manufacturing sector recorded a value of sales 2.7% higher than the same period in 2008, and the food and beverages sector was the main driver of this increase, outperforming all the other manufacturing sub-sectors (Statistics South Africa, 2009). South Africa's main food processing products are corn starch and syrup, canned and frozen fruit and vegetables, frozen seafood, packed and bottled fruit juice, processed meats and dairy. The evidence on the economic performance of Agro-processing suggests that while it has been disappointing in the recent past, there are promising signs for the future (Mather, 2005).

There are two key factors that have affected Agro-processing operations in South Africa. The first is the liberalisation of the South African economy which has led to an increase in food imports from countries with large agricultural subsidies. The second is the structure of retailing in South Africa which is characterised by a small number of large firms, making it difficult for South African suppliers to negotiate good prices for their products.

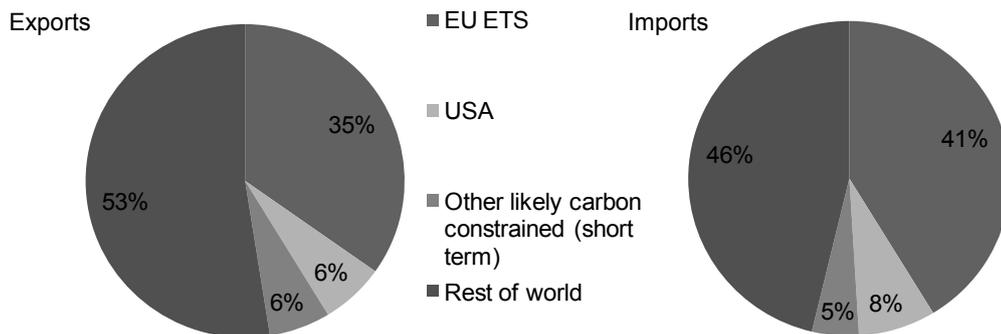
### **Market structure**

The food and beverage industry is highly concentrated with an "oligopolistic structure" (Kirsten and Vink, 2002). The key players are Unifoods or Best foods, Nestle, National brands, Tiger brands, Premier foods and Nabisco, Pioneer Foods, Foodcorp. JSE listed companies include Tiger Brands, Pioneer Foods, AVI Ltd, Tongaat-Hullet Group, Illovo Sugar Ltd and All Joy Foods Ltd.

The size of agro-processors depends on product and technology requirements and therefore manufacturers tend to be large due to investment requirements for expensive machinery and equipment and vehicles required for transport. The key players are also vertically integrated into primary production and retailing. It is not unknown for food processors to have interests outside of the food industry most notably in pharmaceuticals.

## Trade

Over the last ten years the trade regime has moved away from a complex system of quotas and tariffs to a simplified and liberalised system and resulted in increase in cheap processed food imports (Kirsten and Vink 2002). Entry into developed markets is constrained by tariff and non-tariff trade barriers and insufficient spending on research and development, in particular product development.



**Figure 1: Concentration of trade in countries with carbon policies (2006): Agro-processing**

Source: TIPS SADC trade database 200931

The sector is not very export-intensive, with exports accounting for only around 9% of total sales by domestic producers. As illustrated in Figure 1, 47% of exports go to markets which either have carbon policies in place or are likely to do so in the near future, and an even greater 54% of imports originate in these countries. This may prove problematic for South Africa producers as the sector is turning out to be one of the most advanced globally in terms of awareness of GHG emissions issues. Reporting on GHG emissions and activities undertaken to reduce those emissions have already become a market access requirement for food and beverage products for individual retail chains in the United Kingdom and Europe where marketing campaigns have been run by Tesco, Waitrose and Marks and Spencers. Although there is no empirical evidence yet to confirm the trend, it is likely that in the near future food and beverage products with a lower carbon footprint will have a strong competitive advantage.

According to the dti website (dti, 2009b), the top ten food exporters internationally in 2005 were: the USA, the Netherlands, France, Germany, Brazil, Belgium, Spain, China, Canada and

<sup>31</sup> „Other likely carbon constrained (short term)’ refers to countries that are currently either planning or officially considering to implement or join trading schemes or implement carbon taxes. Countries included in this category are Australia, Japan, New Zealand, Canada, Switzerland (adapted from Reinaud, 2009). Norway, Norway, Liechtenstein and Iceland are about to join the EU ETS, and have been included in this category.

Italy. Thirteen of the top twenty exporters were countries where carbon policies are soon to be in place.

The South African Agro-processing industry has a number of competitive advantages which could mitigate the impact of carbon footprint concerns to some extent. South Africa's main advantage in this sector lies in its counter-seasonality to the major developed markets, in particular Europe and the USA (although it does also face competition from other producers in the Southern hemisphere). South Africa is also renowned for producing high quality products, and enjoys a number of other advantages including world class infrastructure<sup>32</sup>, biodiversity and marine resources (dti, 2009b). These factors may make demand for South African food products somewhat more inelastic, which would lessen the impact of any border adjustment measures imposed by Annex 1 countries to prevent carbon leakage. Nevertheless, some efforts by South African producers to lower their carbon footprints will certainly be required in order to ensure continuing market access and this, if enthusiastically entered into, could become a source of competitive advantage in its own right.

On a positive note, since the 1990's exports of processed food to the Southern African Development Community have increased significantly with the main products being cereals, milling products, dairy and sugar. Major food companies have identified growth opportunities in Africa and have focussed on the establishment of regional hubs and acquisitions to improve manufacturing and distribution networks. Examples include Tiger Brand's recent acquisition of Haco industries in Kenya and Chococam in Cameroon (Tiger Brands, 2008).

### **7.2.3. GHG EMISSIONS**

The main sources of emissions for the South Africa Agro-processing industry are CH<sub>4</sub> from waste water treatment, CO<sub>2</sub> from fossil fuel combustion in boilers and furnaces, N<sub>2</sub>O from waste water treatment and electricity consumption. However, there is a distinct paucity of data in terms of quantifying domestic emissions.

Blignaut et al. (2005) calculate that the Agro-processing sector emitted 64 Kt of CO<sub>2</sub>-e in 1998, based on energy usage data provided in the DME's national energy balances. This includes all combustion-related emissions but no process emissions, so will underestimate the sector's emissions to some extent. The national GHG inventory does not provide any information at a disaggregated level for either the Agro-processing or the food industry and the LTMS reports do not identify any abatement options for the sector.

Various industry organisations in the SA food industry were contacted to determine quantitative estimates of GHG and final energy demand for sub sectors. Appendix provides a list of the organisations contacted and the current availability of data. The research demonstrates that there has been no concerted effort by the Agro-processing sector as a whole to quantify and report on GHG emissions. It appears from discussions with industry organisations that there is a limited awareness of climate change as a business imperative and initiatives on GHG reporting are limited to JSE listed food companies that report on it as part of broader sustainability reporting. To the authors' knowledge there is no comprehensive data set currently available on domestic GHG emissions.

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<sup>32</sup> This point is disputed by some, who see South Africa's infrastructure network as inefficient and expensive.

#### **7.2.4. CURRENT SECTOR RESPONSE TO CLIMATE CHANGE**

There are a number of current initiatives to reduce GHG emissions being implemented by the Southern Hemisphere food industry. Food industry forums in Australia are currently investigating how to reduce GHG emissions and improve process efficiency as well as use energy more efficiently and minimise total energy use (Food Science Australia, 2009). Food Science Australia, a joint venture of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Australian government, is a leading research organisation aimed at turning scientific research into innovative solutions for the Australian food industry that include amongst others food processing automation and efficiency.

In New Zealand more than 50% of food and beverage companies that have undertaken environmental compliance do so to comply with local or international regulation (Smith and Cerasela, 2007). Distance to market is a key challenge for the New Zealand sector and will be exacerbated as the drive for emissions reduction increases. The role of environmental information in increasing export competitiveness is becoming increasingly important.

Competitive advantage also lies in the development and application of new technological developments in the field of food preservation and storage to extend the storage and shelf life of high grade food products to increase opportunities for export and transport products by sea rather than air. In Australia, research into high pressure sterilisation and processing is currently being investigated for abalone and the development of low-acid shelf-stable foods like ready-to-eat meals, dairy-based sauces and vegetables in the Australian food industry. A pilot high pressure sterilisation plant has been constructed in Australia that is the only one in the Southern Hemisphere and one of three in the world.

No initiatives are currently being undertaken by the South African food industry collectively. However, the deciduous fruit and wine industry has an ongoing project aiming to generate detailed emissions information for the industry which can inform strategy and emissions reduction activities going forward (see <http://www.climatefruitandwine.co.za/> for further details).

The CDM project portfolio for South Africa shows that only 16 of the 125 potential CDM projects submitted to the South African Designated National Authority (DNA) have been originated in the food and beverages sector. Projects are in agriculture and Agro-processing sector involving fuel switching, renewable energy, biofuels and biomass with varying project lifespans. CDM projected in Agro-processing is predominantly in fuel switching and renewable energy. Table in Appendix gives a detailed list of CDM projects in the sector.

It is expected that with the release of feed-in tariffs and associated market certainty more Agro-processing firms will pursue CDM's.

### 7.2.5. SECTOR MITIGATION OPPORTUNITIES

The desktop review of international initiatives in the Agro-processing sector was restricted to the energy use and emissions of the sub-sectors identified in section as falling into the definition of Agro-processing in this study. The main findings of the review are listed below in Table .

Sub Sectors	Main Energy Consuming Processors	Mitigation Opportunities
Sugar milling	Burning of coal in refinery	Co-generation using bagasse
Fruit and vegetable processing	Refrigeration requirements in US frozen fruit, juice & vegetable production	Energy efficiency in heat sterilisation, blanching and cooking in canning (steam systems) Water efficiency & heat recovery in the pasteurisation process in juice canning Freezing and concentration process in frozen fruit manufacturing On-site combined heat & power (CHP) systems for blanching, evaporation, pasteurisation and sterilisation in fruit and vegetable canning
Wine making	Cooling and pressing in South Africa	Energy savings will be site-specific within cooling & pressing processors
Grain milling	Sieving and milling in South Africa	“Continuous flow system” implementation
Rooibos tea	Pasteurisation in SA	Motor efficiency improvement

**Table : Desktop review of mitigation opportunities in Agro-processing sub-sectors**

*Source: Van Den Berg (2009), Masanet et al (2008), Roussouw (2009), Hardcastle (2009)*

The desktop review demonstrates that due to the extremely diverse nature of the food industry it is not possible to identify mitigation options applicable for the whole Agro-processing sector. The identification of key mitigation options within each sub sector is more feasible.

Other findings from the desktop review are:

- The majority of reports available on energy savings opportunities within sub sectors are for the US.
- Energy savings opportunities are available per process within sub sectors but there is a lack of information on their GHG emissions reduction potential.

The current use and applicability of the available mitigation options in the South African Agro-processing sector was determined by consulting with various local experts (see Table in Appendix for details). These consultations suggested that there are currently no quantitative estimates on energy savings, GHG emission reductions and capital costs for South Africa of the above mentioned mitigation options.

Five mitigation options were identified as the most appropriate for the South African context based on best practice case studies in sugar milling, grain milling, meat processing, fruit and vegetable processing and solar cooling in the fruit industry.

These are:

- Co-generation in the sugar industry;
- Energy efficiency in meat processing;
- Energy efficiency in grain milling;
- Energy efficiency in fruit & vegetable processing; and,
- Solar cooling in the fruit industry.

#### **7.2.5.1. IACC**

The IACC provides a summary of the main mitigation options and how easy it will be to implement each that is based on the risk assessment undertaken in the second part of this section. There is currently no local data available for the key mitigation options identified. Hence information from international best practices was used to determine the cost of implementing the option as well abatement potential. An explanation of the meaning of the IACC is given in section

Note that the mitigation options all reduce greenhouse gases. Opportunities for the sector arising from climate change or greenhouse gas mitigation (e.g. export labelling) that don't themselves reduce greenhouse gases were not included.

The fifth option namely; solar cooling in fruit industry was not included in the IACC and description of risk indicators because of the lack of available quantitative estimates in this specific application (see section for details).

Figure shows that the major abatement option for the Agro-processing sector is in energy efficiency and specifically in grain milling, meat processing and in fruit and vegetable processing. Co-generation in sugar milling was also identified as an option. The major abatement options shown in Figure are mostly low cost and medium risk. Therefore the Agro-processing sector is reasonably well placed for abatement options.

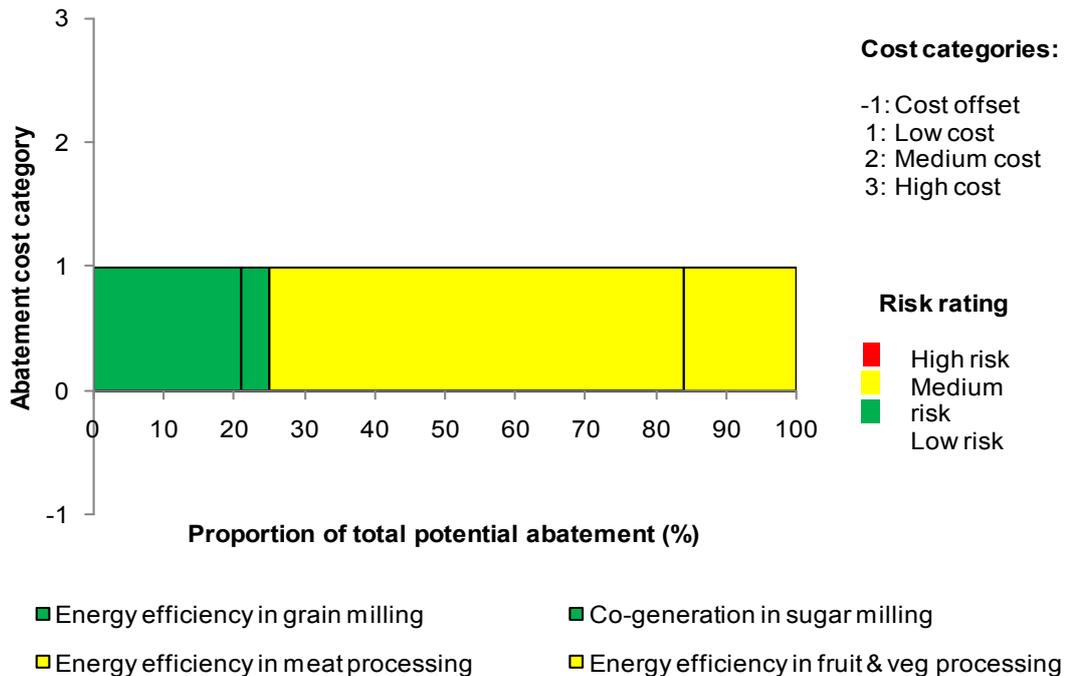


Figure : IACC: Agro-processing<sup>33</sup>

Source: Genesis Analytics, 2010

## 7.2.5.2. DESCRIPTION OF ABATEMENT OPPORTUNITIES AND RISK INDICATORS

### Energy efficiency in grain milling

The grain milling process in SA is run entirely on grid-sourced electricity with milling and sieving being the most energy intensive processes (Wiggil, 2009) using large engines that run continuously. The increased efficiency of motors is the only feasible mitigation option. This generally takes place when an engine needs to be replaced. Eskom's current Energy Efficient Motors Programme is one incentive that may be capitalised upon. The abatement potential of implementing this programme across all industries in South Africa is 10GW of electricity. No figures are available for abatement potential in specific sub sectors for e.g. grain milling.

Energy efficient motors normally cost about 20% more than traditional motors. The Eskom subsidy smoothes the purchase price making it comparable to prices paid for less energy efficient models. Grain milling firms wishing to make use of this scheme are required to return the old motor with all components to the suppliers when they make the new purchase. A disposal certificate has to be submitted to Eskom Demand Side Management to ensure these motors do not re-enter the market. Independent auditors appointed by Eskom monitor the entire process and an independent measurement and verification body authenticates the savings achieved by the programme.

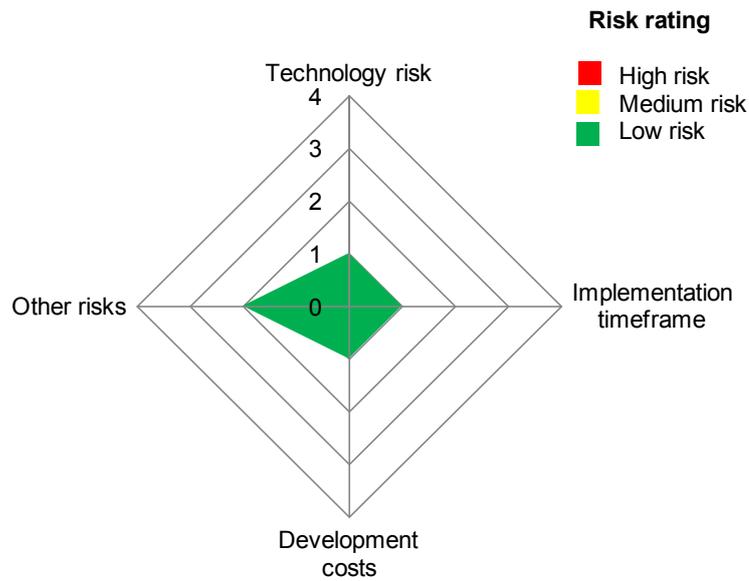
<sup>33</sup> The legend in the IACC should be read from left to right – i.e. in this case the first block in the IACC (green) represents energy efficiency in grain milling, the second (green) co-generation in sugar milling, the third (yellow) energy efficiency in meat processing and the fourth (yellow) energy efficiency in fruit & vegetable processing.

The two benefits are a discount on the purchasing price and the energy cost saving that reduces the payback period of the equipment whilst increasing life-cycle savings.

Additional benefits include compatibility with variable speed drives, which can allow improved drive systems and optimised processes. Co-benefits include a reduction in electricity costs and potentially a reduction in the noise and air pollution.

Replacing all motors within a company will be expensive but should be able to be absorbed over time by company, especially considering the subsidy and monetary savings from energy savings. The payback period is generally between 2- 5 years, depending on the size of the motor. Hence the option is assigned a cost rating of "1" in the IACC.

The risk assessment for this abatement option is detailed below.



**Figure : Radar risk diagram: Agro-processing - energy efficiency in grain milling**

*Source: Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	Efficient motor refit proven in South Africa
Implementation timeframe	1	Immediate if all equipment is in stock- delays have been caused in the past when demand is there but stock is insufficient.
Development costs	1	Technology is developed.
Other risks	2	Rebate is dependent on Eskom and could be discontinued, but as electricity prices increase, the incentive for firms to take up the option themselves will increase. There have been stock shortages and delays in getting the necessary imports. This is a risk if take-up is to be at industry scale.
Composite risk score	5	
Overall risk rating	Low risk	

**Table : Risk ratings: Agro-processing - energy efficiency in grain milling**

*Source: Genesis Analytics, 2010*

### Co-generation in sugar milling

Sugar production involves processing from sugar cane and sugar beet with the former being the main source of sugar in South Africa. In general approximately 10% of sugar cane can be processed into sugar whilst much of the bio-product, bagasse, may be reused.

GHG emissions result from the combustion of fossil fuels used in the processing plant. Bagasse is classified as a renewable fuel source, and is rated zero for emissions. International trends in the sugar cane industry show relatively high emissions efficiency in the milling process due to the utilisation of bagasse. It is now common practice to use bagasse in South Africa (Davis, 2009). Bagasse is, however, only available during the crushing season, particularly in smaller plants where the supply of sugar cane is more limited, and therefore alternative fuel sources are often used. There are mills that export the bagasse for an additional revenue stream.

The large-scale use of bagasse to generate electricity has, up-to-now, been constrained by the lack of appropriate feed-in tariff to justify the capital investment required. This cost is approximately R40 million for the building of a bagasse power plant from scratch, however, most South African sugar mills already have bagasse capturing equipment, so the price should be lower than this in most cases. However, Phase II of the Renewable Energy Feed-in Tariffs approved by the National Energy Regulator (NERSA) in October 2009 makes provision for a feed-in tariff for biomass of R1.18/kWh.

Industry experts<sup>34</sup> suggest that in South Africa there is potential for a 50:50 split between electricity used to fuel the mills and sold to the grid. Six million tonnes of the renewable biomass is produced per year, of which around three million tonnes is required to fuel the mills.

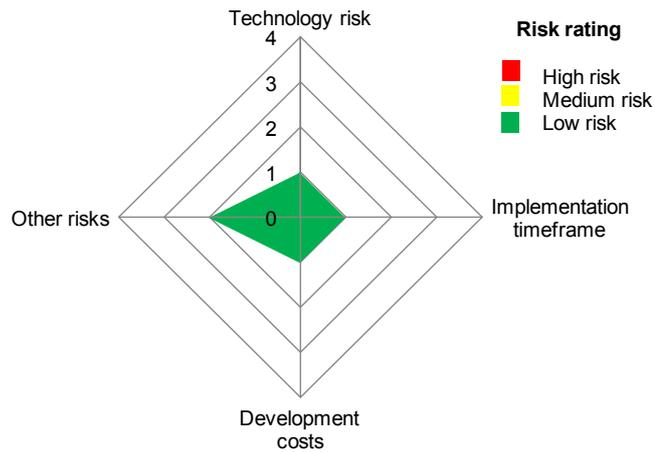
<sup>34</sup> Van De Merwe (2009) and Meadows (2008).

At present much of the remaining three million tonnes is burnt in the field or just left in the field but could be used for generating electricity for sale to the grid. In South Africa co-generation from bagasse has the potential to provide as much as 2755 GWh of electricity per year to the grid (Deepchand, 2005).

The relatively low price of electricity in South Africa has historically been cited as the major barrier to growth of co-generation in all sectors in South Africa. This is however, expected to change as Eskom's prices increase. Lessons from co-generation in Mauritian sugar mills provide good insight into what works and how to go about stimulating investment in the technology. Key lessons are (Deepchand, 2005):

- Institutional capacity is required in the form of a dedicated Technical Committee at the National Department of Energy specifically mandated to investigate price setting mechanisms and power purchase agreements with sugar mills.
- The feasibility of co-generation was improved with additional revenue generated from sale of "surplus" electricity to the national grid. The industry produced enough bagasse to power all its own processing and still have excess to feed in to the grid.
- Economies of scale resulted in the concentration of sugar mills largely due to minimum requirements for crush capacity ranging from 200 to 300 tonnes of sugar cane per hour.
- Tax incentives provided under the Income Tax Act stimulated investment.
- Industrial policy aimed at linking the co-generation of sugar to electricity exports was one of the key factors contributing to the success of the technology in Mauritius.
- The average abatement potential per sugar mill was 2000 MW at 1.2kg carbon dioxide per kWh for a 40MW facility. The average capital cost per sugar mill is R40 million.

The risk assessment for this abatement option is detailed below.



**Figure : Radar risk diagram: Agro-processing - co-generation in sugar milling**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	The technology has been proven and accepted internationally, extensively in Mauritius as well as Reunion, India, Australia and around 80% of South African mills power some or all of their processing with co-generation from bagasse. There is still significant scope for further co-generation, however, in order to provide electricity to the grid.
Implementation timeframe	1	As most SA mills are already using co-generation, the implementation timeframe is short. The support within the industry is dependent on an adequate feed-in tariff for excess electricity which is currently being negotiated with Eskom.
Development costs	1	For implementation of the option, the cost is high (R8400/kW) however most of South Africa's sugar mills use bagasse technology already and therefore the development costs are treated as moderate to low.
Other risks	2	Eskom and government support - Government needs to support the implementation and utilization of renewable energies. Should the current (relatively new) government not fully support this, the technology may not be successfully adopted. However, the NERSA REFIT (Renewable Energy Feed-In Tariff) programme Phase II has approved a feed-in tariff of R1.18/kWh for biomass.
Composite risk score	5	
Overall risk rating	Low risk	

**Table : Risk ratings: Agro-processing - co-generation in sugar milling**

Source: Genesis Analytics, 2010

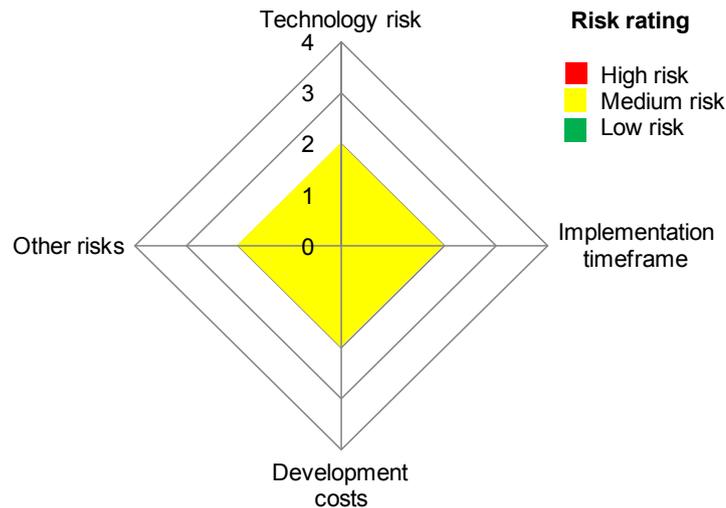
## Energy efficiency in meat processing

The meat processing and rendering industry includes the slaughter of animals and fowl; processing of the carcasses into cured, canned, and other meat products and the rendering of the inedible discarded remains into useful by-products such as lard and oils. Waste from the meat industry is substantial in the form of solid wastes and waste water with a high biochemical oxygen demand although the waste load depends on the kind of meat being processed. However all slaughtering waste (generally 35% of animal weight) can be used as by-products in other processes or for rendering (World Bank 1998). Production systems should be optimised to minimise waste water due to high sanitation requirements during the process.

Key lessons learnt by a meat processing firm called Schneider Foods in Canada provide useful insights into opportunities in energy efficiency and include:

- Energy efficiency opportunities should be focused on ammonia refrigeration and steam systems as these are the highest consumers of energy.
- The main energy efficiency measures implemented are reduction of steam operating pressure, improvement of turn down ration on boilers, elimination of warm stand-by boilers, reduction of generator exhaust and reduction of excess oxygen from 5% to 2%.
- The abatement potential of implementing the five energy efficient measures above is 2.3 million cubic meters.
- Total annual cost savings was \$156 000 and payback period was seven months.

The risk assessment for this abatement option is detailed below.



**Figure : Radar risk diagram: Agro-processing - energy efficiency in meat processing**  
Genesis Analytics 2009

Rating criteria	Rating	Explanation
Technology risk	2	Proven commercially internationally
Implementation timeframe	2	2-5 Years to implement
Development costs	2	Individual firm should be able to bear development cost
Other risks	2	There is some risk since the technologies cannot necessarily be uniformly adopted throughout the industry as each processing plant needs to be individually audited to see what efficiency options are relevant for them. However, the risk of this preventing the adoption of the technology is low.
Composite risk score	8	
Overall risk rating	Medium risk	

**Table : Risk ratings: Agro-processing - energy efficiency in meat processing**

*Source: Genesis Analytics, 2010*

### **Energy efficiency in fruit and vegetable processing**

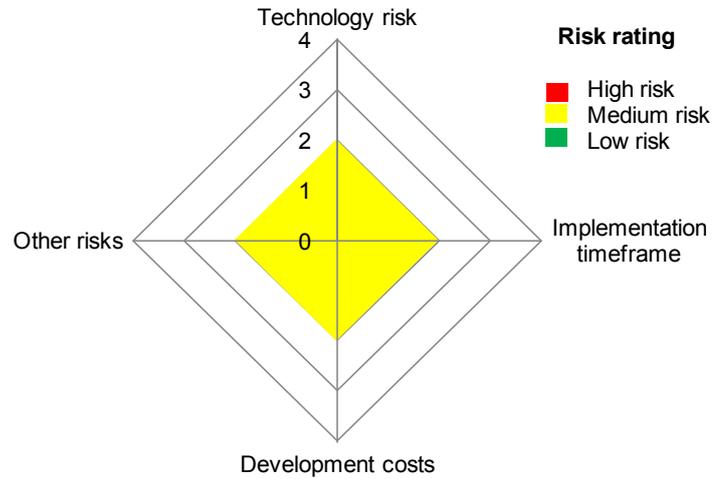
The most energy intensive segments of fruit and vegetable processing are initial cooling, processing and cold storage. The majority of electricity consumed at such plants is through ammonia refrigeration. Electric using devices are lighting, compressed air systems, hydraulic pumps and other process drive motors. Natural gas is the only fossil fuel used at these plants to produce steam for processing and sanitation.

A case study of seven fresh fruit and vegetable processing plants in Canada investigated energy efficiency opportunities in fresh and fruit processing and cold storage facilities (Hackett, Chow and Ganji, 2005). The mitigation opportunities with the highest energy savings potential in large plants was in refrigeration system controls and optimisation. The key energy efficiency measures are demand-based defrost control, floating head pressure control, ammonia sub cooling, reconfiguring of condensers, installation of intermediate pressure suction lines, increasing suction pressure, improvement of pre-cooling of blanched vegetables and two-stage compression instead of one.

The key lessons are:

- Benefits of increasing refrigeration capacity and reducing energy consumption of the existing refrigeration systems.
- Major cost savings may be achieved by changing from timer-based defrost control schemes to the more energy efficient demand-based control. Another major control measure is to set the system head pressure based on the measured outdoor air wet-bulb temperature.
- Moderate implementation costs result in an average simple payback period of less than a year. Demand savings range from 16kW to 319kW. Energy savings range from 44 000kWh per year to 1 200 000kWh per year.

The risk assessment for this abatement option is detailed below.



**Figure : Radar risk diagram: Agro-processing - energy efficiency in fruit and vegetable processing**  
 Source Genesis Analytics 2009

Rating criteria	Rating	Explanation
Technology risk	2	Technology has been commercially proven internationally
Implementation timeframe	2	2 to 5 years to implement
Development costs	2	Individual firm should be able to bear development costs
Other risks	2	Low probability the risk will be triggered and prevent the adoption of the technology/option
Composite risk score	8	
Overall risk rating	Medium risk	

**Table : Risk ratings: Agro-processing - energy efficiency in fruit and vegetable processing**  
 Source: Genesis Analytics, 2010

### Solar cooling in the fruit industry

Fruit packhouses consume energy directly after harvest to reach minimum required temperature for cold storage required for transport to market (local or export). This represents an opportunity to apply solar technology as identified in the expert review of mitigation opportunities.

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favourable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the sun.

Although these technologies have been explored widely in other quite different applications, their use in the specific application of solar cooling in the fruit industry is not well established. Hence a review is required to determine the technology available, its associated risks, abatement cost estimates and greenhouse gas mitigation potential.

### **7.2.6. OPPORTUNITIES ARISING FROM CLIMATE CHANGE MITIGATION**

The key opportunity identified in the Agro-processing sector is demand for products with a lower carbon footprint from changing consumer preferences for environmentally friendly products.

There is also an opportunity to produce and sell renewable energy to the grid, particularly in the sugar industry where co-generation using the sugar cane waste product, bagasse is a well established technology with great potential.

Finally, energy efficiency technologies give the industry the opportunity to reduce their costs and minimise risks through becoming less reliant on electricity from the grid. This should allow the sector to become more competitive.

## **7.3. ELECTRICITY GENERATION AND SUPPLY CASE STUDY**

### **7.3.1. SECTOR DEFINITION AND DATA ISSUES**

The electricity sectoral study considers electricity generation and supply, a sub sector of SIC code 411 (production, collection and distribution of electricity). The scope of the electricity sectoral study (which is defined as electricity supply only) explicitly excludes the consideration of opportunities for demand side management. Energy efficiency is considered in the other sectoral studies, but these cover industry only, and certain considerations, such as solar water heaters to offset demand for water heating, offer a significant contribution to greenhouse gas mitigation in the short to medium term.

A further opportunity which is not covered in the strict scope of this work is burning biomass in boilers for steam and heat provision which would otherwise be powered by electricity, for example, in paper mills and sugar cane mills. This opportunity is covered to the extent that it falls within the Agro-processing sector case study.

Of all the sectors in South Africa, electricity supply probably has the most reliable baseline greenhouse gas emissions data – given that emissions are almost exclusively from a single utility which reports its greenhouse gas emissions and these originate from a relatively small number of generation installations. However, in terms of mitigation options and their potential in the South African context, the same general difficulties were experienced as are described in Appendix .

### **7.3.2. SECTOR CONTEXT**

Electricity generation in South Africa is dominated by Eskom, a single, vertically integrated, state-owned utility. Eskom also owns, operates and maintains the national transmission grid. Eskom is among the top seven utilities in the world in terms of generation capacity, and among the top nine in terms of sales. There are also a number of potential Independent Power Producer (IPP) generation projects in the pipeline, but at the time of writing these were being

hampered by obtaining Power Purchasing Agreements from Eskom, the designated Single Buyer of electricity generated by IPPs. The contribution of these projects to overall generation, even once PPAs are eventually signed, is expected to be relatively small for the foreseeable future.

The biggest component of Eskom's plant mix is the 13 coal-fired power stations with a total nominal capacity of 37 773 MW. Their total net maximum capacity, which excludes the power consumed by their auxiliaries and reduced capacity caused by age of plant and/or low coal quality, is 34 294 MW. Koeberg, the only nuclear station, is also a base load station and has a net maximum capacity of 1 800 MW.

The Eskom mix further includes two conventional hydroelectric power stations and two hydro pumped storage schemes. These stations are used for meeting peak electricity demands which cannot immediately be met by the base load stations. The hydro stations have a joint capacity of 2000 MW.

The final elements of the current mix are four gas turbine power stations which have a total maximum capacity of 2409 MW. These stations are used at peak periods and during extreme emergencies due to their very high operating costs. The two smaller, "older generation" open cycle gas turbine stations (OCGT's) use kerosene to power their engines. The two new gas power stations run on diesel. There is also a demonstration wind farm of 3 MW at Klipheuwel in the Western Cape.

Apart from the few exceptions identified above, Eskom is very much locked into coal (in terms of their operating experience and mandate to provide South Africa with a reliable and affordable supply of electricity), and to a lesser extent, nuclear power. Eskom is also very much an electricity company and does not generally think in broader energy-supply terms. The 2013 Renewables target set by government (discussed further below) is making some progress in addressing these limitations, forcing Eskom to play a role in the implementation of renewable electricity-supply options.

Although Eskom currently dominates the sector, there is the potential for independent power producers (IPPs) to supply electricity into the grid. As mentioned previously, to date there has been little uptake of this opportunity, with a few isolated facilities such as the Darling wind farm.

A distinction can be made between the roles of Eskom and IPPs in electricity supply on the basis of capacity of generating infrastructure. Eskom provides base load power, and their primary focus is on meeting the electricity needs of the country. Small firms are more likely to come in with renewable options and provide off-grid power (e.g. solar or wind) and/or help with peaking power load. IPPs do also have potential to supply base load, but this will require bigger players. For example, it is noted that in April 2009 the mining house Exxaro indicated an interest in building base load coal fired power stations. In December 2009, Eskom expressed an interest in selling a share in Kusile, one of the planned new power stations, to a private entity.

In addition to on-grid supplies, generation capacity is also held by a handful of companies which produce electricity for their own needs (most notably Sasol), and some municipalities which still operate their own power stations, although the latter are generally small and ageing.

The sector is not trade-intensive at all at present (although this may change going forward) with exports accounting for only 5.5% of domestic production and the ratio of imports to domestic

production at 4.3%. All trade in the sector occurs with neighbouring African countries, and as such the carbon policies of trading partners are not likely to be a major issue for the sector.

### **7.3.3. REGULATORY ENVIRONMENT**

Eskom is a state owned enterprise with 100% of ownership vested in the Department of Public Enterprises. It is regulated under licences granted by the National Energy Regulator of South Africa (Nersa) originally under the Electricity Act (41 of 1987) (to be replaced by licenses under the Electricity Regulation Act (4 of 2006) and by the National Nuclear Regulator in terms of the National Nuclear Regulatory Act (47 of 1999). NERSA's mandate is to regulate the electricity, piped-gas and petroleum pipeline industries in terms of the Electricity Regulation Act, 2006 (Act No. 4 of 2006), Gas Act, 2001 (Act No. 48 of 2001) and Petroleum Pipelines Act, 2003 (Act No. 60 of 2003). This includes the setting of tariffs. The Energy Regulator consists of nine members, five of whom are part-time and four are full-time, including the CEO. The Energy Regulator is supported by a secretariat under the direction of the CEO.

In terms of other power producers apart from Eskom, in 2003 government mandated that 30% of new capacity should be established by private suppliers or Independent Power Producers (IPPs). A number of established firms (including some of the world's biggest power companies) have noted interest in taking advantage of this opportunity to develop power generation facilities in South Africa, but to date the process has been fraught with difficulty as mentioned above. In August 2009 the Department of Minerals stripped Eskom of the right to award contracts to IPPs, stating that the function will sit within the Department going forward. It is hoped that this will get the process moving again.

Feed-in tariffs for renewable energy, which offer a substantial subsidy to renewable electricity generation, have been announced by the National Energy Regulator of South Africa (NERSA) in the hope that these will encourage the adoption of renewable technology enabling the country to meet its target of 10 000 GWh of renewable capacity in the generation mix by 2013

### **7.3.4. GHG EMISSIONS**

The energy sector is the main sector contributing to GHG emissions in South Africa, with a contribution of 79% of total GHG emissions being reported in both the previous and current greenhouse gas inventories. Of the 79% of total emissions, 52% is attributed to electricity production, with some 171.58 Mt CO<sub>2</sub>-e calculated for electricity provision from sub-bituminous coal in 2000.

A more recent indication of emissions from the sector can be obtained from the 2009 Eskom Annual report, which suggests total CO<sub>2</sub>-e emissions of 221.7 Mt, excluding emissions from gas fired turbines.

The main greenhouse gas from the sector is CO<sub>2</sub>, which is produced in coal combustion. Little or no methane is produced if combustion conditions are correct. Some N<sub>2</sub>O is also produced, with production depending on combustion conditions and the boiler technology used. In 2009, 2.8 kt of N<sub>2</sub>O was produced (Eskom Annual Report, 2009).

### **7.3.5. CURRENT SECTOR RESPONSE TO CLIMATE CHANGE**

At present all internal efforts with respect to GHG mitigation in the sector are voluntary. There are no legislative requirements for GHG mitigation and no targets set by international agreements. Investment timeframes in the sector are long, with a power station having a 30-40 year life span. As discussed below, there are few major efficiency opportunities once the plant is built (i.e. there are large incremental changes for new build, but only small retrofit options). To achieve significant reductions in emissions will require a new plant being built at very high investment costs.

Eskom has developed a climate change strategy that consists of 6 components (Eskom Annual Report, 2008):

- Diversification of the generation mix to lower carbon-emitting technologies;
- Energy efficiency measures to reduce demand and greenhouse gas and other emissions, including through the Demand Side Management programme;
- Adaptation to the negative impacts of climate change, including implementing water savings and others;
- Innovation through research, demonstration and development of new technologies;
- Investment through carbon market mechanisms; and
- Commitment to progress through advocacy, partnerships and collaboration.

Various activities are being undertaken by Eskom towards implementing this strategy.

In addition to the Eskom response, it is likely that the REFIT tariffs will be effective in supporting the entry of new Independent Power Producers (IPPs) into the supply mix. As identified previously, there a number of such projects in the pipeline, awaiting PPAs to be finalised.

### **7.3.6. SECTOR MITIGATION OPPORTUNITIES**

The indicative abatement cost curve for the electricity supply sector is presented in Figure . The abatement options are discussed in greater detail below. The abatement options are equally relevant to Eskom and any IPPs entering the mix, so no further distinction is made here between the two types of generators unless it is necessary to support the arguments

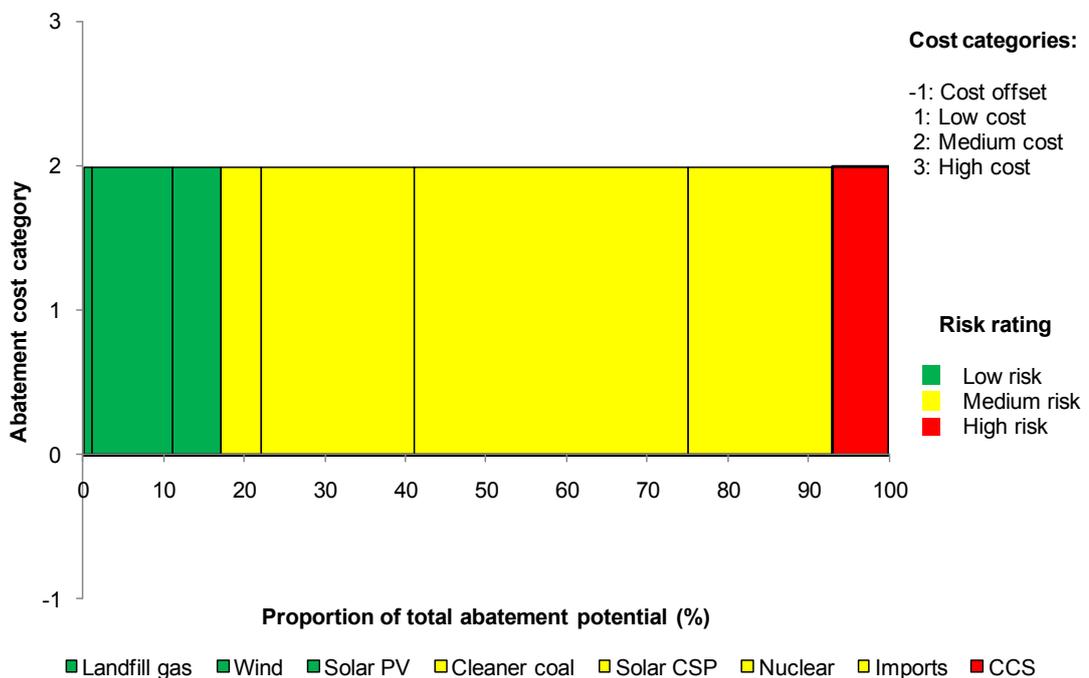
#### **7.3.6.1. IACC**

The largest contributor to abatement in the sector is building more nuclear facilities, due to their ability to provide reliable baseload supply with almost no GHG emissions (apart from those from fuel production). Nuclear does, however come with risks, associated with long implementation timeframes (including those required to obtain licensing/approvals), public perception and potential for cost escalation due to the long implementation timeframes. The potential for imports could be increased; the value shown on the IACC assumes that they will be limited to the current reserve margin as discussed below. As per the discussion which follows, the high cost rating given to imports assumes a requirement for new investment in generation and transmission infrastructure. Should no new investment be incurred, these costs will decrease.

Next in terms of mitigation potential are wind, solar PV and CCS. The potential for wind mitigation is limited as the intermittency of supply limits the extent to which it may contribute to the overall mix in the grid. The potential of solar PV is limited due to high costs at this point. CCS carries a relatively high risk rating due to the significant technological development required. Furthermore, the contribution of CCS has been limited based on the current preliminary indications that South Africa does not have a large number of suitable sites for geological CCS, and that the technology is unproven. Should it be found that such sites are available, this contribution could increase.

In addition to these options, relatively small contributions have been allocated to landfill gas and IGCC. The low contribution of IGCC to overall mitigation is based on the fact that, although this technology results in a reduction of emissions per MWh of electricity, it does not eliminate emissions completely. Other cleaner coal technologies have been discussed below, which could also provide some contribution to the mitigation potential in the sector depending on the technology trajectories in the country.

Biomass is not included on the IACC due to its relatively small abatement potential, but it is discussed in the text due to the large amount of focus on this resource. A number of further abatement options are available in the sector, however many of these will make a negligible contribution relative to the other options in South Africa and hence are not included in this report. Examples are combined cycle gas turbines (CCGT) and geothermal energy.



**Figure : IACC Electricity<sup>35</sup>**  
 Source: *Genesis Analytics, 2010*

<sup>35</sup> For details of how to read the IACC, see footnote in section .

In terms of costs, all technologies are allocated a “2”, which in accordance with the cost category definitions, implying that they cause medium disruption to the way the sector does business, including a move to new technologies and a reconsideration of the mix of products it supplies.

### 7.3.6.2. DESCRIPTION OF ABATEMENT OPTIONS AND RISK INDICATORS

A discussion of each of the abatement options in the electricity sector, along with the radar diagrams for the abatement options and tables providing a short description of the motivation for the ratings, is presented in the sections which follow.

#### Landfill Gas

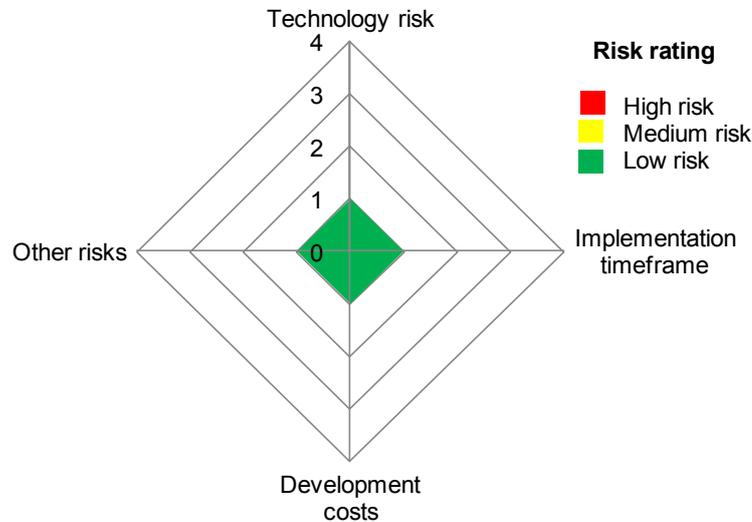
When organic waste degrades in landfills over a period of several decades under anaerobic conditions, methane (in a concentration of 45 - 58%) and other landfill gases (LFGs) including carbon dioxide, nitrogen, oxygen, water vapour and others are produced. The methane in this stream represents a potential energy source. Furthermore, given that methane has a global warming potential of 25 times that of CO<sub>2</sub>, it is highly desirable to prevent release of methane directly into the atmosphere. Hence capture and utilisation of landfill gas represents an abatement option on two fronts, reducing the emissions of methane to the environment and use of the methane instead of other fossil fuels to generate heat or power. A mid-way option sometimes practiced at landfills is to flare the methane (i.e. to convert it to CO<sub>2</sub> because CO<sub>2</sub> has a lower GHG potential than methane), but this is less useful as the heat generated by flaring is not utilised.

LFG generation begins within approximately 9 months after the material in the landfill site has been covered, and continues to be generated over a period of several decades. LFG may be extracted from landfills using a series of wells and a vacuum system that directs the gas to a central collection point. Ideally provision should be made for fitting these gas collection systems during the operational phase of the landfill, although retrospective fitting is widely practiced. From there, the LFG can be used to produce electricity or as an alternative fuel source in industrial and other applications. Such direct use of LFG requires minimal processing and minor modifications to existing combustion equipment. Technologies for extraction and utilization of LFG are well established internationally with thousands of installations around the world, with some limited customization of equipment required depending on site conditions. There are also some local installations (such as at the Marianhill and La Mercy landfill sites in Durban) with growing interest in the technologies. On this basis this option is assigned low technological and development risk ratings.

The cost of LFG projects can sit in the tens of millions of Rand to implement depending on the size of the project, with the Renewable Energy Feed In Tariff (REFIT) regulatory guidelines suggesting a total investment cost of \$2631 per kW installed capacity, and an overall levelised cost of generation (which includes capital recovery and operating costs) of \$0.0896 per kWh. Using the average emissions from the South African energy mix, this translates to a levelised cost of abatement of \$91.6 per tonne CO<sub>2</sub>.

Revenue generation for landfill projects is from the sale of electricity and gas, and the sale of carbon credits – for example eThekweni municipality is generating credits under the Kyoto Protocol’s CDM programme for landfill gas capture and utilisation for electricity generation. Electricity generated from LFG qualifies for sale at the premiums offered under the REFIT programme.

No other major issues of strategic importance or significant co-benefits are identified, with the exception perhaps of the potential for generation of revenue streams for municipalities facing increasingly stringent operating budgets, and reducing the potential for landfill gas build-up and associated explosions.



**Figure : Radar risk diagram: electricity - landfill gas**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Technologies for capture and utilization of gas generated in landfills are well established, both within South Africa and around the world
Implementation timeframe	1	Timeframes for implementation are short
Development costs	1	Technologies can be implemented as is, with no further technology development required
Other risks	1	Some experience has shown institutional barriers and negative public perception issues that create delays in project implementation.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: electricity - landfill gas**

Source: Genesis Analytics, 2010

## Wind

In this mitigation option, the power of the wind is harnessed to drive turbines for the generation of electricity. Smaller stand-alone turbines can be used for distributed generation purposes, such as powering of remote equipment or for single buildings or houses. In wind farms a

number of larger turbines are co-located, and often feed into the distribution grid. Efficient wind generation requires a wind resource of suitable speed and direction.

Turbines may be located either on or off shore. The advantages of offshore compared with onshore wind include higher capacity factors, wind speeds yielding as much as 50% greater output, and lower visual impact. Offshore turbine costs are largely dependent on water depth and the distance from shore, but are significantly higher than those located on shore, although, the cost of offshore wind is expected to fall.

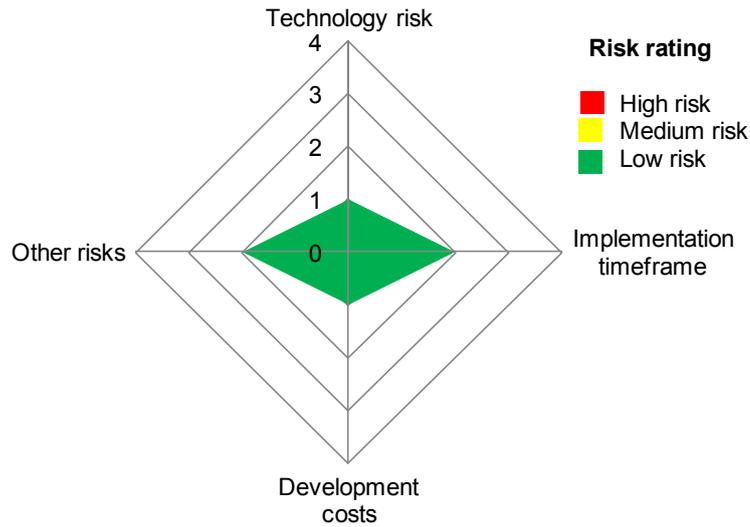
Significant technological advances have been made over the years in increasing output from turbines – in 1985 turbines had an average output of 50 kW compared to the 3600 kW turbines produced in 2005 (IEA, 2008). Ongoing technological development includes a focus on production forecasting, storage, grid integration and power-system design.

Wind power is now well established, with numerous large installations around the world. Most notable of these is Denmark, which has the highest proportional contribution of wind power to its grid of any other country in the world, and is also one of the leading countries in provision of wind energy technologies. Wind farms are also located in the United States, China, Australia, UK and India to name a few. Installed capacity in South Africa is tiny, with the Darling Wind Farm having 4 turbines with a total of 5.2 MW capacity, and two other demonstration units. This despite South Africa having been demonstrated to have high potential for wind generation.

In terms of costs for wind, the REFIT guidelines suggest an investment cost of \$2255 per kW installed capacity, while Marquard et al (2008) suggests to the order of R10 523 per kW in 2006. The REFIT guidelines also suggest a levelised cost of electricity production (including capex and opex) of \$0.1247 per kWh. This is similar to the estimate provided by Marquard et al (2008) of around R0.5 per kWh in 2008. The former translates to a levelised abatement cost of \$127.50 per tonne CO<sub>2</sub>. This is significantly higher than the McKinsey estimate of €14 per tonne CO<sub>2</sub> in 2030 – reflecting learning and technological development likely in this technology between now and 2030. A cost element which needs to be taken into account in establishment of individual wind farms is that of establishing the wind profiles for the potential sites.

Given that wind does not offer a consistent supply of electricity, it needs to be complemented in the energy mix with other sources. As such there is a limit to the proportion of overall electricity supply in a country which can be made up by wind. As the penetration of wind into the energy supply mix increases, provision has to be made for balancing of the grid, which carries with it additional cost implications. Denmark currently has the highest wind penetration at 16.8% of their total electricity mix, with the next highest being Spain at 8.78%. As such, the total contribution to mitigation is limited. A further consideration in establishing increased wind penetration in South Africa is that all of the turbines, and much of the expertise to build wind farms, need to be imported from overseas.

The three main environmental concerns surrounding use of wind turbines are visual impact, noise and the risk of bird collisions and wildlife disruption.



**Figure : Radar risk diagram: electricity - wind**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	South Africa already has installations of wind turbines, and these are used in many places around the world
Implementation timeframe	2	Short turnaround times for building of wind farms
Development costs	1	Turbines may be bought off the shelf and hence no developments costs need to be incurred for their adoption. However they do need to be imported
Other risks	2	The potential for their adoption is limited as too high penetration has implications for grid stability. Furthermore there is often strong public opposition to the establishment of wind farms
<b>Composite risk score</b>	<b>6</b>	
<b>Overall risk rating</b>	<b>Low risk</b>	

**Table : Risk ratings: electricity - wind**

Source: Genesis Analytics, 2010

## Solar PV

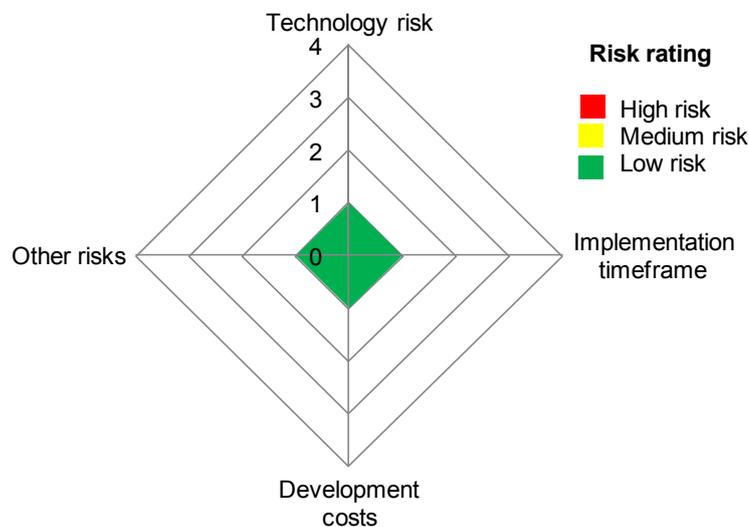
Photovoltaic (PV) systems convert solar energy directly into electricity. The basic building block of a PV system is the PV cell, which is a semiconductor device that absorbs sunlight and converts it into direct-current (DC) electricity. PV systems can be grid-connected or stand alone (off-grid).

PV systems have been used extensively around the world, and their use continues to grow. In addition, PVs have a number of off-grid applications, including water pumping and rural electrification. They are also increasingly being used to generate electricity for feeding into the

grid. In South Africa, however, installations are thus far limited to off-grid applications. Furthermore, at present solar PV technologies are imported into South Africa.

At this stage the investment costs of PV systems are still high. This represents the most important barrier to further penetration of PV in electricity supply. PV systems do not have moving parts, so operating and maintenance costs are much less significant – at around 0.5% of capital investment per year. PV modules account for roughly 60% of total system costs, with mounting structures, inverters, cabling, etc. accounting for the rest. Advances in thin film solar will ultimately bring down the costs of these systems, although they are likely to increase their market share only after 2020. A further factor which influences the profitability of these systems is that availability is low (they generate electricity for, on average, 23% of the time) which increases the levelised costs of the technologies.

Marquard et al (2008) suggests capital costs of R38 377 per kW installed capacity in 2006. The EIA suggests that total PV installation costs were estimated to fall between \$5500 and \$6250 per kW installed capacity in 2006 (which is similar to those of Marquard et al), although these are expected to have dropped between 2006 and 2010 (IEA 2008). By 2030 McKinsey (20098) suggests that the abatement cost associated with solar PV will be to the order of €20 per tonne CO<sub>2</sub>, only marginally higher than solar CSP. This figure takes into account the significant technological advances expected for solar PV.



**Figure : Radar risk diagram: electricity - solar PV**

*Source: Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	A number of different types of solar PV panels are used extensively throughout South Africa and the rest of the world
Implementation timeframe	1	Products can be purchased off the shelf and installation is not time consuming
Development costs	1	No development costs for existing technologies. Ongoing research is, however, being conducted in areas such as thin film solar and use of different types of metals in the panels, all of which have potential to bring down the cost of the panels. Looking at these technologies in detail is beyond the scope of this study but could potentially increase the development cost rating to a "2".
Other risks	1	No other risks are foreseen
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: electricity - solar PV**

*Source: Genesis Analytics, 2010*

### Cleaner coal

Cleaner coal technologies refer to a suite of technologies which demonstrate higher efficiencies and lower emissions than traditionally used technologies for electricity generation from coal. These include supercritical and ultra-supercritical coal technologies, Integrated Gasification Combined Cycle (IGCC) and Underground Coal Gasification used in conjunction with Combined Cycle turbines (UCGCC).

Supercritical and ultrasupercritical coal technologies are a variant of the more commonly used Pulverised Fuel technologies, in that they also burn coal to heat water for generation of electricity. The difference is that these technologies make use of higher temperatures and pressures than conventional technologies, and operate above the critical point for water.

Unlike traditional combustion technologies which burn coal to generate steam to drive turbines for electricity generation, IGCC technologies employ a four step process as follows (IEA 2008):

- Fuel gas is generated from the partial combustion of solid fuels such as coal at pressure in a limited supply of air or oxygen;
- Particulates, sulphur and nitrogen compounds are removed;
- The clean fuel gas is combusted in a gas turbine generator to produce electricity; and
- The residual heat in the hot exhaust gas from the gas turbine is recovered in a heat recovery steam generator – the steam is used to produce additional electricity in a steam turbine generator.

It is noted that IGCC represents a fundamentally different process to a conventional power station. As such, it is not possible to retrofit these technologies – their adoption suggests building of new power stations.

UCGCC is a variant of IGCC being explored by Eskom, in which coal is gasified underground to produce syngas (a mixture of CO<sub>2</sub>, H<sub>2</sub>, CH<sub>4</sub> and CO), which can be used directly as a fuel for either boilers or gas turbines. This is achieved through drilling a matrix of wells into the coal bed, igniting the coal and pumping air/oxygen and water into the injection wells (Eskom, 2009b).

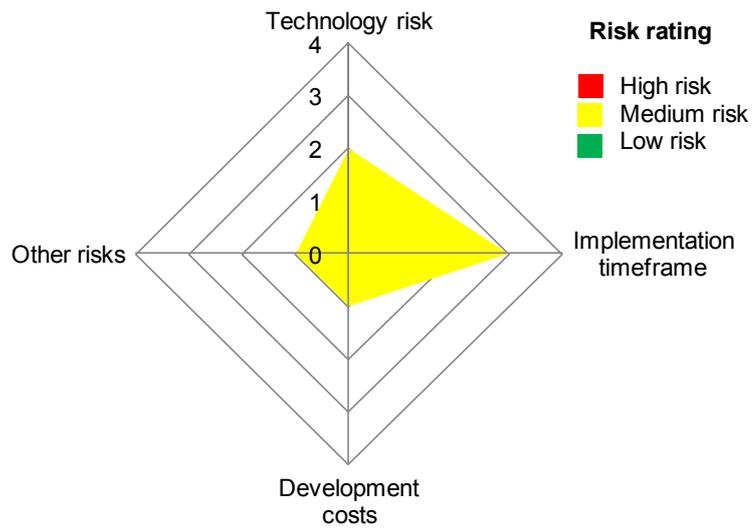
In terms of efficiencies, supercritical coal achieves around 6% higher thermal efficiencies than the currently used pulverised fuel (PF) technologies (Winkler, 2007), and ultra-supercritical up to 15% higher. IGCC achieves about 12% higher than conventional PF (Winkler, 2007) and underground coal gasification used in combination with a combined cycle (or simple cycle) gas turbine is expected to achieve up to 15% higher than PF technologies (Eskom, 2009b). Although these efficiency improvements are significant, the mitigation opportunities associated with implementation of cleaner coal technologies over traditional power stations is not as high as some of the other options considered in this study – these technologies still give rise to significant GHG emissions associated with combustion.

No cleaner coal technologies power stations have been built to date in South Africa. However, supercritical technologies are well established around the world, and there are ultra-supercritical plants in operation in Japan, Denmark and Germany. The other cleaner coal technologies are still in the demonstration/developmental phase (IEA, 2008, Eskom 2009b).

IGCC is predicted to fill the largest proportion of South Africa's electricity generating mix in the future (filling some 56% of installed capacity by 2050 in the "growth without constraints" scenario in the LTMS study). The next new power station built in South Africa will be supercritical coal, but this is likely to be superseded by IGCC by 2025 (Winkler, 2008). As such, in terms of costs and risks, IGCC is the cleaner coal technology considered in this study, although it is acknowledged that future developments may result in the other cleaner coal technologies being explored in South Africa. It is noted that the scenarios proposed by IEA (2008) suggest a role for both supercritical/ultrasupercritical and IGCC in future energy scenarios.

Marquard et al (2008) suggests construction costs of IGCC in 2010 of R13 068 per kW installed capacity. Cost estimates vary among reference sources, with IEA (2008) suggesting that construction costs are to the order of 20% higher than pulverized coal stations. Other reference sources suggest this differential could be greater. There is, however, more uncertainty in IGCC costs, as there are no recently built coal-fuelled IGCC facilities and existing plants around the world were constructed as demonstration plants (IEA, 2008). In addition, the construction times for new power stations is long, and will be influenced by any technology development required, permitting and licensing including Environmental Impact Assessment requirements, raising capital, sourcing equipment and construction.

One of the co-benefits of IGCC is that it fits well with carbon capture and storage, considered further below.



**Figure : Radar risk diagram: electricity - cleaner coal**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	2	Cleaner coal technologies have been used extensively around the world, but to date not in South Africa. Having said this, the new power stations being built in South Africa will employ such technologies
Implementation timeframe	3	The building of new power stations, including considerations such as obtaining licenses and conducting EIAs, is time consuming, taking between 5 and 10 years
Development costs	1	As technologies have been well established overseas, no development costs will be incurred
Other risks	1	No other significant risks are identified
Composite risk score	7	
Overall risk rating	Medium risk	

**Table : Risk ratings: electricity - cleaner coal**

Source: Genesis Analytics, 2010

## Solar CSP

Concentrated solar power (CSP) technologies use sunlight for the generation of electricity. These are considered separately from solarvoltaics, which are discussed in detail below. Here direct sunlight is concentrated to reach higher energy densities and thus higher temperatures.

Three main types of CSP technology are identified:

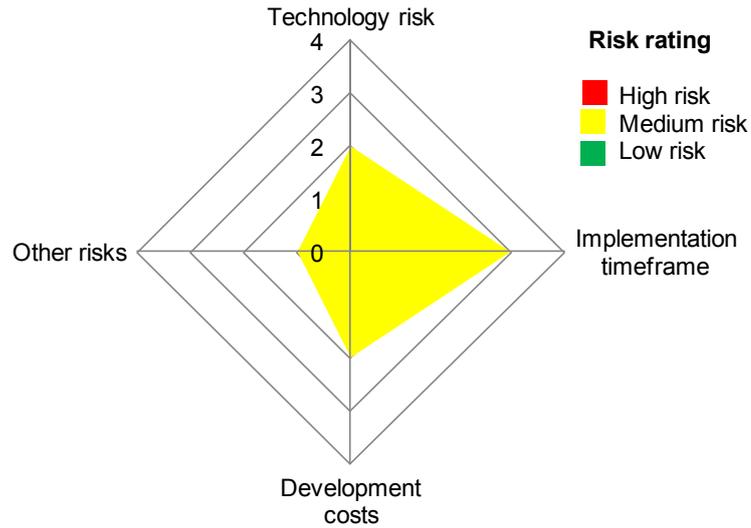
- **Troughs:** parabolic trough-shaped mirror reflectors linearly concentrate sunlight onto receiver tubes, heating a thermal transfer fluid.
- **Towers:** numerous mirrors concentrate sunlight onto a central receiver on the top of a tower where it heats a fluid. This is sometimes coupled with a second concentration step.
- **Dishes:** Parabolic dish-shaped reflectors concentrate sunlight in two dimensions and run a small engine or turbine at the focal point.

Unlike solar PV, where sunlight is converted directly into electric current, the heat gathered in CSP technologies is used to operate a conventional power cycle, e.g. through a steam turbine or a Stirling engine, which in turn drives a generator. Because CSP uses a thermal energy intermediate phase, it has the potential to deliver power on demand, e.g. by using stored heat in various forms. Heat storage also offers the potential for continuous solar-only generation. Alternatively, CSP can be used together with conventional fuels in a hybrid power plant to produce electricity on a continuous basis. Furthermore, CSP can provide combined heat and power although the benefit of this depends on a local need for the heat (this may not have any value in remote locations).

CSP is best suited for areas with high direct solar radiation. A number of installations of all of these technologies exist internationally, most notably in Spain and California in the USA, each of which is less than 100 MW. Despite South Africa being one of the areas identified by the IEA (2008) as having significant potential for CSP, to date there have been no local installations, although there is interest in establishing a local solar tower facility.

CSP technologies today have a cost somewhere between those of PV and wind. Costs are decreasing as markets expand and R&D efforts improve performance. The REFIT guidelines suggest an installation cost of \$5545 per kW installed capacity, and a levelised cost of production of \$0.2092 per kWh, translating to a levelised mitigation cost, including both capex and opex, of \$213.90 per tonne CO<sub>2</sub>, calculated using the methodology described above (NERSA 2009). For comparison, McKinsey (2008) suggests an abatement cost of about €19 per tonne, and Marquard et al (2008) a value of about R613 per tonne. This shows the variability between data sources, which is in turn significantly influenced by underlying assumptions.

The key technology development needs for CSP are to increase the efficiency of mirrors, heat receivers, heat storage systems and balancing mechanisms (IEA, 2008). The limitations facing the technology include the significant land area required for construction of a large scale CSP station, and constraints on water availability in many of the regions where direct solar radiation is highest.



**Figure : Radar risk diagram: electricity - solar CSP**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	2	Although the technology is not as widespread as some of the more common renewable technologies (such as wind, hydro etc), a handful of large scale plants have been built overseas, most notably in Spain and California
Implementation timeframe	3	Although there are a number of technologies on the market, some time would be required for technology and site selection, raising capital, licensing etc
Development costs	2	Some development costs associated with increasing the scale of plants from current plant size (<100 MW), and exploring new energy storage alternatives
Other risks	1	No other risks are foreseen
Composite risk score	8	
Overall risk rating	Medium risk	

**Table : Risk ratings: electricity - solar CSP**

Source: Genesis Analytics, 2010

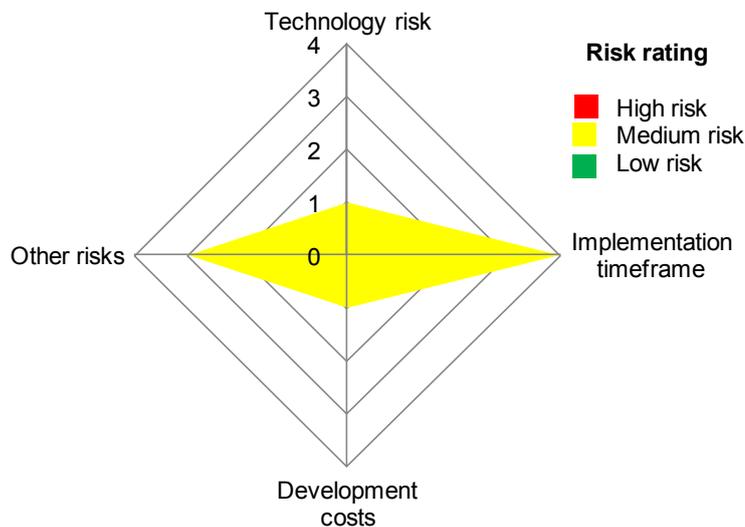
## Nuclear

Nuclear power accesses energy from atomic nuclei through controlled nuclear reactions. At present only one process, known as fission, is used in nuclear energy recovery, with pressurized water reactors being the most common reactor type. South Africa has also invested extensively in another type of reactor known as the Pebble Bed Modular Reactor (PBMR), although this is still under development.

In terms of greenhouse mitigation, nuclear power is in itself almost CO<sub>2</sub> neutral, although there are emissions associated with mining and processing of the uranium fuels used in nuclear reactors. Nuclear technologies are well proven in a number of countries around the world, with 438 operating plants in 30 countries. In South Africa, Koeberg power station was built in 1976. As such, technology and development risks are low.

As with any new build power stations, initial investment in nuclear power stations is high. Costs vary between countries, and depend on, amongst other factors, the cost of capital. IEA (2008) reports on a number of studies which indicate capital investment for nuclear power to be between \$1089 and \$3432 per kW, while Marquard et al (2008) report a 2006 cost of R19 809 per kW, which falls within this range. IEA (2008) suggests levelised costs of \$0.03 to \$0.05 per kWh electricity produced (compared to R0.39 suggested by Marquard et al (2008), representing a levelised abatement cost of \$30.67 to \$51.12 per tonne CO<sub>2</sub>.

Although nuclear is a preferred energy source to coal in terms of gaseous waste emissions, solid wastes high in radioactivity are produced which represent a long-term storage challenge. Nuclear energy has been in decline in much of Europe (e.g. Germany) because of public opposition to long-term nuclear waste storage sites, although the views on this debate change regularly. Furthermore, there are concerns about safety and the link between uranium and the nuclear weapons industry. A final constraint on this technology is a shortage of nuclear engineers worldwide.



**Figure : Radar risk diagram: electricity – nuclear**

Source: *Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	PWR technologies have been used for many years at Koeberg. A number of countries around the world use nuclear power for their base load supply
Implementation timeframe	4	As for cleaner coal technologies, establishment of a nuclear facility requires a significant lead time for both obtaining the necessary permits and for construction
Development costs	1	As the technologies are well established, no further development costs need to be incurred
Other risks	3	There is significant public opposition to nuclear facilities both locally and around the world due to perceived dangers of accidents and issues with waste management. The long time periods associated with both obtaining permits and construction introduce the potential for cost escalation.
Composite risk score	9	
Overall risk rating	Medium risk	

**Table : Risk ratings: electricity - nuclear**

*Source: Genesis Analytics, 2010*

## Imports

Hydropower refers to the generation of electricity by utilising moving water to drive turbines. Different scales of systems are considered in this category, with mini and micro systems operating off-grid power with installed capacities of <1MW, while small (1 – 10 MW) and large (>10 MW) scale hydro are better suited to feed into the grid. Only large scale hydro is considered further here due to the negligible potential contribution of the other options. There is some potential for other imports (such as from a new coal fired power station which was being considered in Botswana), these are not considered mitigation options as they merely transfer the burden elsewhere.

Sub-Saharan Africa has been demonstrated to have huge potential for generation of hydropower. Much of this is located in the DRC, which is reported to have a potential of up to 100 000 MW (Reuters 2009). At this stage the potential in that country is largely untapped, although there is ongoing interest in accessing this resource, including a drive from the DRC government for the realisation of the Grand Inga hydroelectric project which will have 40 000 MW of generating capacity (roughly the equivalent of that currently operated by Eskom). Other countries in the region which have some potential for hydropower include Mozambique (from which South Africa already imports electricity from the Cahora Bassa scheme) and Zambia where there is potential for increased hydropower generation.

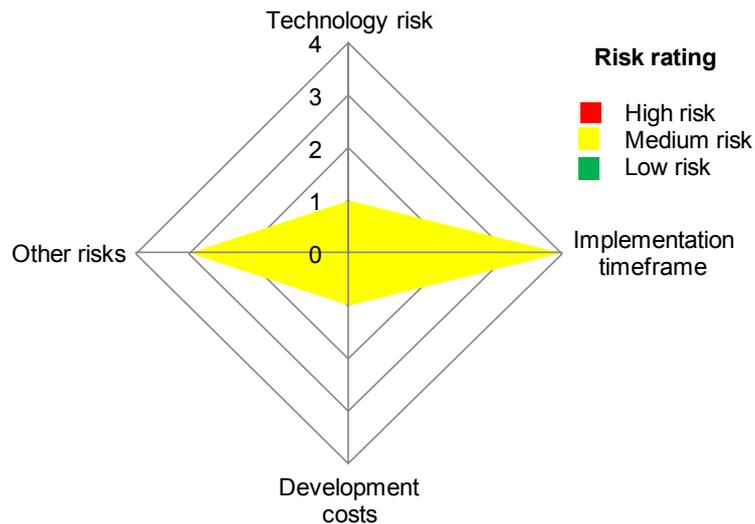
One issue which limits the attractiveness of these options for South Africa is that many of the resources are located in politically unstable regions. To protect energy security, there has been some talk that imports will be limited to the prevailing reserve margin, although this is open for debate.

Although technologies for recovery of hydropower are well established both within Southern Africa and around the world, and hence present little technological risk and development costs, new large scale hydropower projects are capital intensive, with the Grand Inga project projected to costing an estimated \$80 billion. IEA (2008) suggests that in developing countries, investment costs are routinely below \$1000/kW, which is in line with that estimated for the Grand Inga development. The same reference source also suggests generating costs of around \$0.03 to \$0.04 per kWh. Given that the South African electricity mix emits 0.978 kg/kWh of CO<sub>2</sub>, this translates to ongoing operating cost of mitigation of approximately \$31 to \$41 per tonne CO<sub>2</sub> emitted. This figure thus excludes recovery of capital.

As a reference (and not directly comparable as it is likely to be cheaper to build) for small hydro (<10 MW) the REFIT regulatory guidelines suggest a levelised cost of generation (which includes both recovery of capital and operating costs) of \$0.094 per kWh generated, assuming a load factor of 50%. This translates to a levelised abatement cost (i.e. including capital recovery) of about \$96.11 per tonne CO<sub>2</sub>.

Establishment or upgrading of the transmission grid infrastructure for long distance transport represents a further cost.

In constructing the IACC, imports were assigned an indicative cost of 2, assuming a requirement for building new generating infrastructure (including dams) and transmission lines. This may happen for new hydropower, such as the Grand Inga project mentioned above. If, however, there is access to sources in which no investment is made by South Africa in either generating technology or new grid infrastructure, this rating can be changed to a -1.



**Figure : Radar risk diagram: electricity – imports**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	There is significant potential in Africa for hydropower which would be the primary import considered. Technologies for hydropower generation are well established and efficient
Implementation timeframe	4	The rating given assumes building of the infrastructure for hydropower generation which takes a significant amount of time. However if existing generating capacity is available the rating can be changed to a 1, providing power purchasing agreements can be established
Development costs	1	No new technology development costs (although project development costs will be high)
Other risks	3	There is high political instability in many of the regions where hydropower potential exists such as the DRC. Lack of existing infrastructure is a further risk
Composite risk score	9	
Overall risk rating	Medium risk	

**Table : Risk ratings: electricity – imports**

Source: *Genesis Analytics, 2010*

### Carbon Capture and Storage (CCS)

Geological<sup>36</sup> carbon capture and storage (CCS) actively captures emissions from point sources such as power stations and other large scale industrial processes, compresses it to a liquid and stores the CO<sub>2</sub> in geological reservoirs including oil and gas fields, deep saline aquifers and unmineable coal seams. The compression and pumping processes carry with them a cost and efficiency penalty, and power plants with CCS use more fuel than those without (i.e. have lower efficiencies) and do not capture all of the CO<sub>2</sub> emitted (to the order of 86%) (IPCC, 2005). This implies that there are still some emissions from a coal-fired plant with CCS (estimated at around 15%). An additional consideration in the use of CCS is the potential for leakage from injection sites. It is noted that CCS is better suited for point sources with concentrated CO<sub>2</sub> streams as in the case of Sasol which is discussed below. The streams from power stations require concentration before pumping underground.

CCS technology has not been proven at full scale, although there have been demonstration/pilot plants in Germany, Norway, the United States and Australia. The technology thus carries with it significant technology and developmental risks, and it will be at least 10 to 15 years before this mitigation technology becomes viable.

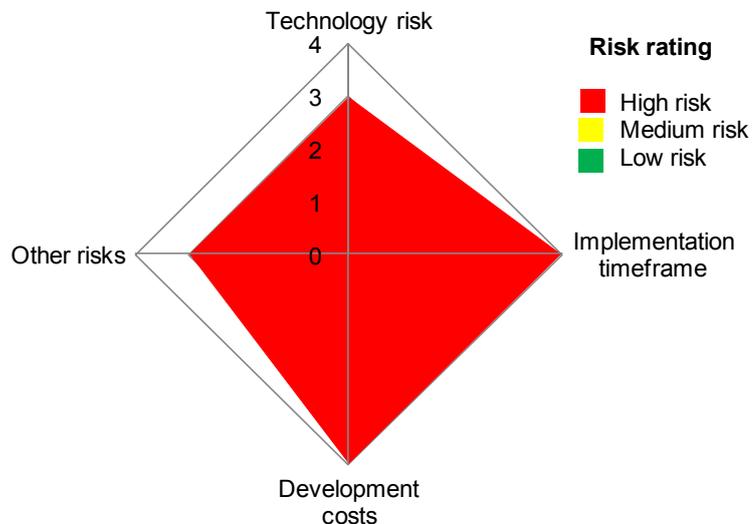
Initial indications are that South Africa has relatively limited storage potential (i.e. that there are only a limited number of geologically suitable sites). In addition, the technology is as yet unproven. The LTMS study considers two scenarios for CCS in the power sector (2 Mt and 20

<sup>36</sup> It is noted that mineral sequestration is also being explored, although this is in its infancy and is not considered here.

Mt) (Winkler, 2007). The higher estimate of CCS storage potential is assumed here (20 Mt). Note that some of this will be taken up by other sectors– see the sector case studies for Iron and Steel and Chemicals. Should significant technology advancements be made in the future, and more sites be identified which are suitable for CCS, the relative potential mitigation contribution of CCS may increase dramatically.

In terms of costs, information is still uncertain due to the novelty of the technology. The IEA (2008) identifies that the bulk of the costs of CCS projects are associated with CO<sub>2</sub> capture and that CCS costs to the order of \$40 and \$90 per tonne of CO<sub>2</sub> emissions avoided, depending on the fuel and the technology that the power plant uses. The figure quoted by McKinsey (2008) also falls within this range. This figure would be highly uncertain due to the early stage of technology development.

Factors that affect storage costs include infrastructure requirements (injection and monitoring wells and retrofitting facilities, especially in offshore environments), the volumes to be injected, injection depth and hydrocarbon economics.



**Figure : Radar risk diagram: electricity – CCS**  
Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	3	A limited number of pilot scale tests are being conducted overseas
Implementation timeframe	4	A long time period will be required for technology development and site identification before full scale implementation of CCS will be viable
Development costs	4	Upfront development costs for both technologies and site identification and preparation will be significant, more than likely requiring investment of public funds. Given the potentially high CO <sub>2</sub> mitigation potential of these technologies, the development costs per tonne CO <sub>2</sub> captured will be lower. However this category looks at upfront costs, thus justifying the rating of "4"
Other risks	3	South Africa does not have the appropriate geology for large scale implementation of CCS. Release of CO <sub>2</sub> from CCS is also a concern – discussed in further detail below
Composite risk score	14	
Overall risk rating	High risk	

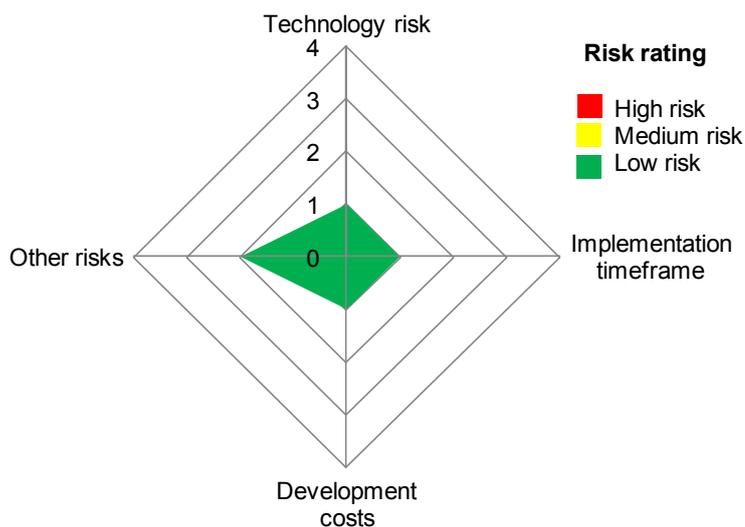
**Table : Risk ratings: electricity – CCS**

Source: Genesis Analytics, 2010

## Biomass

Biomass refers to organic matter such as wood, residues from agriculture, food production, animal feed production or forestry, and organic components in municipal and industrial wastes which can be used to provide heat, make liquid fuels and gas, and to generate electricity. A number of conversion pathways for using biomass for electricity generation are identified. These are outlined in Table below, along with a brief analysis of the risks to the various technologies.

It is noted that biomass does not appear on the IACC for this sector due to the low relative contribution which it can make to mitigation in the sector, estimated to be less than 1% of the total opportunities. This low contribution is due to limitations on the availability of biomass resources in the country. Furthermore, there are concerns about a drive towards increased use of biomass as a fuel source impacting negatively on food security in the country. Its inclusion here is for completeness, and no further consideration is given to this mitigation option.



**Figure : Radar risk diagram: electricity – Biomass**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Technologies for energy recovery from biomass are well established both internationally and in South Africa
Implementation timeframe	1	Timeframes for establishment of facilities are relatively short, particularly for smaller scale, distributed generation systems. Larger biomass power stations may take longer than 2 years to establish, but it is unlikely that these will be built in South Africa
Development costs	1	No new development is required for these technologies
Other risks	2	Biomass availability is relatively limited in South Africa with much of the existing resource already accounted for. Concerns around threats of growing biomass crops for fuel on food supply add a further risk to these technologies
Composite risk score	5	
Overall risk rating	Low risk	

**Table : Risk ratings: electricity - biomass**

Source: Genesis Analytics, 2010

<b>Conversion pathway for biomass to electricity</b>	<b>Description</b>	<b>Risks to the technology</b>
Biomass to electricity – co-firing	Biomass replaces a fraction of the coal feed to coal fired power stations. This is a lower cost and lower risk option than building new dedicated biomass power stations (see below).	Co-firing has been successfully implemented in power stations around the world up to a level of 5-10% on a heat basis. For example, Drax power station in England (4000 MW installed capacity) successfully co-fires biomass, with a target of 10%. Going to higher levels in traditional boilers presents some technological challenges including materials handling challenges, poor flame stability, low thermal efficiency, and slagging and fouling.
Biomass to anaerobic digestion to electricity	Biomass is allowed to biologically degrade in the absence of oxygen, resulting in the production of a methane rich gas known as biogas. This gas can be burned for heat and/or electricity recovery. It can also first be scrubbed of carbon dioxide to improve efficiency.	Very well established technology and hence low technology risk for short chain hydrocarbons such as sugars. Processing of ligno cellulosics (woody materials) requires pre-treatment to break down cell structures, which is still the subject of research. Current research is focussing on ways to speed up AD of cellulosics.
Biogas from sewerage wastes	As above, sewage streams are treated by anaerobic digestion and the biogas produced used for heat and/or electricity recovery.	Many sewage plants already run on AD, with the resulting methane either being flared or released directly into the atmosphere. It is a small step to fitting energy recovery systems onto these plants.
Biomass to gasification to electricity	Biomass is burned in a reduced oxygen environment which causes it to be converted into a syngas (a mixture of hydrogen, carbon monoxide and some carbon dioxide). Syngas is combustible in gas turbine to generate electricity. It can also be used in hydrogen fuel cells and further processed to ultimately produce liquid fuels.	Low risk technology - has been used for over one hundred years
Biomass to electricity - dedicated power stations	Power stations built to exclusively burn biomass to generate electricity, often producing steam at the same time (i.e. co-generation). Can be open cycle, or combined/closed cycle, with the latter being more efficient. Such power stations can either be on or off grid - for example the sugar industry has been subjected to extensive analysis on their potential for using bagasse for onsite generation.	Well established with low technology risks - the technologies are almost identical to those used in coal fired power stations. The primary risks relate to security of supply including seasonality considerations, issues around land availability and food vs. fuel etc. Preferred feed stocks are thus agricultural and forestry wastes etc. In the absence of sufficient volumes of waste to justify a dedicated plant, co-firing could be considered (see below).
Biomass to pyrolysis to electricity	Biomass is combusted at high temperatures and decomposed in the absence of oxygen. The product is pyrolysis oil, char or syngas which can then be burned to generate electricity.	Challenges with the technology particularly surrounding managing the moisture content of the biomass feed stream and the product quality. Hence requires some technology development before this is likely to be viable.

**Table : Conversion pathways for biomass to electricity**

*Source: Genesis Analytics, 2010*

### **7.3.7. OPPORTUNITIES ARISING FROM CLIMATE CHANGE MITIGATION**

A limited number of co-benefits arising from greenhouse gas mitigation have been identified for this sector. Although much of the equipment used in the sector is imported, there is some opportunity for local job creation, particularly during construction phases. Many of these jobs do, however, go to skilled overseas contractors installing the technologies, and the impact of local construction jobs is relatively short lived. The entry of Independent Power Producers (IPPs) into the sector can result in some opportunities for establishment of new local businesses. The recently introduced renewable energy feed in tariffs will potentially provide a stimulus in this regard.

South Africa has invested a significant amount of money in the development of Pebble Bed Modular Reactors (PBMRs). If PBMR is ultimately proven as viable, there is potential for becoming a world leader in this technology. There is, however, a lot of controversy surrounding the technology and the total investment to date.

A renewable technology option in which South Africa has potential to play a leading role is in concentrated thermal technologies. Although these technologies have been technically proven, there has not been significant commercial scale uptake. South Africa has the potential to develop a competitive advantage in the design and manufacture of the technology, particularly if it is able to commercially prove a full scale operation (Marquard et al 2008).

## **7.4. CHEMICALS CASE STUDY**

### **7.4.1. SECTOR DEFINITION AND DATA ISSUES**

According to the Department of Trade and Industry (dti) the South African chemical sector should be categorised into 11 broad categories – commodity organics, primary polymers and rubbers, commodity inorganics, fine chemicals, pure functional & specialty chemicals, bulk intermediate chemicals, pharmaceuticals, consumer formulated chemicals, plastic products, liquid fuels and nuclear fuel processing. (dti, 2005). This paper is concerned with the first nine of these categories, with the Liquid Fuels sector being covered in a separate case study. The nuclear fuel production sub-sector does not fall under the scope of this study.

Our understanding of how the chemical industry is structured is informed by the South African Standard Industrial Classification (SIC) Codes and the sub-sectoral categorisation proposed by the Customised Sector Programme (CSP) of the dti. The Standard Industrial Codes that are represented in this study are: the manufacture of basic chemicals (334); other chemicals (335); man-made fibres (336); rubber products (337); and plastic products (338).

Currently South Africa does not have a reliable GHG emissions inventory by sub-sector, and only limited sectoral data is available from the recently released National GHG Inventory for 2000 (DEAT, 2009). The limited chemical sector GHG emissions data presented in this report is informed by the works of Blignaut (2005) and the Long-term Mitigation Scenarios (LTMS), as well as the GHG inventory (DEAT, 2009). There is a general lack of regulatory stimulus to encourage the industry to invest in generating process level data that can be used to analyse and reduce emissions in the process where they occur. Available data is highly aggregated. While aggregated data may be useful for some purposes, it is not sufficiently user friendly to generate reliable technology and process specific abatement cost curves. Although the information contained in the sources mentioned above is useful, it is either modelled or

aggregated. Generation of an accurate abatement cost curve requires empirical data for specific processes and technologies which is not available for South Africa.

#### **7.4.2. SECTOR CONTEXT**

The chemical industry is a highly diversified and complex industry with a wide range of sub-sectors (see definition above). The sector is a major contributor to the South African economy, making up 25% of manufacturing GDP (CSIR, undated) as well as having significant linkages with the rest of the economy. 60% of basic chemical production is used as feedstock in the rest of the chemical sector. In December 2008 the sector employed 123 000 people (Statistics South Africa, 2009).

South Africa is placed among the 25 leading chemical-producing nations in the world. There are a number of multi-national companies that are major players in the manufacturing and marketing of high value and low volume niche chemicals, for example South Africa-based Sasol, AECI, Afrox, African Products and Omnia; Germany's Hoechst, Bayer and BASF; US-based Shell Chemicals and Rohm and Haas; and UK-based Engen Petroleum and Ineos Silicas. (Business Monitor, 2008).

In 2006, the industry contributed R196.5 billion to GDP including the contribution from the liquid fuels sector. (Ozone Business Consultants (O3BC), 2008).

According to various sources (Business Monitor, 2008; O3BC, 2008; DTI, 2005), the chemicals sector is South Africa's largest in terms of value-added output, as well as the fourth-largest employer in the manufacturing segment. The South African chemical industry is partially dependent on oil and natural gas as the key product feedstocks. The industry is dominated by basic chemicals, with major production of olefins, organic solvents and industrial mineral derivatives. The industry also produces various products including plastics, pulp and paper chemicals, rubber, agricultural chemicals, fertilisers, paints and explosives.

##### **Market structure**

Historically, industrial policy favoured upstream chemical producers, helping them to become internationally competitive, and this resulted in a sector dominated by capital-intensive upstream production of basic chemicals. As a result, most of the chemicals produced locally are low value high volume products and a handful of producers are responsible for between 60% and 70% of local production with low levels of competition in the industry. This is in marked contrast to the international trend where high value, low volume fine chemicals dominate the market (95%). In fact, South Africa produces only 300 of the 80,000 types of chemicals produced commercially in the world and beneficiaries relatively little of the basic chemicals produced in the country (dti, 2005).

The sub-sectors that form part of the downstream chemical sector include pure functional and formulated specialty chemicals, bulk formulated chemicals, pharmaceuticals, consumer formulated chemicals, as well as plastic and rubber products. The majority of operations in the downstream chemical sector can be regarded as smaller or medium sized. O3BC (2008) suggests that downstream operations are typically labour intensive and generally consist of formulation production processes as well plastic and rubber conversion processes. Downstream producers are less competitive as a result of reliance on outdated technology and production processes and little emphasis on international best practice (dti, 2005).

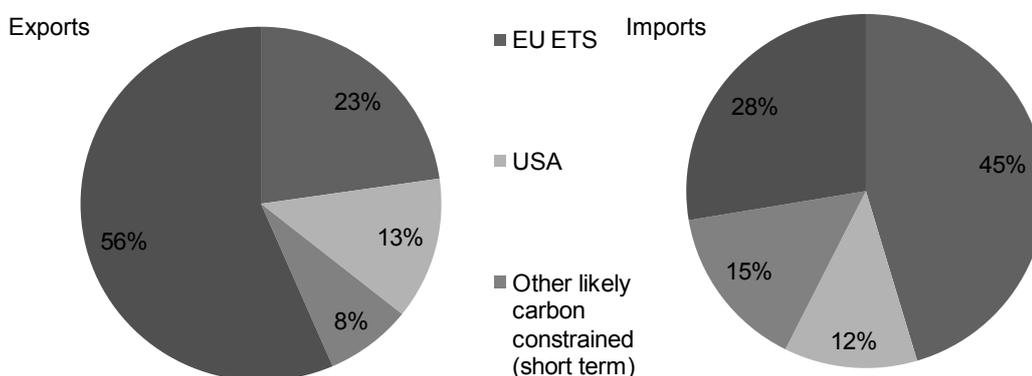
Employment in the industry has been steadily decreasing over time due to restructuring in the industry in response to global trends such as outsourcing, the clustering of production in low-cost global production centres and the offshore listing of technology-intensive South African firms. These developments have mainly been associated with large upstream producers, but have also had a knock-on impact on labour-intensive downstream activities. They have also led to a reduction in innovation and the loss of strategic skills in the industry as a whole which contributed to its worsening international position (dti, 2005).

### International trade

In 2007, exports accounted for only 22.4% of total sales in the sector (dti, 2009a, Statistics South Africa, 2009 and Genesis calculations) and the value of imports was almost twice the value of exports. The trade deficit in chemicals has been progressively worsening over the past ten years.

Going forward, access to international markets is likely to be complicated by carbon concerns. As illustrated in Figure , around 44% of exports are destined for carbon constrained countries and a high proportion of imports (72%) originate there. The ten biggest chemicals exporters in 2005 were Germany, the USA, Belgium, France, the Netherlands, UK, Japan, Ireland, Switzerland, Italy (dti, 2009a). Thirteen of the top twenty world exporters are countries which either already have or are likely soon to have carbon policies in place (dti, 2009a). This suggests that carbon leakage and policies to address it are likely to be a concern in the industry, and carbon intensity is therefore a potentially important competitiveness issue for South African firms. Production processes will need to meet EU requirements and transport distances to major markets will be a particular problem for South Africa in terms of the carbon footprint of exports.

Another concern is that cheap electricity has been a key driver of competitiveness in the industry (CSIR, undated), which suggests that attempts to increase the price of electricity to cost-reflective levels over the next few years may have a major impact on the sector.



**Figure : Concentration of trade in countries with carbon policies (2006): Chemicals**

Source: TIPS SADC trade database 2009

On a more positive note, while basic chemicals are predominantly exported to the West and India and China, an increasing volume of other chemicals are being exported to Africa. South African chemical exports totalled R40bn in 2007, and imports R80bn - leading to a R40bn trade

deficit in chemicals. With Africa, however, SA had trade surplus of R137m in 2006 (UN-Comtrade database). In addition, the sector is quite aware in terms of environmental issues and the Chemical and Allied Industries Association in South Africa drives participation in Responsible Care, a global environment, health and safety initiative for the chemical industry. This initiative encourages participants to address the implementation of international best-practice.

### 7.4.3. GHG EMISSIONS

There are a number of sources of information on emissions from the chemical sector. Blignaut et al (2005) estimate from the Energy Balance for South Africa that in 1998 the sector emitted more than 13.26 Mt CO<sub>2</sub>-e, making up 0.5% of the total emissions generated in South Africa. Blignaut et al's estimations, however, only take into account combustion emissions and as such it is not surprising that they are far below the official 1990 and 1994 National GHG Inventory figures of 39.36 Mt and 38.56 Mt CO<sub>2</sub>-e respectively. Using the 1990 figure as a starting point the LTMS estimates that in 2007 the chemical industry emitted 25.63Mt CO<sub>2</sub>-e from the production of just three main chemicals – ammonia, nitric acid and carbide.

The recently gazetted National GHG Inventory provides details of chemical sector emissions for 2000. These are shown in Table .

	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFCs	PFCs	SF <sub>6</sub>	Total
	Mt CO <sub>2</sub> equivalent						
<b>Chemical industry</b>	23.75	4.284	2.39	No	No	No	30.42

Table : Greenhouse gas emissions for the South African chemical sector  
Source: National Greenhouse Gas Inventory for 2000 (DEAT, 2009)

### 7.4.4. CURRENT SECTOR RESPONSE TO CLIMATE CHANGE

Broadly speaking, environmental performance in the South African chemical sector is less regulated compared to similar European and North American industries. As a result the impetus to change modus operandi tends to be slow and mainly driven by international regulations and protocols. For instance REACH (Registration, Evaluation, Authorisation and restriction of Chemicals) is a protocol of the European Union. Within the existing regulatory frameworks the reduction of greenhouse gas emissions and their impacts on the environment are mainly driven by voluntary mechanisms such as Responsible Care, rather than regulatory disincentives to pollute.

In the marketplace we have identified a number of projects which attempt to reduce GHG emissions while at the same time taking advantage of the incentives and financial benefits provided by the Clean Development Mechanism (CDM). Omnia's agriculture division's EnviNox® has developed a plant for nitrogen oxide and nitrous oxide destruction designed to reduce greenhouse gas emissions in line with the Clean Development Mechanism provision of the Kyoto Protocol. The plant was commissioned in February 2008. To develop the plant, Omnia has entered into a €15-million agreement with the International Finance Corporation (IFC), under which the IFC will buy up to one-million Certified Emission Reductions (CERs), from Omnia Fertilisers, over the next five years. The CERs will be sold by the IFC to international buyers in developed countries. (Omnia, 2008). Sasol Nitro also has a

greenhouse-gas abatement project which is reducing emissions from the nitric acid plants at Sasolburg and Secunda by the equivalent of more than 500 000 t/y of carbon dioxide. Sasol Secunda is also interested in flare gas recovery and usage, the capturing of heat and the digestion of waste streams.

## 7.4.5. SECTOR MITIGATION OPPORTUNITIES

### 7.4.5.1. IACC

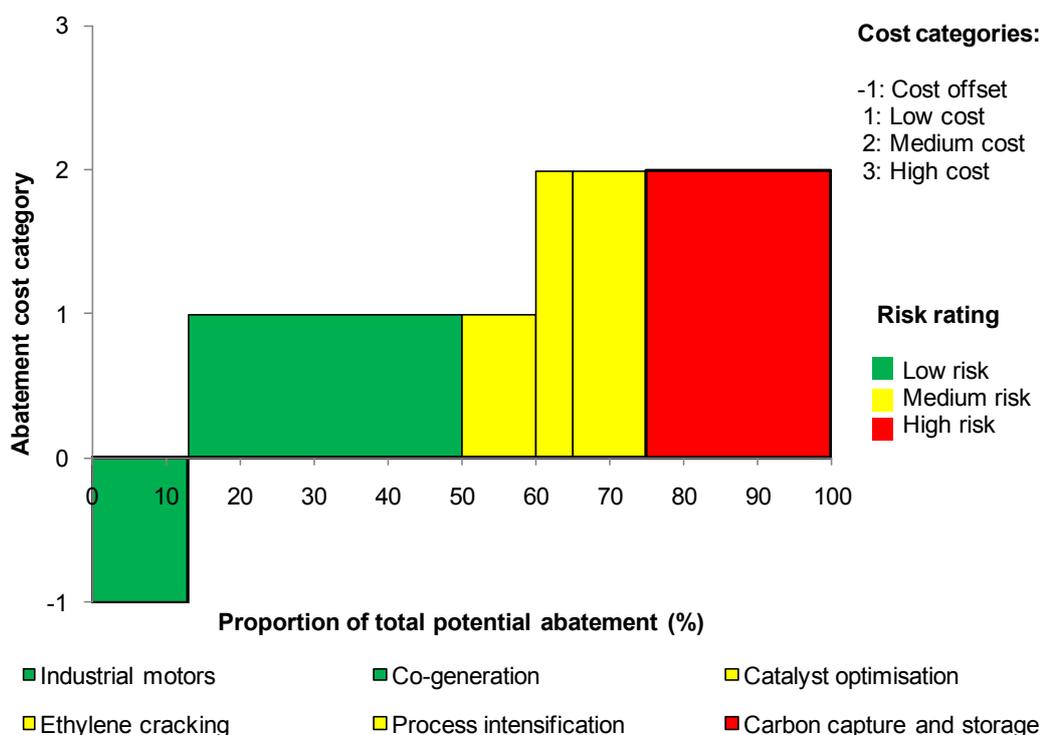


Figure : IACC: Chemicals<sup>37</sup>

Source: Genesis Analytics, 2010

The indicative abatement cost curve for the South African chemical sector suggests that approximately 25% of abatement opportunities will result from carbon capture and storage. However, the benefits of this technology will not be realised in the short to medium term until the unknown variables and associated high risk is addressed. This technology has been assigned a cost rating of “2” as, although the development costs on CCS are expected to be extremely high, predictions are that installation and running costs will not be prohibitive. In the meantime, South Africa can take the initial steps to realise the other 75% of opportunities that are associated with the other technologies identified. For example 13% of the abatement that could be achieved - from industrial motors - will be able to pay for itself from energy savings. As a result this technology is assigned an abatement cost of “-1” in the IACC. Cogeneration is

<sup>37</sup> For details of how to read the IACC, see footnote in section .

assigned a “low cost” rating and is estimated to represent 38% of the identified abatement potential for the sector. Catalyst optimisation is also a “low cost” option. The remaining 15% of abatement potential will require a fair amount of investment, and that is reflected by the assignment of an abatement cost of “2” in the IACC. Medium cost opportunities that are within reach are ethylene cracking and process intensification.

#### **7.4.5.2. DESCRIPTION OF ABATEMENT OPTIONS**

##### **Energy Efficiency**

Energy efficiency abatement options are many and varied and it is not possible to discuss every potential option. After careful consideration of most options, we decided to avoid the common tendency to lump all energy efficiency options together. Instead we have included, in our suite of options, only those options with higher abatement potential and relatively lower costs of implementation. We discuss some of these individual options in the sections below.

On a broader scope of considerations, the rate of technological development in this sector tends to take long-term view. However, the recent shortage of electricity has encouraged the drive towards achieving reduction in electricity consumption, energy intensive production, energy efficiency and the removal of disincentives for companies to invest in energy efficiency technologies and process improvements.

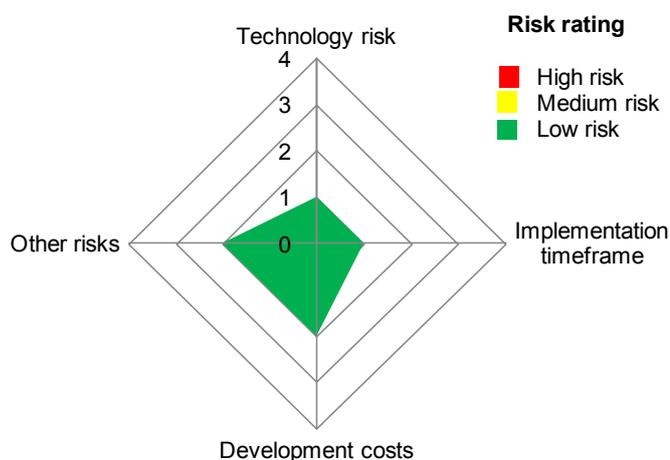
Renewed focus on energy efficiency and growing interest to produce captive power (to produce electricity for internal use) is expediting the emergence of new technologies. Although the change in infrastructure expenditure required to accommodate energy efficiency may be major, there is a prime benefit for companies to invest in energy efficiency. That is, the control of operating and production costs (e.g. fuel and raw material costs) in a competitive, worldwide market.

##### **Industrial motors**

Installation of new motors is a more cost effective exercise than rewinding of industrial motors. However, the rewinding of industrial motors is a common practice in the chemical sector because it is less disruptive in the short term. However, installation of new and more energy efficient motors is less disruptive and more cost effective in the longer term. The risk that the efficient motors may require additional technical capacity to install and maintain is likely to be minimal. Improving the motor electrical efficiency by carefully assessing the practice of rewinding of motors has an added benefit of reducing energy consumption and process emissions. Although larger motors can be more efficient, they can consume more energy if they are not operated at their full capacity. Where the need for large motors is not necessary smaller replacement motors should be considered. Replacement of industrial motors can be undertaken as part of routine maintenance and therefore requires no additional capital investment. The initial costs of energy efficient or controlled drive motors retrofits are higher than business as usual motors. Comparative investment analysis will be required to make the case of the return against investment. The price of a motor represents less than 3% of the electricity costs of running a motor-driven system over its lifetime. So it pays to invest in a higher efficiency model.

Installation of new industrial motors is a straightforward exercise. Although some investment will be necessary, it will be small compared to the long term energy efficiency savings that would be achieved. We estimate that this technology could have a 13% abatement potential.

Since future energy savings would be able to pay for the installation of the motors, industrial motors are assigned a “cost offset” score of “-1”.



**Figure : Radar risk diagram: chemicals - industrial motors**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Risk of rewinding motors is low. Rewinding motors is a simple operation.
Implementation timeframe	1	The technology is immediately available for installation.
Development costs	2	The technology does not require development costs; however the control systems into which the motors would fit would require some further development and optimisations.
Other risks	2	The perceived risk in the change is low and unlikely to prevent adoption of the technology. The risk is slightly higher for retrofit than new build.
Composite risk score	6	
Overall risk rating	Low risk	

**Table : Risk ratings: chemicals - industrial motors**

Source: Genesis Analytics, 2010

## Co-generation

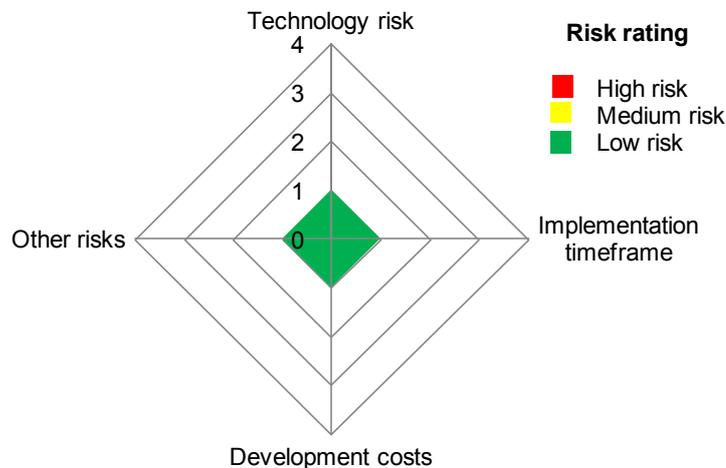
Co-generation, or combined heat and power (CHP) refers to the sequential production of electricity and thermal energy in the form of heat or steam, or useful mechanical work, such as shaft power, from the same fuel source. Further information on co-generation is provided in the Liquid Fuels case study, see section .

The South African co-generation market is currently in its early development phase. However, it is projected to experience significant growth – approximately 30 to 50% per annum – over the next five to ten years. This expansion will be propelled by rising coal prices and by the fact that

current energy demand is close to exceeding supply, creating a pressing need for additional sources of power generation. Co-generation has the ability to achieve up to 90% efficiency whilst current coal-fired power generation in South Africa has less than 40% efficiency. This could offset the start-up costs in the long run as well as maintenance costs. With higher efficiencies, co-generation plants will be producing a higher profit margin than regular generation plants (Frost & Sullivan, 2007).

Globally the technology has a small additional abatement potential for the chemical industry because CHPs tend to form part of chemical plant design (McKinsey, 2009). Likewise the cost of installing new CHP is also small.

The South African chemical sector has a very limited installation and usage of CHP units. Therefore, to achieve the estimated additional abatement potential of 37% would require upfront investment. The cost to the power-using facility are moderate and may require off-balance sheet investments, depending upon size. For this reason we assigned CHP an abatement cost score of "1" on the IACC.



**Figure : Radar risk diagram: chemicals - co-generation**

*Source: Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	No risks as technology is currently proven in South Africa although not at a large scale.
Implementation timeframe	1	There is a short lead-time of 1 year mostly taken up comparing technologies.
Development costs	1	The development costs are minimal as the technology is widely available and customisable internationally.
Other risks	1	None identified, Even if there were any risks associated with cogeneration they would not trigger non-adoption of the technology.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: chemicals - co-generation**

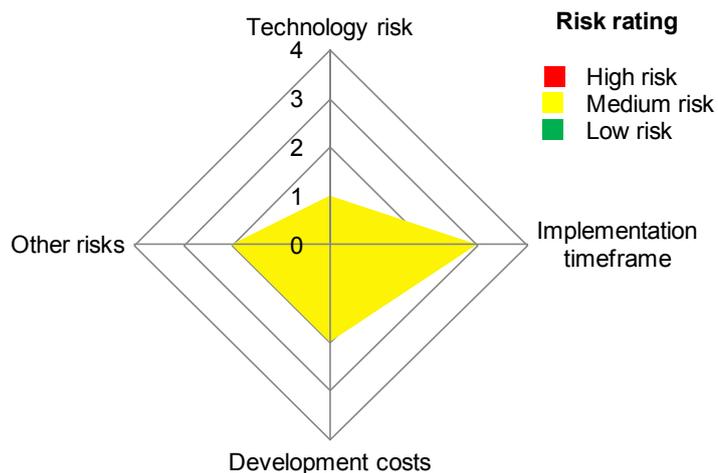
Source: *Genesis Analytics, 2010*

### Catalyst optimisation

Catalyst optimisation refers to the “optimum use of catalysts to reduce direct emissions by improving the chemical structure, enhancing chain reactions and reducing temperatures” (McKinsey, 2009:18). Catalytic reforming is one of the most important processes in refineries where gasoline with high octane number and aromatics such as benzene, toluene and xylene are produced. For instance, the catalytic reforming of naphtha is the best method for producing high-octane gasoline and aromatics in petroleum refineries and petrochemical industries respectively. The naphtha reformer is used to upgrade a significant portion of the crude oil from low octane heavy naphtha that is unsuitable for motor gasoline into a high-octane gasoline-blending component. Although catalytic reforming can be used to reduce emissions by improving process efficiency, it often increases the prices of feedstock used by chemical companies in the supply value chain (Reza et al, 2008). Catalytic reforming and by extension catalyst optimisation technology is proven in South Africa and it does not require substantial investment. Enough expertise has been accumulated to deal with any potential risk.

McKinsey (2009) estimates that globally, catalyst optimisation would have abatement potential of 24 MtCO<sub>2</sub>-e by 2030. The associated cost of achieving the abatement potential is estimated to be a negative cost of €18 per tonne of CO<sub>2</sub>-e. Our own estimates for the South African chemical sector suggest that technology could have a 10% abatement potential of the overall mitigation potential from this industry.

But, a moderate investment would be necessary to achieve the benefits. Based on the cost considerations catalyst optimisation is assigned an abatement cost of “1” on the IACC.



**Figure : Radar risk diagram: chemicals - catalyst optimisation**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Catalyst optimization is a proven technology in South Africa
Implementation timeframe	3	The timeframe for further optimization may be 5 to 10 years, for a new class of optimization. Optimisation is ongoing in the light of input and output pricing and costs.
Development costs	2	The development costs are likely to be absorbed by firms.
Other risks	2	There is a medium chance of risks triggering non-adoption in the short to medium term. The risks are mainly around the successful collaboration amongst industry and academia and the players likely to develop and take optimization solutions to the market. There are significant costs involved in this.
Composite risk score	8	
Overall risk rating	Medium risk	

**Table : Risk ratings: chemicals - catalyst optimisation**

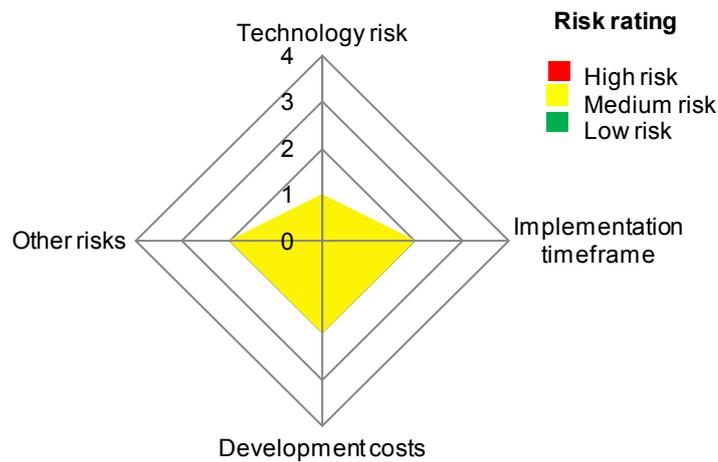
Source: Genesis Analytics, 2010

### Ethylene cracking improvements

Ethylene is produced in the petrochemical industry by steam cracking. In this process, gaseous or light liquid hydrocarbons are heated to 750–950 °C, inducing numerous free radical reactions followed by immediate quench to freeze the reactions. This process converts longer hydrocarbons into shorter ones and introduces unsaturation. Ethylene is separated from the resulting complex mixture by repeated compression and distillation. This process is energy intensive.

Potential techniques for improving the efficiency of ethylene cracking include furnace upgrades, better cracking tubes materials, improved separation and compression techniques that will lower direct energy used in the cracking process (McKinsey, 2009). However, typically large-scale projects have a lead-time of up to 5 years. Substantial investment is required. Under the current economic conditions investments may well take a while to materialise. Thus there is a risk factor for the estimated 5% abatement potential that can ultimately be derived from the technology.

Ethylene cracking presents an opportunity for thermal efficiency improvements in the South African chemical sector, something which will reduce GHG emissions. However, this may require substantial investment in technology development if replacement of existing systems is required. Taking into consideration the substantial financial investment that will be needed to achieve a small GHG emissions reduction; we have assigned ethylene cracking an abatement cost of “2” in our IACC.



**Figure : Radar risk diagram: chemicals - ethylene cracking improvements**

*Source: Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	Ethylene cracking efficiency improvements have been commercially proven in South Africa.
Implementation timeframe	2	Typically for large-scale projects the lead time is likely to be less than 5 years.
Development costs	2	Ethylene cracking is a common industrial activity throughout the industrialised world and in larger developing country economies. The technology is constantly maturing and efficiency improvements are the subject of ongoing industrial research and plant optimisation.
Other risks	2	South Africa is among the lowest-cost producers of ethylene in the world, thanks to abundant access to low-grade coal and leading-edge process technology..
Composite risk score	7	
Overall risk rating	Medium risk	

**Table : Risk ratings: chemicals - ethylene cracking improvements**

*Source: Genesis Analytics, 2010*

### Process intensification

Process Intensification (PI) is an engineering expression that refers to making changes that render a manufacturing or processing design substantially improved in terms of energy efficiency, cost-effectiveness or enhancement of other qualities (Andrzej et al, 2003). For Mohunta (2009), the aim of process intensification is to optimize the capital, energy, environmental and safety benefits of a chemical process by radical reduction in the physical size of the plant.

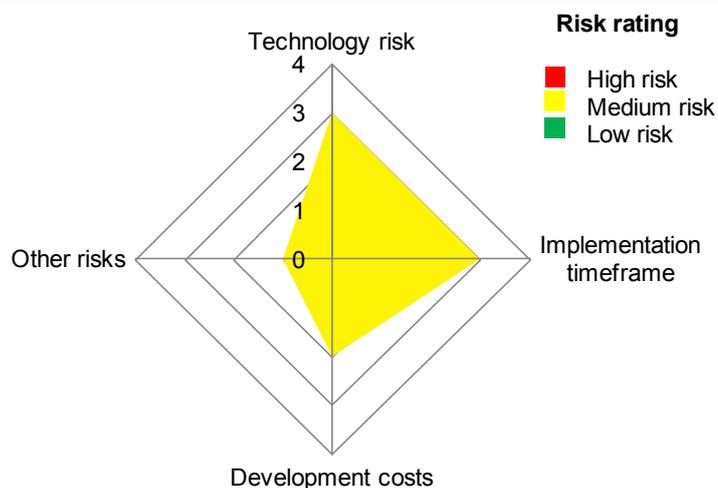
Some of the established PI benefits that have been identified by a group of independent technology companies in the United Kingdom include substantial reductions in capital cost, impurity levels resulting in significantly more valuable product, energy usage and hence substantial reduction in operating cost and reactor volume for a potentially hazardous process, leading to inherently safe operation (BHR Group, 2009).

It is a mature technology with well-understood costs of implementing the technology in a broad range of chemical processes. Enough expertise has been accumulated to encourage rapid standardization of PI. Promoting smaller process plants has a number of co-benefits, including cost reduction and emissions reduction. According to a 2006 Arthur D. Little report for SenterNovem, 30% reduction in CapEX and OpEX can be achieved as a result of implementing PI.

A number of issues should be borne in mind in terms of the adoption of this technology in South Africa. Each process type requires standardisation. Smaller should be favoured over bigger plants because smaller and more disparate plants would improve proximity to markets and they could customize product streams with greater efficiencies than larger plants. Other

issues would include cost and non-carbon gaseous emissions reductions. The development costs should be able to be absorbed by individual firms.

McKinsey (2009) estimates that globally the cost of achieving an additional abatement of 180 MtCO<sub>2</sub>-e by 2030 from the expanded use of this technology would be €20 per tonne CO<sub>2</sub>-e. Making South African chemical plants smaller could assist the industry in achieving 10% of the overall identified mitigation potential from this industry but the cost of doing that would be high. Therefore, the technology was assigned a cost rating of “2” in the IACC.



**Figure : Radar risk diagram: chemicals - process intensification**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	3	Process intensification heading towards miniaturization is at a pilot phase and has some high technology risks associated with its implementation.
Implementation timeframe	3	The larger scale implementation is still up to 10 years away.
Development costs	2	The development costs will be in optimising the process units in a chemical industry system.
Other risks	1	The risk is rightsizing the processes for the size of markets and establishment of plants sufficiently close to these markets to make them feasible. Risks are unlikely to trigger non-adoption into the future as the requirement for decentralized efficiency options are pursued.
Composite risk score	9	
Overall risk rating	Medium risk	

**Table : Risk ratings: chemicals - process intensification**

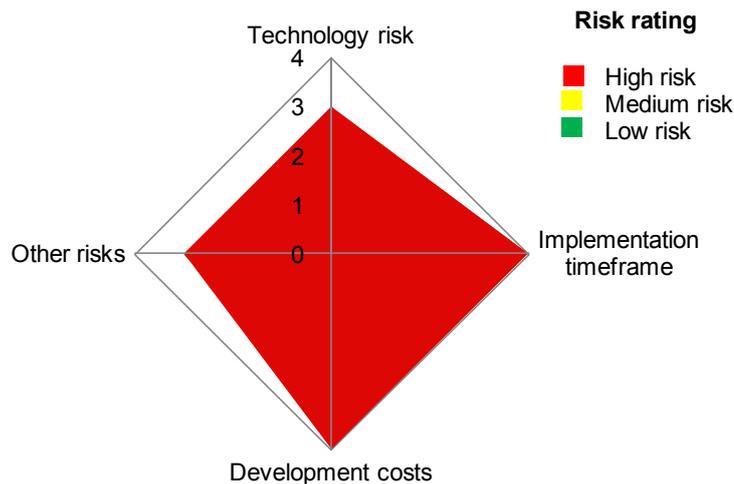
Source: Genesis Analytics, 2010

## Carbon Capture and Storage (CCS)

Carbon sequestration is “the process by which carbon can be either removed from the atmosphere (as CO<sub>2</sub>) and stored, or separated from fuels or flue gases and stored. Carbon can thus be technologically (usually called capture and storage) or biologically (biological carbon sequestration) sequestered” (Capehart, 2007: 125). An extended definition of CCS can also be found on the Liquid Fuels sector case study (see section ).

According to the LTMS production of ammonia is one of the major contributors of GHG emissions in the chemical sector. Adoption of CCS by the South African chemical sector would assist the sector to better manage its GHG emissions from the production of ammonia. Additionally, CCS could also help the sector to deal with combustion related emissions. This is where the second greatest abatement potential lies for the sector.

CCS is relatively new technology with many unknown variables and initial indications are that South Africa is limited in terms of number of sites for implementation. Further research and development should still be undertaken to address the outstanding issues. Although the IACC suggests that this technology contributes 25% of the overall abatement opportunities for this sector, it will be some time before this abatement potential is realised. The IEA (2008) identifies that the bulk of the costs of CCS projects are associated with CO<sub>2</sub> capture and that CCS costs are to the order of \$40 to \$90 per tonne of CO<sub>2</sub> emissions avoided, depending on the fuel and the technology that the plant uses. Thus, although development costs to get the technologies to full scale operation are exceptionally high, this option is assigned an abatement cost rating of “2” – reflecting the lower installation and operational costs once the technology is proven.



**Figure : Radar risk diagram: chemicals – CCS**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	3	Potential risk could include leakages and explosion. Fossil fuel generation with CCS remains unproven at commercial scale. Therefore, large-scale deployment will require scaling up of the proposed pilot and demonstration plants.
Implementation timeframe	4	The first planned test injection of carbon dioxide in South Africa is planned for 2016 and a demonstration plant for 2020. Full scale implementation of CCS will be beyond 2035
Development costs	4	The development cost will most likely be high but South Africa will certainly benefit from the technology development by other countries. That will lower the cost of implementing the technology
Other risks	3	While South Africa has a better chance of undertaking separation of CO <sub>2</sub> from other gases, there is a possibility that geological sequestration may be hampered by the suitability of the geology for permanent storage. Of course there are other routes to sequestering or storing carbon that may be more appropriate in South Africa.
Composite risk score	14	
Overall risk rating	High risk	

**Table : Risk ratings: chemicals - CCS**

*Source Genesis Analytics 2009*

#### **7.4.6. OPPORTUNITIES ARISING FROM CLIMATE CHANGE MITIGATION**

In the long term CCS will most likely be one of the technologies that the sector will pursue to reduce its GHG emission reductions. However, CCS requires substantial capital investment in research and development to eliminate potential risks, and furthermore the number of potential sites for geosequestration is limited. In the interim, other potentially viable and cost effective technologies or combination of technologies must be considered. In this paper we have presented a number of technologies that we believe would be suitable to meet South Africa's short to medium objectives to deal with GHG emissions.

South Africa is a global leader in the implementation of all the technologies that are discussed in this section except CCS. Enough knowledge and expertise has been accumulated from early learning and implementation of these technologies. From the point of view of those companies that have used these technologies, the capital outlays and operating expenditures are relatively well-known, even though these costs are not always publicly available.

## **7.5. LIQUID FUELS CASE STUDY**

### **7.5.1. SECTOR DEFINITION AND DATA ISSUES**

This sector is defined by SIC code 332: Petroleum refineries/synthesisers. In terms of this definition, liquid fuels include products such as diesel, petrol, jet fuel, paraffin, and liquefied petroleum gas.

For the purpose of this study, various sources of available data in South Africa were reviewed. In particular, various documents that formed part of the Long Term Mitigation Scenarios (LTMS) were carefully considered. Additionally, we also reviewed a number of studies that were completed by McKinsey to develop cost curves for various other countries. The work of the IPCC relating to the development mitigation cost curves was also considered. (Hughes et al. (2007), McKinsey, (2007, 2008 and 2009)).

Although it was possible to access relevant sources of global and some national sectoral data, the data was not very useful for the purpose of constructing cost curves for this sector. The sectoral data was high level in scope and also highly aggregated. It was not specific to any particular technology. It was not possible to find any data that is aligned either with South African Standard Industrial Classification Codes (SIC codes) classifications or the sub-sectoral categorisation proposed by the Customised Sector Programme (CSP) of the DTI.

The data used to produce the LTMS cost curves is largely based on a modelling approach developed for the South African Country Study by Clark and Spalding-Fecher (1999). Given the fact that the data was not empirical, its relevance and usefulness for current purposes was limited. The McKinsey and IPCC studies and the LTMS both assume targets and timeframes. Sectoral targets and timeframes influence the costs of the abatement options open to a sector. In South Africa, the National Government has not yet announced sectoral targets and timeframes. Without this information, other data issues notwithstanding, it is practically impossible to compile correct and detailed cost curves and sector action plans.

Based on knowledge of the industry, the authors are aware that there are individual companies that are taking steps to reduce their GHG emissions through the development of innovative projects and technologies. Although this information would be useful to construct cost curves, it is not available for public consumption and it is protected by confidentiality agreements. Reliable data on emissions, mitigation opportunities and costs is very limited and it is a constraint.

### **7.5.2. SECTOR CONTEXT**

According to the Oil and Gas Journal, as quoted in the African Oil and Gas Country Briefs (African Oil and Gas Journal, 2009) South Africa had proven oil reserves of 15 million barrels as of January 2008. Further information contained in the document suggests that in 2007 South Africa produced 199 000 barrels per day (bbl/d) of oil, of which about 16 000 bbl/d was crude oil and 160 000 bbl/d was synthetic liquids processed from coal and natural gas. The remaining 66% of South Africa's total crude oil consumption is imported. South Africa has the second largest refining capacity in Africa (485 000 bbl/d). Major refineries include Sapref (180 000 bbl/d) and Enref (125 000 bbl/d) in Durban, Chevref (100,000 bbl/d) in Cape Town, and Natref (92 000 bbl/d) at Sasolburg (SAPIA, 2008). In addition, a new refinery is proposed in the Coega Industrial Development Zone which is anticipated to have a capacity of 400 000 bbl/d.

According to the BP Statistical Review of World Energy (BP, 2009), South Africa consumed an average of 558 000 barrels a day of oil in 2008, which constitutes 0.7% of the world total and an increase of 1.7%, compared to 2007. The survey further states that due to South Africa's abundant supplies of cheap coal, liquid fuels provide 21% of the energy requirements of the country and oil produced in coal synfuels plants provides a significant proportion of South Africa's liquid fuels (BP, 2009). South Africa has a highly developed synthetic fuels industry, in which Sasol and PetroSA are the major players. PetroSA manages the country's commercial assets in the petroleum industry, including the world's largest commercial natural-gas-to-liquids plant at Mossel Bay in the Western Cape, with a capacity of 45 000 bbl/d.

Sasol produces synthetic fuels from low-grade coal and a small amount from natural gas at its Secunda refinery. It operates the world's only Coal-to-Liquids (CTL) synthetic fuels facility, and produces 36% of liquid fuels consumed in South Africa. Sasol produces automotive fuels for consumers, premium fuels and lubricants for industry, as well as jet fuel, fuel alcohol and illuminating kerosene. It also converts natural gas to more environmentally friendly fuels and chemicals, with a total capacity of 150 000 bbl/d. (Energy Information Administration, 2009)

According to the South African Petroleum Industry Association (SAPIA, 2007), the South African petroleum and liquid fuels industry consists of the following six major petroleum companies, which together represent South Africa's petroleum refining and marketing capabilities:

- BP South Africa Energy (Pty) Ltd;
- Chevron Oil (SA) (Pty) Ltd;
- Engen Petroleum Ltd;
- PetroSA (Pty) Ltd;
- Sasol Oil (Pty) Ltd; and
- Total South Africa (Pty) Ltd
- Shell (Pty) Ltd

The rate of technological development in this sector tends to take long-term view. However, the renewed focus on efficiency, pinch technology, the need to reduce flaring and interest in producing captive power (to produce electricity for internal use) is expediting the emergence of new technologies and South Africa is a world leader in coal-based synthesis and gas-to-liquid technologies. South Africa is a global leader on the cracking of coal to produce gas using platinum catalysts. Thus, South Africa has an international upstream edge on gas to liquids technology (Mbendi, 2009).

The recent shortage of electricity has encouraged the industry's drive towards achieving a reduction in electricity consumption and the energy-intensity of production. More attention is also being paid towards encouraging efficiency. The industry is considering increasing energy efficiency as the most promising route to serve this objective of reducing energy consumption, particularly since this contributes simultaneously to the reduction of greenhouse gas emissions and to the improvement of the industry's international competitiveness. This approach is fully in line with the Responsible Care programme, whereby the industry takes responsibility for continuous performance improvement, amongst others in the field of energy efficiency. Although the change in infrastructure expenditure required to accommodate energy efficiency may be major, the prime benefit of energy efficiency to the liquid fuels industry is controlling

operating and production costs (e.g., fuel and raw material costs) in a competitive worldwide market, as well as controlling the quantity and quality of energy supply.

For a long time investment in this sector focused mainly on the development of small plants within existing facilities, and general upgrades of the existing infrastructure. However, there is a renewed interest and a number of proposed investments on large scale projects. Investment in this sector requires substantial amounts of capital and the lead times are very long (Country Risk South Africa, 2007). Therefore, certainty about the paybacks is necessary. Large up-front fixed investment costs associated with emissions reduction will be necessary for new capital projects. In the case of existing facilities, up-front fixed investment costs associated with emissions reduction will be small.

### Trade

The industry has access to cheap inputs, labour, energy and growing African economies. However, the distance between South Africa and the European markets is a big disadvantage. If the advantages were removed, the South African industry would struggle to become globally competitive (Country Risk South Africa, 2007).

Most liquid fuels produced and refined in South Africa are used domestically, with only a small proportion being exported. In 2007, exports accounted for only 10.3% of total sales in the sector (dti, 2009a, Statistics South Africa, 2009 and Genesis calculations). On the other hand, imports of crude oil to be refined for use in South Africa are high, and the country also imports processed fuels. In terms of trade partners, South Africa's exports and imports are not weighted towards countries with carbon policies in place. As illustrated in Figure , a mere 14% of exports go to such countries whilst only 6% of imports originate there.

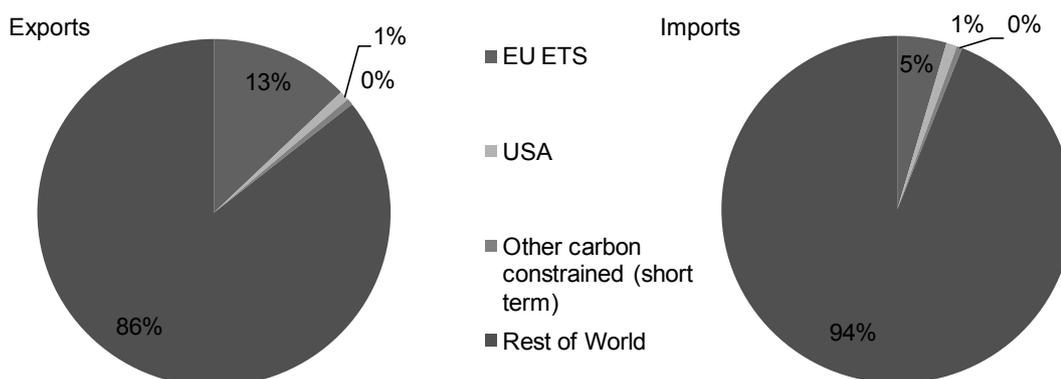


Figure : Concentration of trade in countries with carbon policies (2006): Liquid fuels

Source: Genesis Analytics, 2010

### 7.5.3. REGULATORY ENVIRONMENT

The South African liquid fuel sector is primarily governed by the Department of Energy's all encompassing Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002), and key associated regulations including Regulation 28 of the Petroleum Products Act (Act No. 120 of 1977). The price of petrol is regulated by government, and changed every month. The

calculation of the new price is done by Central Energy Fund (CEF) on behalf of the Department of Minerals and Energy (DME).

Environmental governance and performance is subject to the provisions of the National Environmental Management Act 62 of 2008. Air Quality Management & Climate Change is governed by the Air Quality Management Act, Act 39 of 2004.

#### **7.5.4. GHG EMISSIONS**

All six of the GHG emissions identified by the UNFCCC are produced by various companies within the South African liquid fuels sector. Through studying the Corporate Sustainable Development Report (CSDR) of the oil majors in South Africa, we were able to find some independently verified GHG emissions inventories. However, the main challenge is to disaggregate these emissions by operations and individual processes. For instance, in its CSDR Sasol reports that its “independently verified global greenhouse gases (GHG) have decreased from 73-million tons to 71-million tons in 2009. Its emissions intensity, measured as carbon dioxide equivalent for each ton of production, was 3.24, compared with 3.0 in 2008 and 3.29 in 2007.” The same applies to the other majors.

Although this information is very useful, it does not give a crystal clear picture about GHG emissions from local operations. Moreover, quantification of emissions from the petroleum industry is complicated by the variety of emission sources and nature of fuels that are consumed. However, according to a recent study by the International Petroleum Industry Environmental Conservation Association (IPIECA, 2003) large fractions of the industry’s combustion emissions come from the burning of hydrocarbons. With this in mind, the following processes can be isolated as the key sources of GHG emissions from oil production:

- Combustion sources;
- Flaring;
- Acid gas venting;
- Glycol dehydration;
- Tank flashing;
- Process fugitive emissions;
- Other process and non-routine sources.

Key sources of GHG emissions from petroleum refining and petrochemicals include:

- Combustion sources;
- FCC Coking;
- Flaring;
- Hydrogen plant;
- Process fugitive emissions;
- Other process and non-routine sources.

As far as South Africa is concerned, besides the crude oil refineries, the country's liquid fuel supply is dominated by the synfuel coal-to-liquids (CTL) refineries. CO<sub>2</sub> emissions from coal liquefaction are the number one source of emissions generated in this sector (LTMS, 2007). Other major emissions from both CTL conversion technology and refining system are methane and N<sub>2</sub>O. Studies have shown that the CTL has a higher GHG intensity relative to a crude oil refining system (Sasol SDR, 2008).

Estimates of emissions for the liquid fuels sector could not be determined from the recently published national GHG inventory. Emissions from this industry have been included in the overall energy industries' emissions presented in the table below. Noteworthy, these statistics highlight one important challenge – the need to disaggregate data. It is impossible to determine the percentages of emissions that are attributable directly to the liquid fuels, as a standalone economic sector, without additional sources of relevant information.

Source of Emissions	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	TOTAL
	CO <sub>2</sub> -e (Mt)	CO <sub>2</sub> -e (Mt)	CO <sub>2</sub> -e (Mt)	Total
<b>Fuel Combustion</b>	212 226	78.23	1070	213 375
<b>Fugitive Emissions from Fuels</b>	24.33	40 386	-	40 411
<b>Solid Fuels</b>	24.33	40 366	-	40 391
<b>Oil and Natural Gas</b>	0	20	-	20

Table : Sources of emissions in energy sector

Source: DEAT 2009

### 7.5.5. CURRENT SECTOR RESPONSE TO CLIMATE CHANGE

Except for the Long Term Mitigation Scenario (LTMS) planning and some small projects driven by the Refinery Managers Environmental Forum (RMEF), a forum where sharing of information takes place, co-operation at plant level in this industry is still very limited. The scope for collaboration is significant but the existing culture of separate research and development is a great impediment. Due to the confidential nature of proposed initiatives, project details tend to be very vague. However, some of the following projects have been mooted at plant level to improve energy efficiency:

- Co-generation
- Development of catalysts, which make possible lower process temperatures and/or shorter reaction times and/or less by-products
- Bio-processes at low temperature levels
- Re-utilisation of steam / hot water, cascading it through several levels of pressure and temperature
- Computerisation, improved process controls and process optimisation
- Increased use of insulation
- Increased use of by-product fuels
- Research and development, investment in new and improved plant and equipment

The list above is by no means exhaustive and represents only a selection of opportunities that are available. Government regulation of environmental performance in this industry is still very weak compared to the liquid fuels industries in Europe and North America. As a result, local companies in this sector generally lack the motivation and incentive to invest in Clean Development Mechanism (CDM) projects. In Europe and North America tougher air quality legislation forces companies to think broadly about possible alternatives to limit their exposure to penalties. CDM projects have been adopted as one possible avenue to comply with the legislative requirements. Perhaps local companies are also discouraged by the upfront costs for bringing CDM projects to the market and the time that it takes to realise a return on invest in these projects. However, there are a small number of existing proposed projects in the pipeline. For example, Sasol Nitro has developed a GHG abatement project which is reducing emissions from nitric acid plants at Sasolburg and Secunda by the equivalent of more than 500 000 tonnes per year of carbon dioxide. The fact that there are only a small number of validated and approved CDM projects in South Africa means that a lack of critical mass is hampering the development of further CDM projects.

In March 2009 a South African Centre for Carbon Capture and Storage was launched, an initiative led by the South African National Energy Research Unit with sponsors including Anglo Coal, Eskom, Exxaro, Sasol, Schlumberger and Xstrata Coal.

It is acknowledged that the sector may be somewhat constrained in its ability to implement measures to reduce GHG emissions as the price charged to consumers is regulated, so the extent to which costs can be passed on to consumers will be determined by the appropriate regulator.

#### **7.5.6. SECTOR MITIGATION OPPORTUNITIES**

In this section the indicative abatement cost curve for the petroleum and liquid fuels sector is presented, followed by a detailed explanation of each individual mitigation opportunity that was considered.

##### **7.5.6.1. IACC**

The following IACC provides a summary of the main mitigation options available to the sector, how costly they will be to implement, the risk associated with them and how effective each will be in relation to the other options available within the sector to reduce GHG emissions. The main mitigation options were identified primarily from the authors' industry experience, using the LTMS technical document together with other relevant reports. These mitigation options cover more than 80% of the foreseeable emissions opportunities in terms of a balance between volume of emissions reductions and cost. The IACC suggests that CCS and co-generation will provide the biggest abatement opportunities. While the benefits of CCS will not be achievable in a short to medium term, it is possible to realise the benefits of co-generation long before 2030. There are also other smaller technological improvements that can assist this industry achieve at least 39% of the potential reduction in GHG emissions.

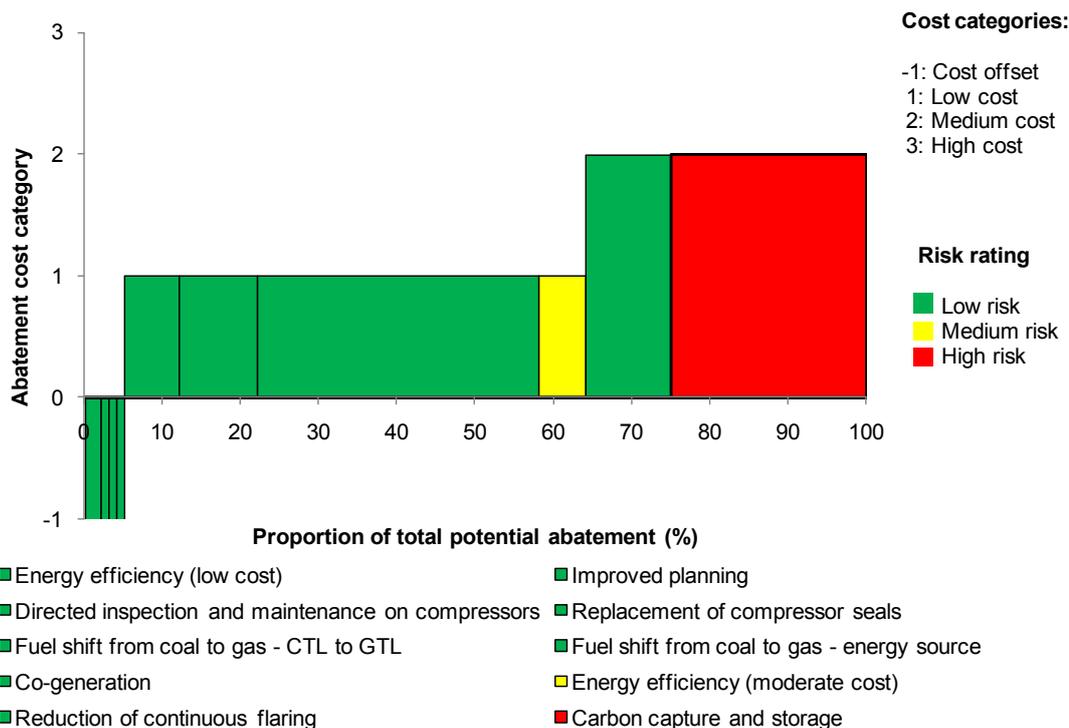


Figure : IACC: Liquid fuels<sup>38</sup>  
 Source: Genesis Analytics, 2010

## 7.5.6.2. DESCRIPTION OF ABATEMENT OPTIONS

### Energy efficiency (low cost)

Energy efficiency means obtaining increasing energy service from fuels/electricity and the technologies that transform the energy to the desired services. Energy efficiency involves more efficient hardware and improved management of the hardware, commonly referred to as behavioural change. In almost all cases, behaviour is characterised by lower life-cycle costs than business as usual. However, part of the characterisation is that efficiency measures are normally higher first-cost than business as usual technologies and the savings follow in a reduction costs of fuels/electricity.

Efficient technologies are promoted on the basis of their cost savings. To be able to have verifiable proof of cost savings, independent testing and labelling have become essential in the marketing and promotion of the technologies. Behavioural change is less amenable to standardisation; however, it can be incentivized. The co-benefits of energy efficiency include the reduction of costs and emissions of GHGs and other potentially harmful gases and particulates. Strategically, reduction in the demand for energy reduces the strain on energy infrastructure, and hence improves its reliability. In addition, lower demand on the energy infrastructure implies a lower demand on fiscal allocations to energy infrastructure. One of the

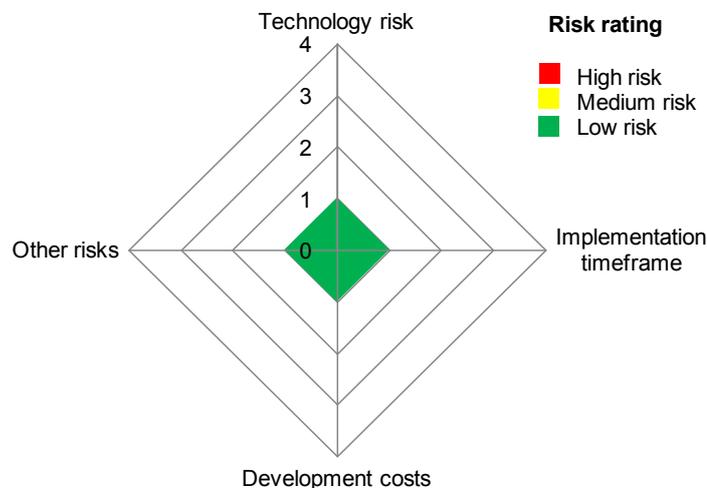
<sup>38</sup> For details of how to read the IACC, see footnote in section .

institutional barriers for increasing the efficiency of facilities is that very often operational and capital budgets are different line items on budgets and managed differently. This institutional difference is a barrier to optimization.

Compared to other mitigation technologies such as co-generation and carbon capture and storage, energy efficiency lacks the scale that is needed to achieve significant GHG emissions reduction in the South African liquid fuels industry. We could not identify any single energy efficiency technology that could, by itself, result in major reduction. To achieve significance energy efficiency technologies need to be grouped in a manner in which they can complement one another to produce a significant abatement potential.

In the IACC we have include two groups of energy efficiency measures which we divided into cost offset and low cost options. While the cost offset option will be able to pay for itself, the latter is going to require relatively moderate upfront investment. Research conducted by McKinsey (2009) has identified theoretical abatement potential that could be derived from energy efficiency and abatement cost that would be incurred as a result. McKinsey (2009) suggests that it is possible for energy efficiency in the oil and gas industry to achieve an abatement potential of 120 MtCO<sub>2</sub>-e per year globally at a negative average abatement cost of €60 per tonne of CO<sub>2</sub>-e. Given the full scope of all abatement options considered this abatement potential represented a 10% abatement potential. Based on our own IACC for the South African context the cluster of low cost energy efficiency options that we have chosen would represent 2% abatement potential per year relative to all options considered. We have allocated this 2% potential a cost rating of “-1” because the cost of implementation could be covered by cost savings.

We highlight these observations not for the purpose of comparing South Africa to the countries studied by McKinsey, but rather to indicate energy efficiency could be a useful abatement lever. We believe that it would be incorrect to superimpose any of McKinsey's data on a South African situation where coal is a significant contributor on the fuel mix compared with countries (primary sources of the data) which derive their fuel from crude oil.



**Figure : Radar risk diagram: liquid fuels - energy efficiency low cost**

*Source: Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	Energy efficiency is a low risk technology. However, system changes can affect the performance of the plant.
Implementation timeframe	1	Implementation timeframes will be short. There is widespread understanding in the South African liquid fuels industry of the small changes that are required to implement energy efficiency measures. Changes can be implemented as part of the general maintenance schedule
Development costs	1	Development costs
Other risks	1	The only minor risk factor could be slow behavioural change. However, the risk is minor and unlikely to trigger non-adoption of energy efficiency technologies.
Composite risk score	4	
Overall risk rating	Low risk	

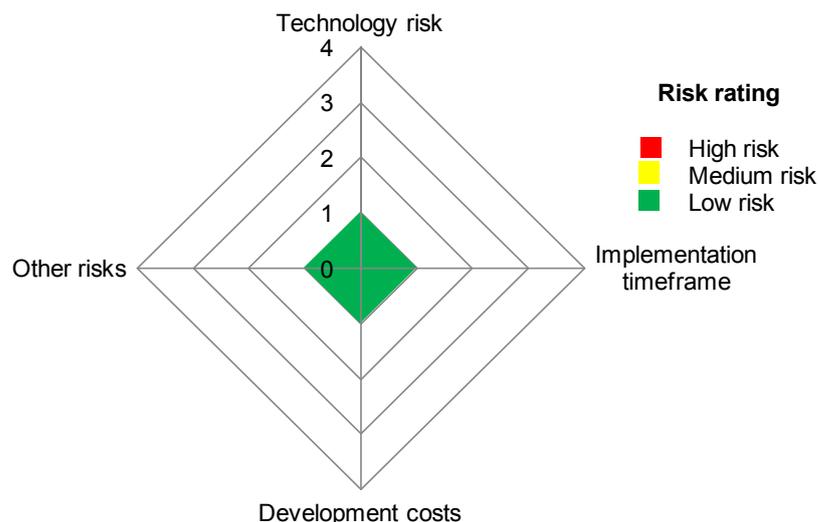
**Table : Risk ratings: liquid fuels - energy efficiency low cost**

*Source Genesis Analytics 2009*

### Improved planning

Improved planning implies taking current planning and applying this to installing, commissioning, operating and maintaining technologies and processes at a plant level. The costs for this cannot be estimated, as there is no sense of what constitutes improved planning as a single package. However, from McKinsey (2009), improved planning can be achieved at a negative average abatement cost. There are standardised approaches to planning such as pinch technology for the identification of the optimization. The term "pinch technology" refers to a development in process design and energy conservation that has been around for quite some time, but one that is not widely utilised.

The abatement potential of improved planning and the cost of implementing it will both be small. But, the long term benefits could be substantial as "mind shift" will promote better methods of doing things. The abatement potential is small, 1% per year according to our estimates on the IACC. McKinsey (2009) suggest that it is possible to achieve an abatement potential of 10 tonnes of CO<sub>2</sub>-e per year globally at a cost of -€80 per tonne CO<sub>2</sub>-e. This represents 1% of the abatement potential of all the abatement options considered. As with low cost energy efficiency option improved planning was assigned a "cost offset" rating of "-1" because the cost of implementation could be covered by the savings achieved as a result of effecting the proposed changes. In South Africa the abatement potential of this option will be minute compared to other options considered.



**Figure : Radar risk diagram: liquid fuels - improved planning**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	No risk
Implementation timeframe	1	Timeframes will be shorter depending on the complexity of the proposed planning improvements. Short time frame for changing inspection routines
Development costs	1	There will be no development costs
Other risks	1	No other risks. But, a change of mindset and alteration of the routines will be necessary.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: liquid fuels - improved planning**

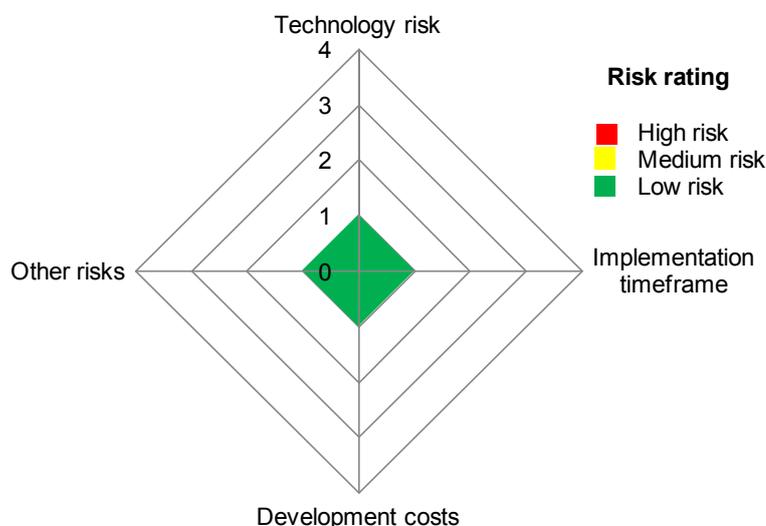
Source: Genesis Analytics, 2010

### Directed inspection and maintenance of compressors

A gas compressor is a mechanical device that increases the pressure of a gas by reducing its volume. Compressors are similar to pumps – both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. A number of processes in a refinery require compressors to function. If they are not frequently inspected and maintained, these compressors can leak and release some GHG emissions. In addition, they are highly energy intensive in their operation, so inspection and maintenance can optimise their energy consumption.

The abatement potential is small. We estimate that it would be around 1%. The abatement benefits of this technology can be achieved at a relatively low cost of implementing directed inspection and maintenance of compressors. We assigned this option a “cost offset” rating of “-

1” because it is possible to incorporate the implementation of this option on routine maintenance schedule.



**Figure : Radar risk diagram: liquid fuels - directed inspection and maintenance of compressors**

*Source: Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	No risk
Implementation timeframe	1	Short time frame for changing inspection routines
Development costs	1	Negligible investment required
Other risks	1	No other risks
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: liquid fuels - directed inspection and maintenance of compressors**

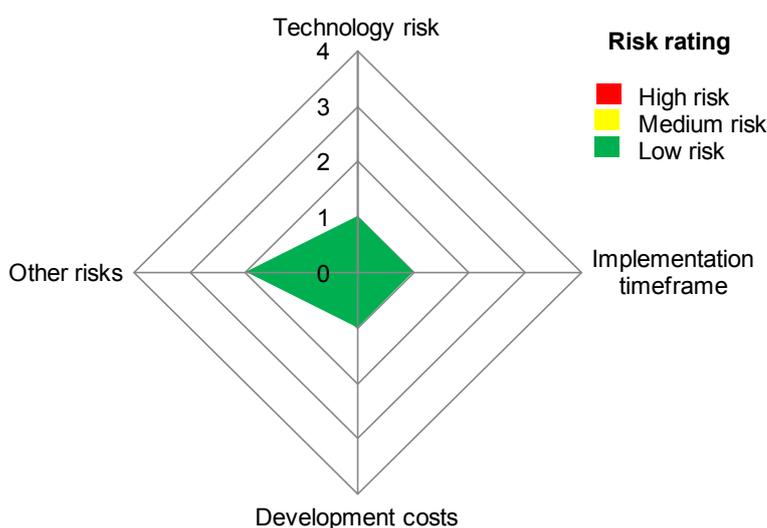
*Source: Genesis Analytics, 2010*

### Replacement of compressor seals

Inspection and maintenance of compressor seals and replacement of compressor seals is necessary to avoid leakages. As far as cost estimates are concerned, these are very low cost unless the inspection or change of the seals will take the plant out of operation. The inspection and replacement of seals can be standardised as part of a maintenance regime. Co-benefits include energy savings and hence financial benefits. Replacement of compressor seals is strategically important to improve energy efficiency of the plant but currently it is not done as well as it should in the local liquid fuels industry. Hence, avoidable fugitive GHG emissions are released into the environment.

Replacement of compressor seals has a very small abatement potential, equivalent to only 1% of the total possible potential of all options and an abatement cost rating of “-1”. Clearly the

benefit is small but the replacement of compressors seals has a multiplier effect in terms of its ability to reduce fugitive emissions and increase the efficiency of production. McKinsey (2009) predicts that globally firms can achieve, at no cost, abatement of 40 MtCO<sub>2</sub>-e annually. That would be equivalent to a 5% abatement potential of the options available to the industry. On our own IACC the technology was assigned a “cost offset” rating and a small 1% abatement potential. The abatement potential in South Africa was considered to be lower than the McKinsey estimate valve and compressor types are process- and therefore refinery-specific, and the technology was judged to have a smaller potential to reduce emissions in South African refineries.



**Figure : Radar risk diagram: liquid fuels - replacement of compressor seals**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	No risk
Implementation timeframe	1	Short time frame for changing inspection routines
Development costs	1	Negligible investment required
Other risks	2	Moderate risk of triggering non-adoption of the technology
Composite risk score	5	
Overall risk rating	Low risk	

**Table : Risk ratings: liquid fuels - replacement of compressor seals**

Source: Genesis Analytics, 2010

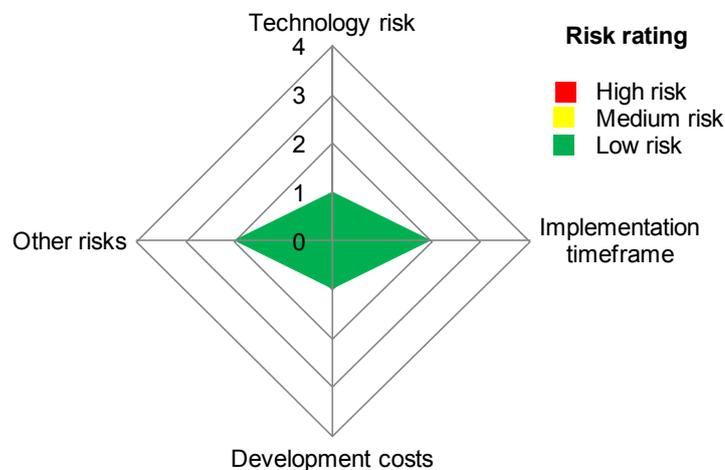
### Fuel shift coal to gas - feedstock for CTL to GTL processes

This type of fuel shift refers to the change of feedstock from coal to gas or biomass with the new feedstock converted to liquids. Natural gas is put through a GTL plant to produce 75% fuel (diesel) and 25% Naphtha. According to Sasol, globally there are a 2000 tcf ~ 360 billion boe of total uncommitted gas reserves. A good example of a GTL is Sasol's 645km natural gas

pipeline running from Mozambique to its Secunda coal-to-liquids plant, along with the requisite gas conversion and processing technology and the development of natural gas fields in Mozambique.

The cost of Sasol GTL was \$34,000/pbd (1997) and it dropped to \$24,000/pbd (1999). Sasol's experience clearly demonstrates that like other capital-intensive processes, GTL costs come down with experience and further reductions can be achieved as installed base increases. Using natural gas instead of coal reduces greenhouse gas emissions. The associated value of carbon credits that can be derived from this fuel shift is considerable. For example the Sasol project aims to save 6.4 Mt of GHG a year and with the potential to earn Sasol carbon credits revenue of R1.1 billion per year over 10 years. Since the technology to promote the transition is already available and seems to come down in cost with time and experience we assigned an abatement cost of "1" to the technology. We estimate that its abatement potential for this industry would be equivalent to 7% of all available options.

The fuel shift from a CTL to GTL processes is unique to Sasol. Although Shell has ventured into the development a few pilot plants, these are very tiny in comparison to the Sasol process, and therefore we could not use them as benchmark for the required technological transition that is taking place at Sasol.



**Figure : Radar risk diagram: liquid fuels - fuel shift coal to gas – CTL to GTL**

Source: *Genesis Analytics, 2010*

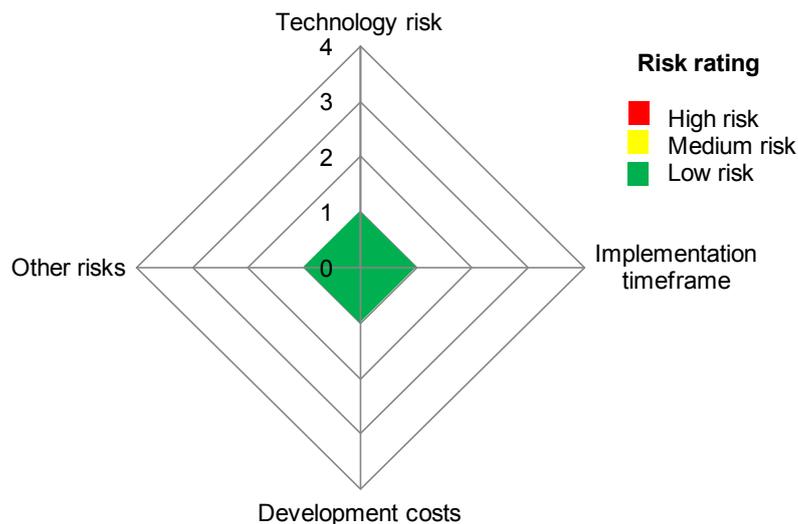
Rating criteria	Rating	Explanation
Technology risk	1	Sasol is already involved in the conversion of gas to liquids processes.
Implementation timeframe	2	The timeframe may be between 2 and 5 years depending on availability of gas, which is an issue, as bulk and distribution gas infrastructure is immature in South Africa.
Development costs	1	No development costs anticipated
Other risks	2	No risks other than the constant supply of gas of a stable quality. In the chemical industry this includes natural gas, liquid petroleum gas and gasses that are purges from cracking activities. In the foreseeable future there are sufficient gas reserves to meet the short-term demand at both Sasol and Mossgas but the infrastructure to get the gas to where it is used is constrained. Further gas reserves are being explored off the Namibian coast close to South Africa where there is a 90% certainty of 1.3tcf and a 50% chance of 4.3tcf. However, the use of this gas is in question. Namibia Power (NAMPower) have been keen to generate power but are unable to confirm power purchase agreements for the excess power, while others have been looking to compress or liquefy the gas and transport it to markets. It is clear that the confidence in the quantities still need further exploration that will be affected during exploitation of the gas.
Composite risk score	6	
Overall risk rating	Low risk	

**Table : Risk ratings: liquid fuels - fuel shift coal to gas – CTL - GTL**

*Source: Genesis Analytics, 2010*

### **Fuel shift coal to gas - fuel source for normal refineries**

This fuel shift refers to switch of fuel source, not feedstock. It is an option which is more appropriate for standard refineries than for Sasol as it refers to a switch in the fuel used to power the refinery, generate steam, fuel boilers etc. It has been assigned an abatement cost of “1” because the required retrofits are relatively simple to accomplish. We estimate that its abatement potential for this industry would be equivalent to 10% of all available options. From a Brazilian point of view, McKinsey (2009) concluded that fuel shift could generate a 20% (7 Mt CO<sub>2</sub>-e) abatement opportunity for the petrochemical sector (liquid fuels and chemical) at a negative economic cost estimated to be below €20 per tonne of CO<sub>2</sub>-e by 2030.



**Figure : Radar risk diagram: liquid fuels - fuel shift coal to gas – fuel source**  
 Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Coal to gas technology is mature. Existing boilers can be retrofitted with gas burning nozzles.
Implementation timeframe	1	The timeframe should be less than 2 years.
Development costs	1	No development costs anticipated
Other risks	1	No other risks could be identified.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: liquid fuels - fuel shift coal to gas – fuel source**  
 Source: Genesis Analytics, 2010

### Co-generation

Cogeneration refers to the sequential production of electricity and thermal energy in the form of heat or steam, or useful mechanical work, such as shaft power, from the same fuel source. Cogeneration projects are typically represented by two basic types of power cycles, topping or bottoming. The topping cycle has the widest industrial application.

The South African co-generation market is currently in its early development phase. However, it is projected to experience significant growth – approximately 30 to 50% per annum – over the next five to ten years. This expansion will be propelled by rising coal prices and by the fact that current energy demand is close to exceeding supply, creating a pressing need for additional sources of power generation. Co-generation has the ability to achieve up to 90% efficiency, even though current generation in South Africa has less than 40% efficiency. This could offset the start up costs in the long run as well as maintenance costs. With higher efficiencies co-

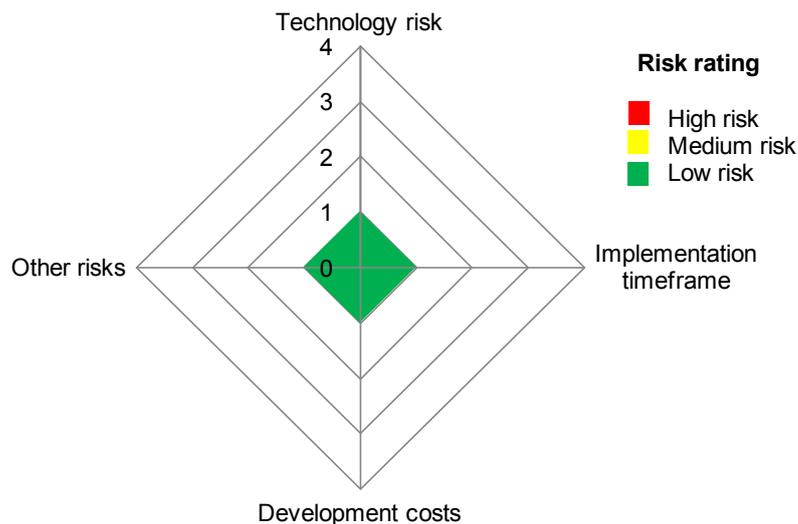
generation plants will be producing a higher profit margin than regular generation (Frost & Sullivan, 2007).

The promise of higher efficiency bestows advantage even as sizeable start-up costs pose barrier to investments. The growing prominence of less expensive, more efficient technologies paralleled by the rising price of fossil fuels will help create a highly lucrative market for co-generation in South Africa. With higher efficiencies, co-generation plants will be able to attain higher profit margins than regular sources of generation. This could offset start-up as well as maintenance costs in the long run. In addition to offering higher efficiencies, co-generation offers environmental benefits; it reduces the use of fossil fuels as well as conserves resources, resulting in fewer greenhouse gas emissions (Frost & Sullivan, 2007).

Frost & Sullivan (2008: webpage) cautions that “sizeable start-up costs are acting as a major restraint, hindering companies from establishing co-generation plants. Despite the offer of financial assistance from Eskom and the government, market participants are adopting a cautious approach. Joint ventures in the private sector could help minimise start-up costs. Furthermore, purchasing equipment in the grey market could, in some cases, alleviate start up costs by up to 30 per cent.”

On a 29 January 2009 statement to its shareholders (Sasol, 2009), Sasol confirmed that in July 2006, the first plant in South Africa to employ the co-generation of electricity and steam with pipeline gas was commissioned in Richards Bay and the second came into operation in Newcastle in 2007. The report further highlighted that during 2009 Sasol will re-route additional natural gas supply to increase electricity production through the installation of new gas-based co-generation technology. This will improve energy-efficiency and reduce Secunda’s reliance on external energy supply from Eskom. This serves to confirm that individual South African firms do have financial capacity to bear the cost of developing co-generation opportunities. Appetite for co-generation under current uncertainty around the quality and quantity and rising costs of energy coupled with the possibility of CDM income will continue to increase the appetite for co-generation in South Africa.

The abatement potential and co-benefits of this technology are relatively big. But, they will come with moderate development and implementation costs. McKinsey (2009) estimates that co-generation can provide a global abatement potential of 100 Mt CO<sub>2</sub>-e per year at a low cost of €5 per tonne CO<sub>2</sub>-e to replace, upgrade and installation of co-generation units (boilers, heaters, turbines and motors). We estimate that the South African liquid fuels industry can derive an annual benefit equivalent to 36% of the total abatement potential. Because of the required investment we have assigned the technology a cost rating of “1”.



**Figure : Radar risk diagram: liquid fuels - co-generation**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Technology has been proven at scale in South Africa.
Implementation timeframe	1	Time frame for implementation is short and can be less than 2 years depending on the time taken to select the appropriate hardware.
Development costs	1	Individual firms should and do have financial capacity to bear development costs. Appetite for co-generation under current uncertainty around the quality and quantity and rising costs of energy coupled with the possibility of CDM income increase the appetite for co-generation in South Africa.
Other risks	1	None identified, Even if there were any risks associated with cogeneration they would not trigger non-adoption of the technology.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: liquid fuels - co-generation**

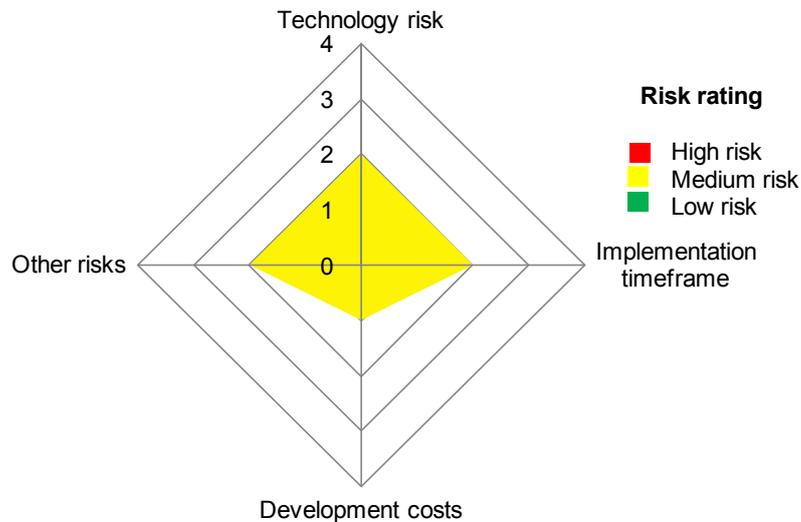
Source: Genesis Analytics, 2010

### Energy Efficiency (moderate cost)

The need to pursue every energy efficiency option available to the sector cannot be over-emphasised. In this section we present a different cluster of moderate cost options to improve energy efficiency. Individually, the impacts of these strategies are relative small but collectively they an attractive and cost effective combination of technologies and business approaches to consider in the short to medium term.

Moderate cost energy efficiency interventions include energy efficiency requiring CAPEX at process unit level and energy efficiency from maintenance and process control on retrofits. For example, improved process control that reduces suboptimal performance. This and other possible options may be slightly costly because of the necessary structural adjustments to the plants and the research that is required to effect the changes and pilot the options. Therefore, additional resources may be required. As shown in the IACC, moderate cost energy efficiency could produce 6% of the total abatement potential of all the options that we considered. In terms of its significance this abatement potential is equivalent to combination of the low cost energy efficiency, improved planning and directed inspection and maintenance of compressors.

Realising the benefits of implementing the moderate cost energy efficiency option requires a moderate amount of capital investment. Therefore this option has been assigned a low cost rating of "1". McKinsey (2009) predicts that globally the industry could achieve a 33% abatement by implementing a cluster of moderate cost energy efficiency options.



**Figure : Radar risk diagram: liquid fuels - energy efficiency moderate cost**  
 Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	2	Structural adjustments of the plants will be necessary. Therefore changes will require research and piloting of the options.
Implementation timeframe	2	Efficiency measures could take 2 to 5 years to install, particularly with low cost measures. Due to the required research, piloting and testing implementation timeframes will be slightly longer than the low cost efficiency option.
Development costs	1	The development costs are very low because the knowledge and resources that are required to make the change are readily available.
Other risks	2	Risk factors are unlikely to trigger non-adoption of the technologies. As a result of the dominant culture in the industry water rather than energy is seen as limiting resource. There is also a dominant culture of centralized energy utility. Budgets for capital expenditure are separate from operational expenditure. Price of energy (electricity and coal) is still very low by international standards to the extent that it has been seen in the past as South Africa's major international competitive advantage. Energy recovery is based on electricity constraints and the electricity recovery plan that has included incentives for co-generation and Independent Power Producers. However, this is changing quickly. Other industrial facilities are looking into captive power and cogeneration in order to reduce exposure to electricity quality and quantity fluctuations.
Composite risk score	7	
Overall risk rating	Medium risk	

**Table : Risk ratings: liquid fuels - energy efficiency moderate cost**

*Source: Genesis Analytics, 2010*

### Reduction of continuous flaring

Continuous gas flaring refers to the petroleum production process whereby surplus gas is disposed of by open combustion in an elevated vertical stack. Flaring also disposes of sour gas containing hydrogen sulphide (H<sub>2</sub>S) and waste gas containing contaminants such carbon dioxide (CO<sub>2</sub>). Flaring is primarily a safety measure; to prevent the accumulation of gases that would pose a hazard to workers and nearby residents. However, the refineries use flaring as a cheap method to get rid of their waste gases. An efficiently burning flare does not produce visible smoke. Black smoke indicates incomplete combustion, caused by wind, water, impurities in the fuel, or poor mixing with air.

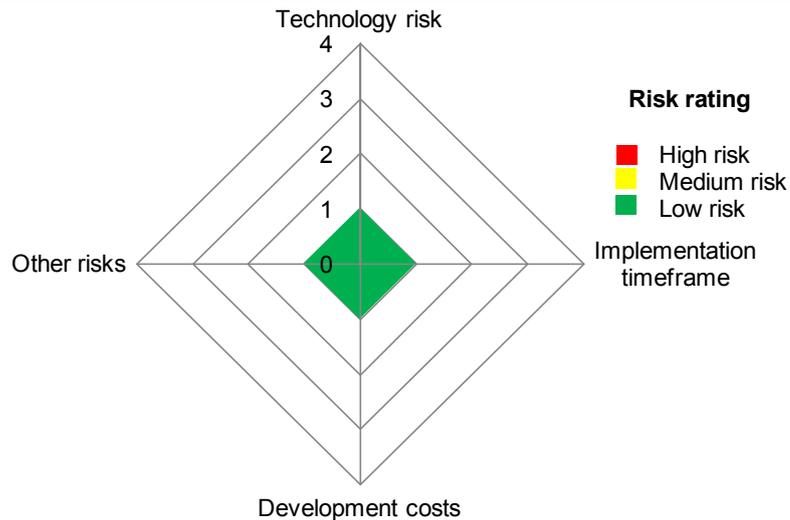
According to the World Bank's First Global Satellite Survey on Gas Flaring report, gas flaring wastes resources and results in GHG emissions. Capturing and using flared gas will result in reduced emissions and can also be positive in terms of ensuring energy security. The

technology has been demonstrated in a number of countries and is widely considered a “low-hanging fruit” compared to other mitigation options. (World Bank, 2006)

Cost estimates will depend upon the nature of the flares and the use to which the recovered gasses will be put. One of the main reasons streams are flared is that they are of variable quantity or quality which is not always compatible with the end-use. The end-use can also differ considerably as to its requirements. For example combined cycle co-generation of electricity requires a stable quantity and quality, making flare recovery for these classes of application expensive. However, thermal applications such as boilers are less sensitive to variable quality and quantity, and therefore flare recovery units (FRUs) are not so expensive. There are no FRUs in South Africa, and as such there are no examples of flare recovery so no local costs can be presented. But what can be said is that the cost of FRUs is at least as costly as the generation units that might employ the recovered gas (from sources that are bound by confidentiality).

As far as standardisation potential is concerned, it will be approached as experience is gained. The environmental benefits of the gases that are products of the flaring are likely to be better managed when burned in boilers and generation systems. Costs over the long term are likely to decrease as more experience is gained. The strategic importance of this technology arises from the fact that the use of flare gases will also contribute to a hedge against the fluctuations in the prices of fossil fuels. We assigned gas flaring a moderate cost rating of “2” in the IACC primarily because flare recovery, dewatering and stabilisation in a Flare Recovery Unit is not a mature technology in South Africa. The abatement potential is smaller compared to CCS and CHP. But, like CHP the benefits can be realised in relatively shorter timeframe.

Globally the abatement potential of 50 Mt CO<sub>2</sub>-e per year that can be achieved represents a 5% of total potential of all options considered. An abatement cost of €20 per tonne CO<sub>2</sub>-e would be required to achieve this benefit. However, the data does not equally apply to both conventional refineries and CTL producers because of the nature of their processes. There's a marked difference between conventional refineries and the CTL processes. As a result, quantities of emissions generated by these processes also differ. Most of the data here refers to conventional refineries. CTL process such as the one used at Sasol are unique and have not been thoroughly investigated in terms of the emissions. Therefore, any policy formulated on the basis of this sectoral analysis should take into consideration that the results from this analysis may not equally apply CTL producers and their more conventional counterparts.



**Figure : Radar risk diagram: liquid fuels - reduction of continuous flaring**

Source: Genesis Analytics, 2010

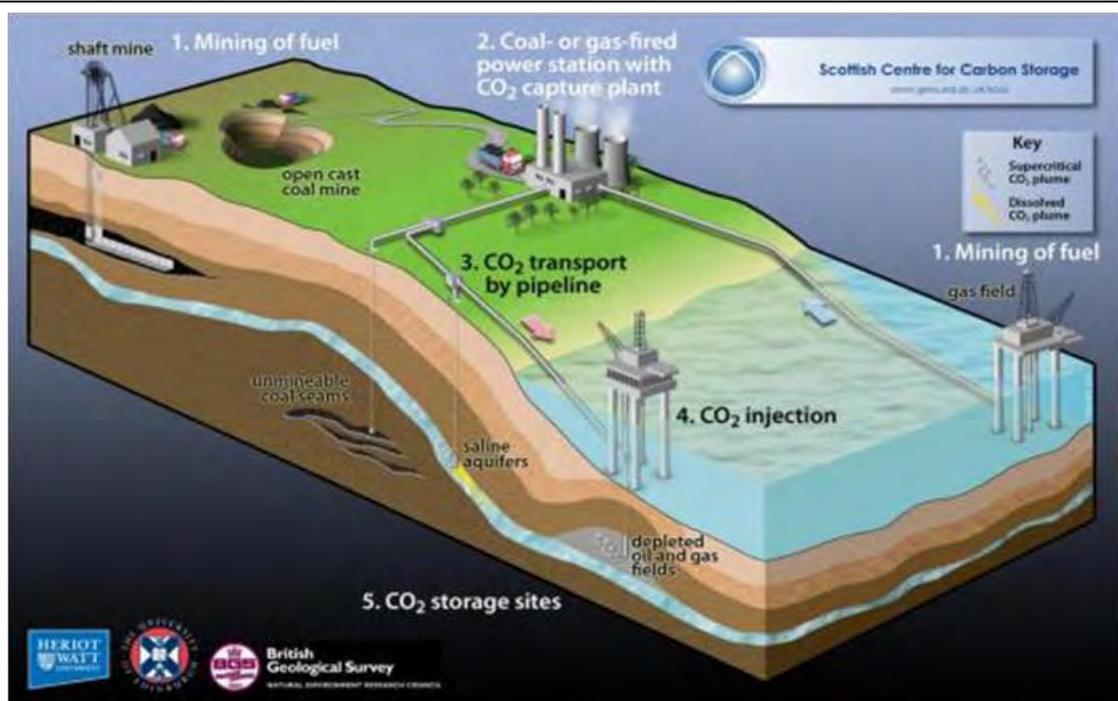
Rating criteria	Rating	Explanation
Technology risk	1	Flaring is a safety mechanism to burn off excess gases. Refining units use flares to maintain safe operating pressures during the production process. Production flaring primarily results from burning excess field gas that cannot be used to fuel operations. The flaring of this gas is most common in petrochemical plants lacking sufficient infrastructure to transport the excess natural gas to market. There is no technology risks if there is a destination for the gas that otherwise would have been flared.
Implementation timeframe	1	Timeframes for the location of new destinations/swaps for the flare gas with other streams can take some time. Flare recovery and stabilization and stripping of flare streams of varying qualities and quantities can take time to design and cost. Retrofit is more complex than new-build where optimization can be accomplished at initial design although optimisation is not a static exercise in fluctuating oil price regimen.
Development costs	1	Flare recovery, dewatering, and stabilisation in a Flare Recovery Unit is not a mature technology in South Africa but it is internationally.
Other risks	1	The risks are unlikely to trigger non-adoption in current energy situation.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: liquid fuels - reduction of continuous flaring**

Source: Genesis Analytics, 2010

## Carbon capture and storage (CCS)

Information contained in the National GHG Emissions Inventory (2009) suggests that the energy industry including liquid fuels produce 79% of all GHG emissions in South Africa. A preliminary study commissioned by the Department of Minerals and Energy of the CSIR indicated that South Africa emits over 400 million tonnes of carbon dioxide per year. Of those emissions, approximately 60% are capturable and therefore potentially available for CCS. A detailed study to identify and assess potential storage sites in South Africa is being addressed in the form of a Carbon Geological Storage Atlas. Work on the Atlas started in September 2008 and is scheduled for completion by April 2010 (Central Energy Fund, 2009)



**Figure : Diagram of CCS process**

Source: Scottish Centre for Carbon Storage

Information on the costs of CCS is only available for small pilots. It is not feasible to judge what the ultimate cost of this technology would be from what has been piloted so far. However, Stuart Haszeldine, as quoted by Whiteman & Hart, (2008) suggests that for a new-built \$1.5 billion power plant, the cost of fitting the capture equipment on the first experimental plants would be around \$700 000. The costs are divided between the separation of CO<sub>2</sub> from the rest of the exhaust stream and the storage of the gasses either in a solid or gaseous form. So where streams of exhaust gases have concentrated CO<sub>2</sub>, such as in the coal-to-liquid process, the removal of the CO<sub>2</sub> will be less energy intensive and costly. Typically oil refineries have higher concentrations of CO<sub>2</sub> than power stations that burn fossil fuels and hence are better suited to this technology (Whiteman & Hart, 2008). The LTMS technical report (Winkler, 2008:81) confirms this, stating that “for power stations the costs of separating fairly dilute streams of CO<sub>2</sub> from other gases make it more expensive than CCS from synfuels”.

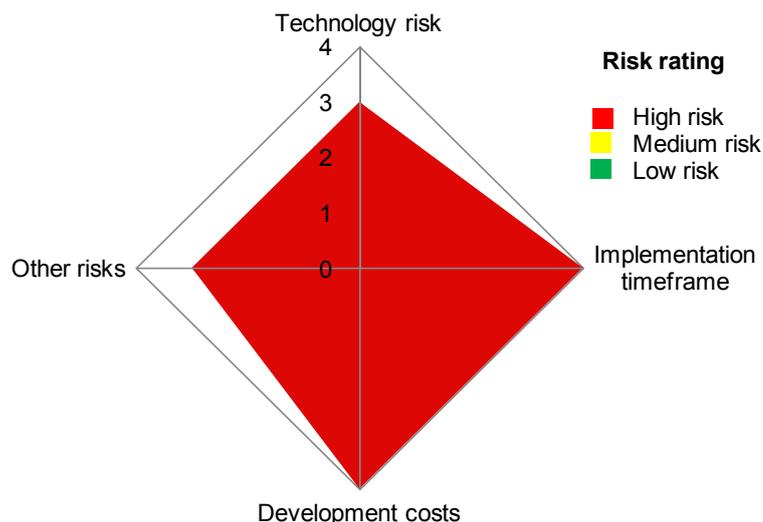
From a synfuels perspective, Sasol is a world leader in coal-to-liquid technology. However, Sasol's conversion of coal into diesel gasoline produces a significant amount of greenhouse gas emissions. The company produced 72.7 million tonnes of greenhouse gas emissions in FY2008 compared to 69.8 million tonnes in FY2007 (Sasol Corporate Sustainable Development Report, 2008). Sasol has applied for a manufacturing license for its proposed Mafutha project, a new coal-to-liquids (CTL) plant in Limpopo. If and when the plant is ultimately developed Sasol GHG emissions would increase dramatically above the current levels.

Both Sasol's own study of the relative emissions-intensity of CTL compared to alternatives (Sasol, 2008) and the LTMS (Winkler, 2008) note that the technology is well-suited to Carbon Capture and Storage, should the technology be perfected and made commercially viable. Indeed in the LTMS, it is found that CCS from synfuels represents the largest potential reduction in non-energy emissions. Since roughly half the CO<sub>2</sub> is in concentrated form, this significantly reduces the cost of capture (Winkler, 2008). As identified in the other sectoral studies, the LTMS notes that the key constraint in terms of CCS in the liquid fuels sector will be the availability of storage, rather than prohibitive cost (Winkler, 2008).

If more CTL plants are built without carbon capture and storage (CCS) becoming a reality, however, they will have a massive impact on South Africa's ability to achieve the required level of abatement. In the „Growth Without Constraints' scenario of the LTMS, CTL continues to account for around 10% of total emissions, whilst by 2050 total emissions will have quadrupled. CCS is essential for companies in this industry to reduce their climate change burden. However, CCS will not be a panacea for GHG emissions reduction. Therefore, it cannot and should not be pursued in isolation from other potentially viable and cost effective climate mitigation options.

It is too early to standardise CCS, but there may be potential in the future for standardisation. CCS will present very few, if any, co-benefits. Some employment will be created but this will be very small in comparison to the quantity of investment. However, CCS is essential if fossil fuels are to be used into the future. While CCS is a very useful long-term mitigation technology to pursue its development is still at infancy stages. Bringing the technology to the market is going to be highly expensive and the research and development to market timeframe is going to be long.

McKinsey (2009) suggests that CCS is the single largest abatement lever for the oil and gas sector with 430 Mt CO<sub>2</sub>-e of potential abatement worldwide in 2030. This would be equivalent to a 40% abatement potential for the industry globally. However, as identified previously, the number of storage sites in South Africa may be limited and hence potential here may be lower than the global average; contributing an estimated 25% of the total potential abatement from the options identified. As for the other sectors for which CCS is considered this technology is given a cost rating of "2", reflecting the costs of installation and operation, rather than the development costs associated with getting the technologies to full-scale operation. Preliminary investigations regarding the feasibility of CCS suggests that it will take more than 30 years for the full benefits to be realised.



**Figure : Risk ratings: liquid fuels – CCS**  
 Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	3	A limited number of pilot scale tests are being conducted overseas
Implementation timeframe	4	The first planned test injection of carbon dioxide in South Africa is planned for 2016 and a demonstration plant for 2020. Full-scale implementation of CCS will be beyond 2035.
Development costs	4	The development cost will most likely be high but South Africa will certainly benefit from the technology development by other countries. That will lower the cost of implementing the technology.
Other risks	3	Storing carbon underground is risky. Of greater concern are the potential risks of carbon sequestration to human health, mainly through asphyxiation and groundwater contamination. Large-scale applications of CCS will pose significant liability risks, including negative health effects and damage to ecosystems, groundwater contamination including pollution of drinking water, and increased greenhouse gas emissions resulting from leakage. Safe and permanent storage of CO <sub>2</sub> cannot be guaranteed. Even very low leakage rates could undermine any climate mitigation efforts.
Composite risk score	14	
Overall risk rating	High risk	

**Table : Risk ratings: liquid fuels – CCS**  
 Source: Genesis Analytics, 2010

## **7.5.7. OPPORTUNITIES ARISING FROM CLIMATE CHANGE MITIGATION**

The South African liquid fuels and chemical industries are inextricably linked, with the former providing feedstocks for the latter. These linkages along the value chain have multiplier effects embedded in them. For example, upstream improvements in the quality of feedstocks from the chemical industry could mean that processes for final chemical products produce lesser GHG emissions. In the same vein, there are strong links between the synthetic fuels and mining industries. Fuel shift from coal to gas may encourage coal suppliers to produce much cleaner coal. The adoption of Combined Heat and Power (co-generation) as a more efficient, cleaner, and reliable alternative energy generation technology could create opportunities for waste steam exchanges between industries within the same area. Sustainability can be a leverage to achieve industrial competitiveness. This industry should consider taking a lead in reducing flaring. This is one „sustainability lever’ that could improve the competitiveness of the industry.

Potential also exists for the industry to develop carbon capture and storage in South Africa as a combined technology option linked to the coal-to-liquid process. The sector is already a world leader in CTL and could develop a further specialisation in the combination of CTL and CCS.

Some of these technologies are “low hanging fruits” that do not require substantial capital investment. Both Sasol and Mossgas are already taken the necessary steps to modify their process to accommodate fuel shift from coal to gas. We believe that it is possible for the chemical industry to follow this lead with other technologies.

## **7.6. IRON AND STEEL CASE STUDY**

### **7.6.1. SECTOR DEFINITION AND DATA ISSUES**

The iron and steel sector is covered by SIC code 3510, - Manufacture of basic iron and steel, including code 35101 - Basic iron and steel industries, except steel pipe and tube mills.

It is difficult to compare emission estimates from these various data sources as they are all based on different years and different bases. The method of Blignaut et al to calculate CO<sub>2</sub>-e based on fuel use only provides data of greater relevance to this study, as it provides emissions data on a sectoral basis consistent with South Africa’s national energy balance, i.e. according to the SIC system. The Blignaut et al. (2005) data is, however, limited because it includes only energy related emissions (i.e. that from fuel combustion and electricity production) and does not include process emissions, which the IEA (2008) estimate to account for about 4% of total emissions from the sector.

The National GHG Inventory on the other hand is compiled according to the IPCC guidelines for national greenhouse gas inventories (IPCC 2007), which follows a different classification structure in which energy emissions are reported separately from process emissions. Thus, according to the IPCC guidelines, emissions from iron and steel should be reported under Fuel combustion / Manufacturing Industries & Construction, whilst process emissions fall under Industrial Processes and Product Use (IPPU) / metal production. The degree to which this split between energy and process emissions occurs in the National GHG inventory is not entirely clear. DEAT (2009: 25) states:

“In circumstances where it is impossible to separate energy and process emissions, IPCC Guidelines make provision for locating both process and energy emissions under one sector.

This was the case for South Africa's iron and steel industry, where energy and process emissions could not be separated due to lack of relevant information from the industry. Thus Tier 1 methodology and IPCC default emission factors for stationary sources had to be used in the emissions computation."

This would seem to imply that emissions are separated into energy and process-related emissions but that this has an effect on the uncertainty of the result (i.e. Tier 1 IPCC emission factors had to be used with an uncertainty of  $\pm 25\%$ ). However, under "Planned Improvements", DEAT (2009: 25) states "A further improvement would be a separation between process- and energy- related emissions". This seems to contradict the previous statement, and thus makes it difficult to interpret the National GHG inventory data. However, it is clearly stated that the split into energy and process related emissions does not occur for emissions relating from the use of coke, and that these are all included under process related emissions (i.e. under IPPU/metal production). Nonetheless, the distinction between energy and process related emissions clearly is made to some degree as these are separated out as 3rd and 4th on the list of key GHG emission sources for South Africa.

No mitigation options are included for the iron and steel sector in the LTMS study. Initial data were gathered, but no results were given in the report as key parameters still needed to be identified (Winkler 2007). Iron and steel are considered in the McKinsey global GHG abatement cost curve (McKinsey 2009) and included in the IEA's scenarios and strategies to 2050 (IEA 2008). In both these sources CCS from blast furnaces plays a major role. Increased energy efficiency also holds significant potential. The indicative abatement cost curve developed here is therefore largely based on these sources, but they have been adapted to better represent South Africa wherever possible (discussed in detail in the section below). The potential for CCS and switching from BF/BOF to EAF, in particular, have been adjusted from these global estimates, whilst the other mitigation options are kept in the same proportion as their global abatement potential (i.e. the other mitigation options are assumed to hold the same relative abatement potential in South Africa as the global average).

The IEA also identify electricity supply side measures as holding significant abatement potential (i.e. since EAFs are large consumers of electricity, if this electricity comes from renewable or nuclear rather than coal-based sources, there is significant potential for GHG abatement). This latter option is not included in this assessment as there is little potential to switch to greener fuel sources within South Africa (e.g. to move the steel mills to a different region of the country). However, it is useful to note that as the measures discussed in the electricity sector case study are implemented, so will these have strong knock-on effects in the iron and steel sector.

### **7.6.2. SECTOR CONTEXT**

The iron and steel sector is the second-largest industrial consumer of energy in the world and the largest emitter of CO<sub>2</sub>. In 2005, it accounted for 20% of world industrial energy use and 30% of energy and process CO<sub>2</sub> emissions (IEA, 2008). The sector is no less significant in South Africa, consuming 28% of South Africa's industrial energy use in 2005, and accounting for 41% of industrial emissions (IEA, 2008). Using level and trend analyses, energy consumption in iron and steel processes is found to be the 3rd most significant source of GHGs in South Africa, followed by process emissions from iron and steel consumption, and is the only industrial process in the top five key sources of GHG emissions in South Africa (the others are public electricity and heat production, road transport and enteric fermentation) (DEAT, 2009).

South Africa ranks about 20th in terms of crude steel producing countries in the world, producing approximately 1% of the world's crude steel. South Africa is also the largest steel manufacturer in Africa, producing more than half of the total crude steel production of the continent (SAISI, 2009). In 2007, South Africa produced 9098 kt crude steel, primarily as continuously cast slabs and billets. 3219 kt semi-finished and finished steel products were exported in 2007, with a relatively modest amount imported (757 kt) (Worldsteel 2009). South African primary steel producers manufacture in excess of 8 million tonnes of finished steel products per year of which about 5.5 million tonnes are consumed domestically. Imports account for about 9% of locally consumed primary steel (SAISI, 2009). Approximately 40 million tonnes of iron ore is mined per annum in South Africa, of which about 12 million tonnes are consumed locally and 27 million tonnes are exported (DME, 2007).

The range of primary carbon steel products and semi-finished products manufactured locally includes blooms, billets, forgings, slabs, light-, medium- and heavy sections and bars, reinforcing bar, wire rod, railway track material, seamless tubes, plates, hot- and cold-rolled coils and sheets, electrolytic galvanised coils and sheets, tinplate and pre-painted coils and sheets. The range of primary and semi-finished stainless steel products manufactured locally includes plates, slabs, and hot- and cold-rolled coils and sheets (SAISI, 2009).

There are three principal modern steel processing routes:

- The blast furnace (BF) and basic oxygen furnace (BOF) method (BF/BOF), based on 70% to 100% iron ore for the iron input, with the remainder scrap (the so-called "integrated" route)
- The scrap/electric arc furnace (EAF) method, based on scrap for the iron input;
- The direct reduced iron electric arc furnace (EAF-DRI) method based on iron ore and often also scrap for the iron input.

In the BF/BOF process, iron ore is reduced in the blast furnace using coke and pulverized coal injection (PCI) to form hot metal, which is then treated in a basic-oxygen furnace to remove impurities with oxygen and produce steel. An EAF uses scrap metal, or direct reduced iron (DRI) produced with gas or coal, that is melted by the energy produced by very high-current electricity. A third, older steel-making technology still in use mainly in Russia and the former Soviet Union is open hearth furnace (OHF), but this is expected to be discontinued over the next decade.

Steel production in South Africa is split fairly evenly between these two technologies, with 53% of South Africa's steel produced by the BF/BOF route and 47% produced in EAFs (Worldsteel, 2009).

### **Market structure**

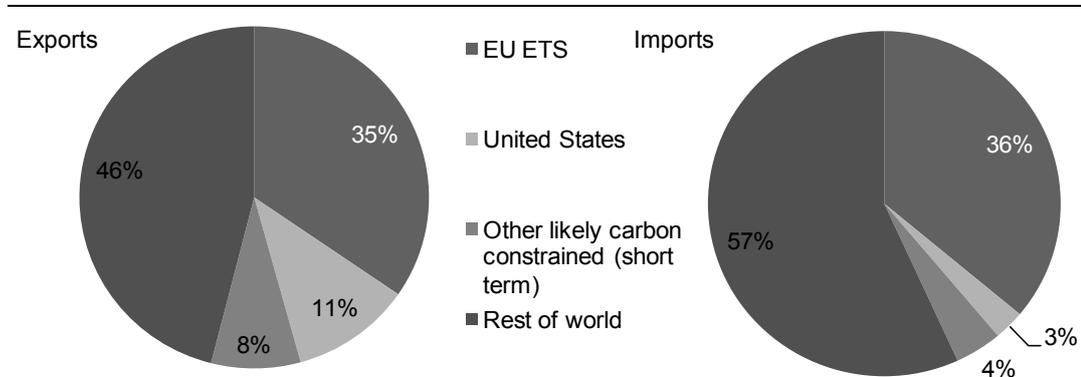
The South African iron and steel industry is dominated by a few major players including Arcelor Mittal SA Ltd, Highveld Steel and Vanadium Corporation Limited, Cape Gate (Pty) Ltd, Cisco (Cape Town Iron and Steel Works (Pty) Ltd), Columbus Stainless (Pty) Ltd and Scaw Metals Group. Arcelor Mittal has such a dominant market position that the Competition Tribunal has recently been called upon to investigate allegations of excessive pricing (DME, 2007).

There is potential for recycling collectors to play a bigger role in smelting and minerals processing which will introduce some small players into the sector, but by and large, the capital intensity of the industry dictates that it is likely to remain fairly concentrated and made up of a small number of large firms.

### International trade

Both these sectors are very export oriented and significant players internationally. South African primary steel producers manufacture in excess of 8 million tonnes of finished steel products per year of which about 5.5 million tonnes are consumed domestically. Imports account for about 9% of locally consumed primary steel (SAISI, 2009). Approximately 40 million tonnes of iron ore is mined per annum in South Africa, of which about 12 million tonnes are consumed locally and 27 million tonnes are exported (DME, 2007).

As illustrated in Figure , a high proportion of South Africa's trade in iron and steel is with developed countries which either have or are in the process of putting in place market-based carbon mitigation policies. Around 54% of exports go to such countries and a slightly lower 43% of imports originate there. This indicates that regardless of the South African policy context, the industry is going to come under pressure in the near future to reduce the emissions-intensity of production.



**Figure : Concentration of trade in countries with carbon policies (2006): Iron and steel**

Source: TIPS SADC trade database 2009

According to WTO trade data published by the dti, in 2005 the world's five biggest exporters of iron and steel were Japan, Germany, China, Russia, and Belgium. In addition, 10 of the top 20 producers worldwide are made up of EU countries and the USA (dti, 2005). This is cause for concern since these are all countries where there is already or, in the case of the USA, is about to be, a price on carbon in the economy and trade adjustment measures to avoid carbon leakage are expected to follow. Without similar initiatives and with their relatively high carbon-intensity, South African exports will be at a disadvantage. A further cause for concern is the possibility that there may be higher demand for products with a high recycled content.

A further consideration is that South African exports in the sector are still dominated by primary products and not products further down the value chain. For example, South Africa exports only 1% of the world's stainless steel production but 40% of the ferrochrome (required in the production of stainless steel). This is concerning since products with a greater degree of value-

added have more scope for product differentiation and therefore competitive advantage, rendering emissions-intensity less important as a determinant of competitiveness.

### 7.6.3. GHG EMISSIONS

There are two primary sources of carbon emissions arising from iron and steel production. Direct process and fuel-combustion emissions, primarily from the BF/BOF process, and indirect emissions mainly related to electricity consumption in the EAF process. The integrated BF/BOF process is the most GHG-intensive process, emitting around 1.6–2.8 t CO<sub>2</sub>-e per tonne of steel (excluding coke/sinter-making and after-treatment), compared with about 0.6–1.8 t CO<sub>2</sub>-e per tonne of steel for the EAF process (excluding after-treatment) (McKinsey, 2009). However, EAF emissions depend heavily on how the electricity is produced, so South Africa is expected to lie on the high end of this global range.

According to South Africa's National GHG Inventory 2000, metal production accounts for 39% of total emissions from Industrial Processes and Product Use, some 24.2 Mt CO<sub>2</sub>-e (DEAT, 2009). This figure is for process-related emissions only (i.e. does not include energy-related emissions), but does include coke-related emissions in iron and steel. The GHG inventory is only presented at a high level of aggregation, but some resolution can be obtained in this figure by using the activity data and emissions factors presented in Table 4-4 (DEAT, 2009).

Using the data in Table 4-4, the following is calculated:

- Iron and steel: 15.5 Mt CO<sub>2</sub>-e
- Ferro-alloys: 5.1 Mt CO<sub>2</sub>-e
- Non-ferrous: 3.7 Mt CO<sub>2</sub>-e

Iron and steel production thus accounts for 64% of emissions from metal production. The bulk of these process emissions arise from iron production in blast furnaces (47%), followed by steel production in oxygen furnaces (44%). Iron production by DRI contributes 7%, whilst steel production in electric arc furnaces just 2%. The low contribution by electric arc furnaces is because the bulk of GHG emissions from their use arise from electricity use, and are thus classified under "Energy" in the national GHG inventory. According to the national inventory, GHG emissions arising from energy use in the manufacturing industries and construction amounted to 39.1 Mt CO<sub>2</sub>-e. Iron and steel energy use is included in this figure, but no detailed breakdown is given in the current published version of the national GHG inventory (DEAT, 2009).

Rather different figures result from looking at energy use statistics, with coke ovens and blast furnaces consuming some 28% of South Africa's total industrial final energy use in 2005 (some 7 Mtoe/yr) (IEA, 2008). This translates to 26 Mt CO<sub>2</sub>-e per year (41% of industrial emissions). Of this, the bulk of emissions relate to energy use, with under 4% attributed to process emissions (IEA, 2008).

Based on DME (2000), Blignaut et al. (2005) calculate that in 1998 iron and steel production accounted for 25% of South Africa's total economy-wide coal use, 79% of gas use and 12% of electricity use. Overall, this amounted to 13% of South Africa's total final energy demand, some 308,567 TJ. Using their own conversion factors, Blignaut et al. (2005) convert this to 17.4 Mt CO<sub>2</sub>-e, or 4.9% of South Africa's total GHG emissions. The South African energy balance (on

which the work of Blignaut was based) shows that final energy demand in the iron and steel sector rose to 422,047 TJ in 2006 (an increase of 37%). Assuming that emissions would also rise by about 37%, this gives updated figure of GHG emissions of around 23.8 Mt CO<sub>2</sub>-e.

For the base year considered in the LTMS report (2003), iron and steel production is calculated to have a GHG emission intensity of 1.6 tonnes CO<sub>2</sub>-e per tonne product, and ferro-alloy production a GHG emission intensity of 1.4 tonnes CO<sub>2</sub>-e per tonne product. Winkler (2007) obtains these figures by simple spreadsheet extrapolation from the national GHG inventory figures for 1990, by either applying the relevant 1990 emissions factor to the annual growth rates of the industries concerned or modifying the emissions factor according to relevant technology developments in the industries between 1990 and 2003.

Without any mitigation, global emissions from the iron and steel sector are forecast to grow by 3.2% to 2030 (a 118% increase over 2005 emissions). Global production of iron and steel is predicted to grow at a slightly higher rate (3.4%). The 0.2% difference between industry annual growth and emissions growth is due to ongoing energy-efficiency programs (McKinsey, 2009). No growth predictions for South Africa were found during the literature search for this study

#### **7.6.4. CURRENT SECTOR RESPONSE TO CLIMATE CHANGE**

Current mitigation activities in the sector are largely focused on energy efficiency interventions, with some limited interest in fuel switching. Furthermore, the technology shift from BF/BOF to EAF in new build plants contributes to emission reductions from the sector. Further technology developments, such as direct casting, will contribute to emissions reductions. These opportunities are all discussed in detail below.

There are currently no CDM projects in the iron and steel sector in South Africa. Internationally, there are a handful of co-generation projects (using the blast furnace gas to generate heat or electricity) in India and China.

#### **7.6.5. SECTOR MITIGATION OPPORTUNITIES**

##### **7.6.5.1. IACC**

The indicative abatement cost curve for the iron and steel sector is shown below. A number of options hold potential for GHG mitigation in this sector, with no single technology dominating (the top 3 options each hold roughly a 5th of the overall mitigation potential for the sector). Energy efficiency options hold the greatest potential for GHG mitigation, followed by switching furnace type and co-generation.

Energy efficiency options are broken down into moderate cost options and low cost options. The higher cost bundle of energy efficiency measures include oxygen injection into EAF, scrap preheating, flue gas monitoring systems, improved recuperative burners, improved motor and pumping systems, BOF gas recycling and advanced heat recovery options. These options require medium to high capital cost investments but are assigned a "1" (low cost) in the IACC to better reflect that they have significant cost savings associated with them (fuel and/or electricity savings). The lower cost energy efficiency measures offer about half the GHG mitigation potential of the moderate cost measures, and include preventative and better planned maintenance, the insulation of furnaces, improved process flow (management, logistics, IT systems), sinter plant heat recovery, coal-moisture control and pulverised coal

injection. The individual capital cost of each measure varies considerably with the particular efficiency measure, but all the options are assigned a “-1” (cost-offset) in the IACC to emphasise that these measures will be able to pay for themselves in a relatively short timeframe. Both the moderate and low cost energy efficiency measures are designated as low risk, as they include easy to implement, “off the shelf” interventions that have been demonstrated in South Africa or internationally.

Switching from the BF/BOF steel processing route to the scrap/EAF route holds some mitigation potential because it is significantly less energy-intensive (4 GJ/t to 6 GJ/t) than the BF/BOF route (13 GJ/t to 14 GJ/t). However, opportunities for increasing its application are fairly limited as steel recycling is already relatively high in South Africa. Furthermore, it represents relatively high cost (a whole new steel plant has to be built) and is somewhat risky as it depends on the availability of scrap iron. Holding roughly equal GHG mitigation potential to technology change is co-generation, in which the gas generated by the blast furnace is recovered and used for power generation at the steel mill. Co-generation requires a relatively modest capital investment and is assigned a “1” (no or low cost) in the IACC because it is likely that the investment will be able to pay for itself to some extent through the electricity savings achieved. Co-generation is low risk as it is a well established technology and can be considered BAT (best available technology) for the integrated route of steel-making.

Moderate GHG mitigation potentials are predicted for carbon capture and storage (CCS) and smelt reduction, at around 10% and around 7% respectively. The former is still under development so is designated as high risk, and is also an extremely costly option in terms of R&D – although installation and operation will not be excessive once the technology is developed. A relatively low contribution by CCS to the overall mitigation potential of the sector is predicted because other sectors (notably power generation) are expected to lay greater claim to the limited carbon storage sites in South Africa. Smelt reduction refers to new, more efficient reactor designs that substitute a single process for the ore preparation, coke-making and blast furnace iron-making steps of a traditional facility. This option is low risk as it has been demonstrated in South Africa, but it has relatively low potential as it is only applicable to small-to-medium-scale facilities employing the BF/BOF processing route. It also has high capital costs as extensive process technology changes are required, although it is designated as medium cost in the IACC because fuel and electricity savings offset this over the long term.

Much lower GHG mitigation potentials are predicted for coke substitution and direct casting, at just over 3% each. The former carries some risk because of the possibility of competition for biomass resources, but carries a net saving for the steel plant (i.e. a cost offset due to charcoal being cheaper than coking coal). Direct casting is also somewhat risky because the technology is still in the demonstration phase with further R&D required. Capital costs are fairly high, but are still lower than for a traditional continuous caster and hot-rolling mill, so direct casting is designated as low cost in the IACC to emphasise that energy savings are possible as a result of the technology change.

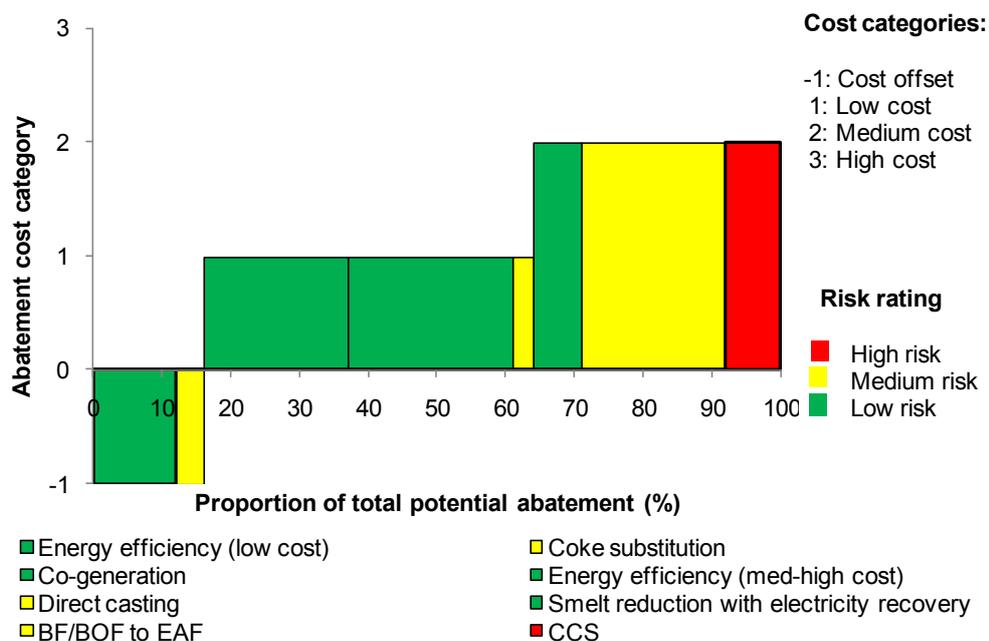


Figure : IACC: Iron and steel<sup>39</sup>

Source: Genesis Analytics, 2010

### 7.6.5.2. DESCRIPTION OF ABATEMENT OPTIONS

The following sub-sections describe the salient features of each of the abatement options. Abatement costs are taken from McKinsey (2009). These are quoted primarily to support the cost category into which the abatement option is placed in the IACC (i.e. cost offset, low, medium or high). In McKinsey (2009) abatement costs are the average cost of avoiding 1 tonne of CO<sub>2</sub>-e by 2030 through that opportunity. The cost is a weighted average across sub-opportunities, regions and years. All costs are in 2005 Euros. The McKinsey abatement costs are quoted in the sections below primarily to provide a comparative index of costs for the different options, and should not be read as actual costs relevant to the South African iron and steel sector. This is because they contain a large number of assumptions in their calculation, e.g. cost of capital, interest rates etc. Furthermore, the abatement costs in McKinsey (2009) are specifically designed to aid comparisons across the opportunities, as they are calculated from a societal perspective, i.e. they exclude taxes, subsidies, and have a capital cost similar to government bond rates. The costs are thus different from what a company or consumer would see.

#### Energy efficiency (low cost)

There are considerable differences in the energy efficiency of primary steel production between countries and even between individual plants. These differences can be explained by factors

<sup>39</sup> For details of how to read the IACC, see footnote in section .

such as economies of scale, the level of waste energy recovery, the quality of iron ore, operations know-how and quality control (IEA, 2008).

Energy efficiency measures offer the greatest abatement potential in the iron and steel industry. In the IACC, energy efficiency is broken down into two abatement options, each consisting of a bundle of integrated energy efficiency measures, with low cost measures offering about half the potential of the moderate cost measures. The relative abatement potential of these two levels of energy efficiency options as presented here is after McKinsey (2009).

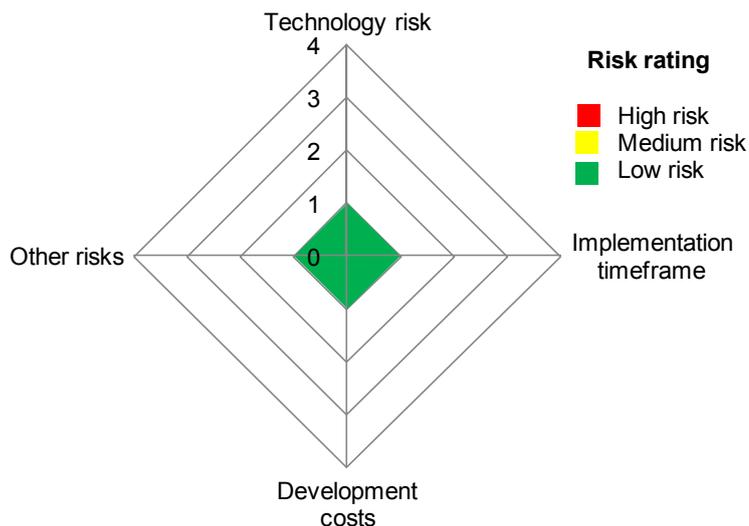
The first option consists of cheaper to implement measures, including continuous improvement measures, preventative and better planned maintenance, the insulation of furnaces, improved process flow (management, logistics, IT-systems), sinter plant heat recovery, coal-moisture control and pulverised coal injection.

The IEA estimate an emissions reductions potential for South Africa of 0.29 tonne CO<sub>2</sub> per tonne steel produced based on BAT (best available technology) (IEA, 2008). Based on current steel production, this equates to approximately 10% emissions reduction potential for these well proven and demonstrated efficiency measures.

Energy efficiency measures can require high upfront investments but McKinsey (2009) estimate that typically between 30 and 50% of these low cost measures can be realisable with limited investments. Such measures lead to both operational cost savings (fuel savings) and GHG abatement. A total capital expenditure of €25 per tonne abated CO<sub>2</sub>-e is estimated for all these efficiency measures (McKinsey, 2009); although the individual capital cost of each measure varies considerably with the particular efficiency measure (e.g. better planned maintenance requires no capital expenditure). Abatement cost per tonne CO<sub>2</sub>-e will also depend on the particular efficiency measure but these low-cost measures are together predicted to have a total abatement cost of €20 per tonne CO<sub>2</sub>-e abated (McKinsey, 2009). However, these options are assigned a “-1” (cost-offset) in the IACC because many of the options are expected to be able to pay for the investment through the fuel and electricity savings achieved in a relatively short timeframe, i.e. to emphasise that these measures will be able to pay for themselves.

The low cost bundle of energy efficiency options include easy to implement, “off the shelf” interventions that have been demonstrated internationally and in South Africa. Many of the efficiency options are not specific to the iron and steel industry, and thus have been proven in a number of other industries with good local experience available, e.g. furnace insulation.

These energy efficiency measures have good standardisation potential across the industry, although the extent of efficiency options available depend on the current baseline of the plant. Many of the steel mills in South Africa are expected to have already implemented one or more of the efficiency measures.



**Figure : Radar risk diagram: iron and steel - energy efficiency (low cost)**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Options mostly generic to heavy industry and have been demonstrated in South Africa.
Implementation timeframe	1	Short timeframe as relatively small interventions in the process.
Development costs	1	No development costs anticipated.
Other risks	1	None identified.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: iron and steel - energy efficiency (low cost)**

Source: Genesis Analytics, 2010

### Coke substitution

This abatement option investigates the potential of fuel switching, i.e. substituting a percentage of the coke used in BF/BOF furnaces with fuel based on biomass (charcoal). Charcoal-based iron-making has been used historically in South America, predominantly in Brazil (IEA 2008).

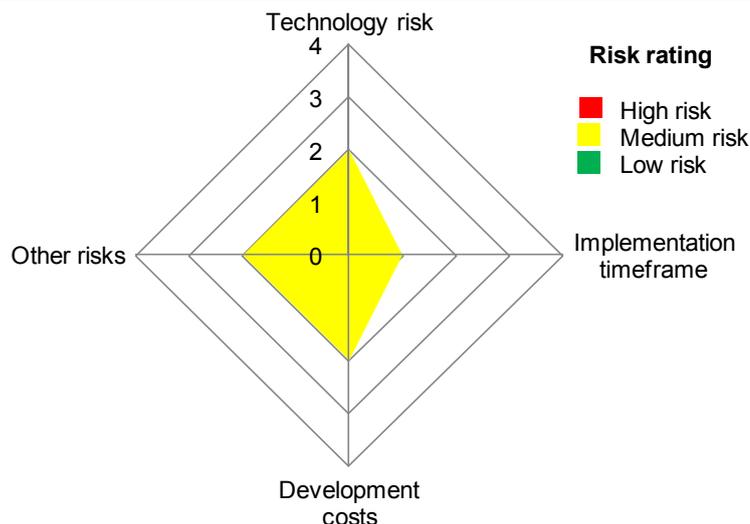
A relatively modest relative abatement potential is estimated for coke substitution. This is based on the McKinsey prediction of global abatement options in the iron and steel sector (McKinsey 2009). It assumes that it is possible to substitute 10% of coke use in the BF/BOF process with biomass-based fuel. It also assumes that the biomass fuel source is carbon neutral, i.e. that there is a 100% carbon intensity decrease from coke to biomass fuel (this may not strictly be the case where virgin rather than waste biomass sources are used, where arguably life cycle carbon emissions should be included for the biomass, e.g. those arising during agriculture).

No capital investment is required for this option and operating cost savings occur as a result of the price difference between coke and biomass-based fuel. Abatement cost per tonne CO<sub>2</sub>-e is estimated to be in the region of -€10 (McKinsey, 009). Fuel switching is therefore assigned a “-1” (cost-offset) in the IACC because it is assumed that the biomass-based fuel will be cheaper than coke (especially if based on a waste biomass source).

Coke substitution is applicable only to the BF/BOF steel processing route. Use of charcoal in blast furnaces is currently limited to small furnaces. With increased research, the size of furnace and percentage of coke that can be substituted is likely to increase, but it is still likely to vary with process specific factors (e.g. with ore grade). Coke substitution therefore has fairly limited standardisation potential across the sector.

A possible co-benefit of coke production is the creation of new industry, that of charcoal production from biomass. It might be possible to base this on waste biomass sources or, for example, on invasive alien vegetation, creating additional value. Job creation in small, rural enterprises is a possibility.

Biomass is identified as a potential GHG mitigation option in many sectors, e.g. electricity generation and bio-fuels. There is therefore expected to be fair competition for biomass sources, and the other sectors, as bigger consumers of biomass, will be stronger competitors. Furthermore, biomass production is somewhat contentious, as when viewed on a life cycle basis, it is not as carbon neutral as claimed, e.g. a fair amount of GHGs are emitted during agriculture and processing. Thus, only waste biomass sources can be viewed as strictly carbon neutral. This, together with fears of diverting agriculture away from food production, has caused many to question high biomass targets. There is therefore some risk associated with substituting coke with biomass (classified in the IACC as “medium”) even though it is technically and economically a viable option.



**Figure : Radar risk diagram: iron and steel - coke substitution**  
 Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	2	Technology used in South America.
Implementation timeframe	1	Short timeframe as merely entails switching input material (no process technology change).
Development costs	2	Development required to test in South Africa conditions and also to perhaps increase furnace size and percentage coke substitutable.
Other risks	2	Possible competition for biomass resources might be a factor (e.g. with bio-fuels). Also completion for land resources (e.g. for food production).
Composite risk score	7	
Overall risk rating	Medium risk	

**Table : Risk ratings: iron and steel - coke substitution**

*Source: Genesis Analytics, 2010*

### Co-generation

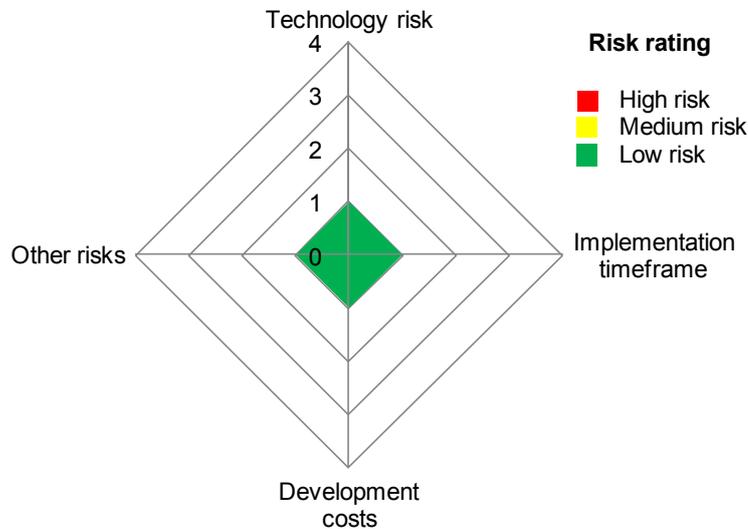
The BF/BOF steel process generates gas as a by-product. In co-generation, this gas is recovered, cleaned and used for power generation at the steel mill. Co-generation can thus be used to reduce the total energy demand of the steel-manufacturing process. Co-generation has significant abatement potential in the South African iron and steel sector, contributing nearly as much as all other energy efficiency measures combined. This relatively high estimate of abatement potential (after McKinsey, 2009) assumes that all indirect energy in BF/BOF plants can be generated by co-generation, allowing them to essentially go off-grid. It is possibly an overestimate for South Africa, since South Africa has a relatively high proportion of the EAF steel manufacturing process, and this technology is only applicable to the BF/BOF steel process. However, South Africa's electricity is also particularly carbon-intensive, so reducing electricity at the steel mill offers significant abatement potential. Its potential is thus strongly linked to the chosen timeframe. It has relatively high potential at present, but dropping in the future, as there is a greater shift towards EAF and as South Africa's electricity grid mix becomes "greener".

Co-generation is a well established technology and can be considered BAT (best available technology) for the integrated route of steel-making. It is estimated to have reasonably short implementation timeframes (around 2 years or less).

Co-generation requires a relatively modest capital investment. This is estimated to be of the order of €70 per tonne steel production capacity. Significant savings in operational costs are realisable depending on the electricity price. Abatement cost per tonne CO<sub>2</sub>-e is estimated to be in the region of -€65 (McKinsey 2009). Here the minus sign suggests that it has a net cost benefit. In this current study co-generation is assigned a "1" in the IACC to reflect an investment that will be able to pay for itself through the electricity savings achieved over a relatively short time period.

Co-generation is applicable to any plant using the BF/BOF processing route, both new build and as retrofit; it therefore has good standardisation potential across the sector.

No other risks or issues are identified for this technology.



**Figure : Radar risk diagram: iron and steel - co-generation**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Proven technology.
Implementation timeframe	1	Customization of existing process technology, so reasonably short timeframes are anticipated.
Development costs	1	No development costs.
Other risks	1	None identified.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: iron and steel - co-generation**

Source: Genesis Analytics, 2010

### Energy efficiency (moderate cost)

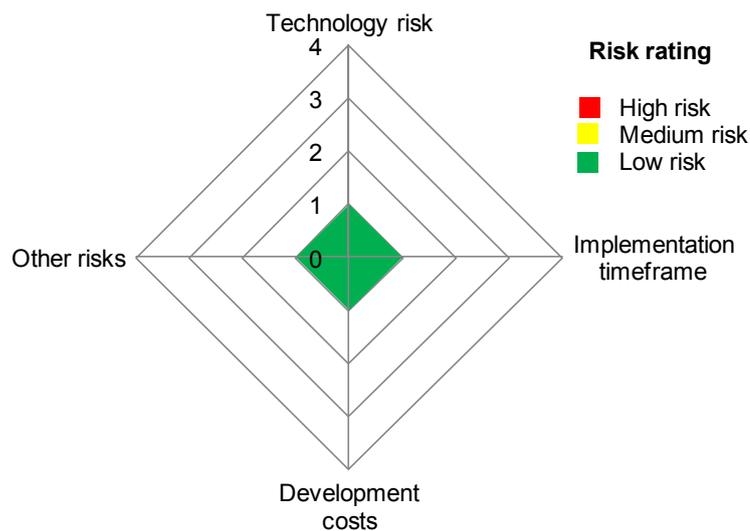
With respect to the “moderate” cost bundle of energy efficiency measures (requiring medium to high capital cost investments), these include oxygen injection into EAF, scrap preheating, flue gas monitoring systems, improved recuperative burners, improved motor and pumping systems, BOF gas recycling and advanced heat recovery options. McKinsey (2009) estimate a low 0.2% efficiency increase per annum for this bundle of options because the easy to implement options are already assumed to have taken up much of the efficiency “slack” and lower and lower returns are realisable as absolute performance improves.

A total capital expenditure of €45 per tonne abated CO<sub>2</sub>-e is estimated for the medium-high cost bundle (after McKinsey 2009); although again the individual capital costs for each measure will vary. Abatement costs will also vary with the particular efficiency measure, but the total abatement cost for this bundle of options per tonne CO<sub>2</sub>-e is estimated to be in the region of €40 (McKinsey 2009). However, these options are assigned a “1” (low cost) in the IACC to better reflect that these measures have significant cost savings associated with them. However, they are not placed in the “cost offset” category because their much higher investment costs mean that it will take a fair amount of time to recoup the investment through the fuel or electricity savings achieved (5+ years).

The moderate bundle of energy efficiency options include interventions that have been demonstrated internationally and in South Africa, as well as a few that are still undergoing development or have not yet been proven in South Africa. Given strong efficiency drivers internationally it is expected that these technologies will move towards becoming standard in the industry over time.

These energy efficiency measures have good standardisation potential across the industry, although the options do vary with the particular steel processing route chosen (e.g. different options for BF/BOF and EAF). As the less efficient process, the BF/BOF processing route tends to have more efficiency options open to it.

Energy efficiency measures are generally a “win-win” situation, improving environmental performance and decreasing energy costs. Lower operational costs will help to make South African steel more competitive in a highly competitive export markets. There are also indications that increasingly a higher premium will be placed on “green” steel, e.g. through carbon footprint labels, also helping to improve international market access for South African iron and steel.



**Figure : Radar risk diagram: iron and steel - energy efficiency (moderate cost)**

*Source: Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	Options mostly generic to heavy industry and have been demonstrated in South Africa.
Implementation timeframe	1	Short timeframe as relatively small interventions in the process.
Development costs	1	No development costs anticipated.
Other risks	1	None identified.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: iron and steel - energy efficiency moderate cost**

Source: *Genesis Analytics, 2010*

### Direct casting

Technology changes in the post refining process steps (e.g. direct casting and continuous casting) reduces energy consumption in these steps by 18% on average (McKinsey 2009). These downstream process steps are estimated to provide approximately 3% of the total abatement potential for the sector globally (McKinsey, 2009).

Continuous casting is where, rather than casting into ingots, products are cast continuously. This contributes very little abatement potential as many steel plants in South Africa already use continuous casting. In 2007, the breakdown in crude steel production in South Africa was 98% continuously cast slabs and billets, 0.5% ingots and 1.2% liquid steel for castings (Worldsteel, 2009). Whilst retrofitting is unlikely, all new plants will use continuous casting technologies as other methodologies have been outdated since the 1950s.

Continuously cast slabs, billets or blooms then have to be reheated when they are later rolled into final shape. Direct casting (sometimes also called strip casting) integrates the casting and hot-rolling of steel into one step, thereby reducing the need to reheat the steel before rolling it. Near net-shape casting and thin strip casting are two recently developed direct casting techniques. This technology leads to considerable savings of capital and energy. Compared to a current, state-of-the-art casting and rolling facility, the specific energy savings of direct-cast technologies are estimated at about 90% (between 1 and 3 GJ per tonne of steel). Direct casting also leads to indirect energy savings because of reduced material yield losses (thin-slab casting gives a 98% yield; thin-strip casting gives a 99% yield) (IEA 2008). These IEA (2008) estimates of energy savings are considerably more than the McKinsey estimate (18%). This suggests that the abatement potential assigned to direct casting in the IACC might be an underestimate and that considerable further potential might be possible developments continue on their current trend.

Direct casting is only applicable to new build so has a relatively long implementation timeframe.

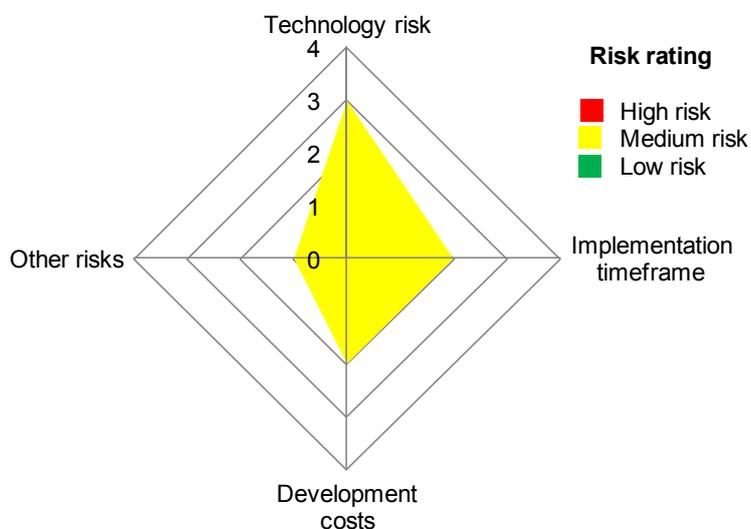
The technology is in the demonstration phase with further R&D still required. The main challenges for the further development of direct casting technology relate to the quality of the product and its usability by steel processors and users. Increased reliability, control and the

adaptation of the technology to larger-scale production units will benefit its wider application. It is predicted that the direct casting technique will go commercial by 2015 (IEA 2008).

Capital costs are fairly high, and are estimated at €80 per tonne steel<sup>40</sup> by McKinsey (2009) and between \$150 and \$200 per tonne by IEA (2008). However, it is notable that these capital investment costs are 30% to 60% lower than for a traditional continuous caster and hot-rolling mill (about \$70/t lower) (IEA 2008).

Abatement cost per tonne CO<sub>2</sub>-e is estimated to be in the region of €25 (McKinsey, 2009). Technology changes in post-refining process steps are therefore assigned a “1” (low cost) in the IACC because it is assumed that, even though energy savings are possible as a result of the change, the capital investment is such that the time to recoup the investment through the fuel and electricity savings is medium to long term.

The option has good standardisation potential across the industry and it is likely that all new build will be equipped with such technology.



**Figure : Radar risk diagram: iron and steel - direct casting**

*Source: Genesis Analytics, 2010*

<sup>40</sup> Note that in McKinsey (2009) the units are based on the annual capacity of the direct-casting facility (not on steel production)

Rating criteria	Rating	Explanation
Technology risk	3	Technology is in R&D / demonstration phase in a number of countries including the US, Italy, Germany, Canada, Austria and Japan.
Implementation timeframe	2	New plant build so 2- 5 years to implement.
Development costs	2	Low development costs anticipated (R&D well advanced internationally).
Other risks	1	None identified.
Composite risk score	8	
Overall risk rating	Medium risk	

**Table : Risk ratings: iron and steel - direct casting**

Source: *Genesis Analytics, 2010*

### Smelt reduction

Small-to-medium-scale iron-making facilities can be made appreciably more efficient through new reactor designs for smelt reduction that substitute a single process for the ore preparation, coke-making and blast furnace iron-making steps of a traditional ore-based facility. Theoretically, emissions savings result because less fuel is used when integrating the preparation of coke with iron-ore reduction. Recent smelt reduction development work has led to the commercially available COREX plant design, which uses coal fines and agglomerated ore. This concept is only marginally economic, but it is the only smelt reduction process in current industrial use, in South Africa, Korea and India (IEA, 2008). More recent smelt reduction designs, such as the FINEX design being developed by POSCO in Korea, aim also to eliminate ore agglomeration. HiSmelt, another smelt-reduction design using ore fines, may possibly have a better energy balance than FINEX. The first commercial plant of this type is being built in Australia, with other major research projects launched in Japan (a direct iron-ore smelting process), in Europe (a cyclone-converted process) and in the United States.

McKinsey (2009) estimate approximately 8% less direct energy is required in smelt reduction processes over traditional blast furnaces. Other reports, however, suggest that the COREX process has higher emissions than blast furnaces, particularly when taking into account indirect emissions associated with electricity production. However, COREX technologies can provide GHG mitigation benefits when the off gases are used for electricity production, replacing electricity from the grid. Further credits can be achieved through using slag from the process to replace cement (Hu et al, 2009, Scaife et al, 2009, Spanig, 2009).

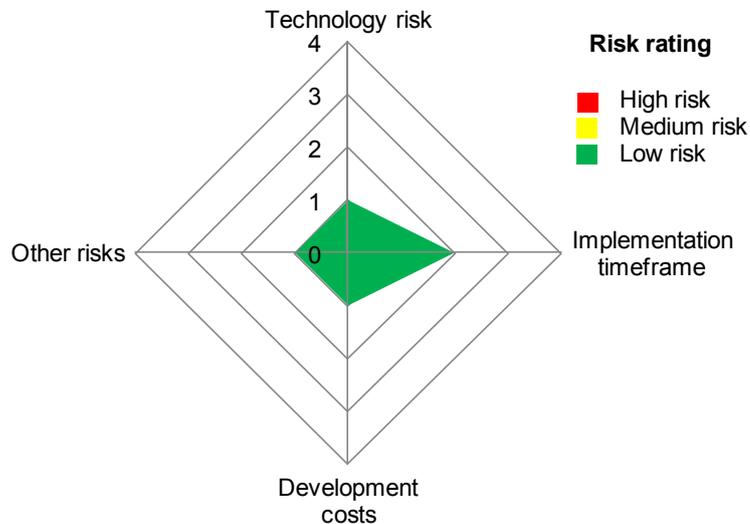
Smelt reduction, such as the COREX process, is included here as an abatement option assuming it is utilised in conjunction with electricity production and slag recovery. It is designated a "low risk" option in this analysis as the COREX process is demonstrated in South Africa. However, the technology is still advancing and further abatement potential will become available with further development and integration with electricity production. It seems likely that the process will be sold as a proprietary process technology, i.e. that the reactor modules will be bought, rather than the development cost borne by South African industry.

Capital costs are high and are estimated to be around €100 per tonne of steel (on an annual production capacity basis), excluding the cost of electricity generation infrastructure.

Abatement cost per tonne CO<sub>2</sub>-e depends very much on whether the smelt reduction is integrated into new build or whether it is a retrofit. The former is fairly cost effective at around €25 per tonne CO<sub>2</sub>-e, whilst the latter is estimated to be in the region of €45 (McKinsey, 2009); however the McKinsey estimates exclude cost and potential for electricity generation. Smelt reduction is therefore assigned a “2” (medium cost) in the IACC because it is assumed that, even though 8% energy savings are possible as a result of the change, the capital investment is such that the time to recoup the investment through the fuel and electricity savings is long term.

Smelt reduction is an abatement option that only applies to the BF/BOF processing route, i.e. it has potential in only about half of the currently installed steel manufacturing capacity. Furthermore, it is most applicable to small-to-medium scale facilities. It therefore has little standardisation potential across the industry.

Smelt reduction, with its richer CO<sub>2</sub> off-gases, especially when nitrogen free (i.e. technologies using oxygen rather than air), would be an enabling technology for CCS.



**Figure : Radar risk diagram: iron and steel - smelt reduction**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Technology demonstrated in South Africa.
Implementation timeframe	2	Process technology change so 2- 5 years to implement.
Development costs	1	No development costs anticipated.
Other risks	1	None identified.
Composite risk score	5	
Overall risk rating	Low risk	

**Table : Risk ratings: iron and steel - smelt reduction**

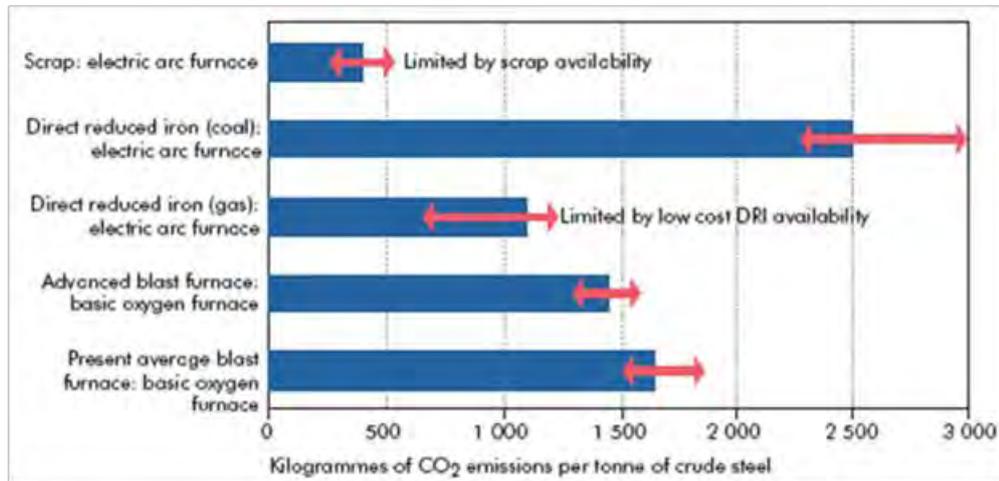
Source: *Genesis Analytics, 2010*

### BF/BOF to EAF

Over the last several decades, Electric Arc Furnace (EAF) production, which relies on scrap as one of its feeds, has grown world-wide and BOF production has held steady. This trend has also been true for South Africa, with BF/BOF declining from a share of 65% of crude steel production in 1998 to 50% in 2007. Globally BOF is still the most widely used process, largely due to local limitations on scrap availability, one of the prerequisites for EAF. EAF production is higher in the United States and certain European countries, where more scrap is available than elsewhere. Direct Reduced Iron (DRI)/EAF production (which uses gas or coal rather than scrap) is widespread in the Middle East, South America, India and Mexico. Most DRI production is based on cheap, stranded natural gas, except in India, where it is largely coal-based (IEA, 2008).

The Scrap/EAF route is much less energy-intensive (4 GJ/t to 6 GJ/t) than the BF/BOF route (13 GJ/t to 14 GJ/t). This is because there is no need to reduce iron ore to iron and it cuts out the need for the ore preparation, coke-making and iron-making steps. Thus, significant energy savings can be made by switching from the BF/BOF to the Scrap/EAF route (IEA 2008). The large difference in emissions intensity between these processes is shown in Figure , which suggests a potential for emission reductions of between 50% and 95% (excluding any reductions that might be achieved through CO<sub>2</sub> capture from blast furnaces), although this full potential might not be realisable because the overall potential of EAF is limited by scrap availability. Using gas based DRI yields some, but far more limited, emissions reductions.

Coal based DRI yields emissions higher than the average BF/BOF route. DRI/EAF therefore has very limited potential in South Africa. Coal-based DRI cannot be seen as an abatement technology, whilst gas supply is relatively limited and expensive in South Africa. This means that gas based DRI is unlikely to play a major role in abatement in South Africa.



**Figure : CO<sub>2</sub> emissions per tonne of crude steel produced by technology**

Source: IEA 2008

South Africa already has a high percentage of EAF production relative to many countries worldwide. 58% of USA crude steel is produced in EAF, and whilst the EU 15 average is only 43%, certain European countries, e.g. Norway and Switzerland, have 100% EAF (Worldsteel, 2009).

Current research suggests that the gap between apparent steel consumption and scrap production, even when accounting for storage, suggests considerable further potential. However, the absence of detailed statistics makes it impossible to determine the scale of this potential (IEA 2008). A better understanding of the global steel materials balance is needed to assess the additional recycling potentials. South Africa currently exports 752 kt scrap per year (figure for 2007, Worldsteel, 2009) and has a steel can recycling rate of 70%<sup>41</sup>. This suggests only limited potential for increased recycling and hence increased EAF in South Africa.

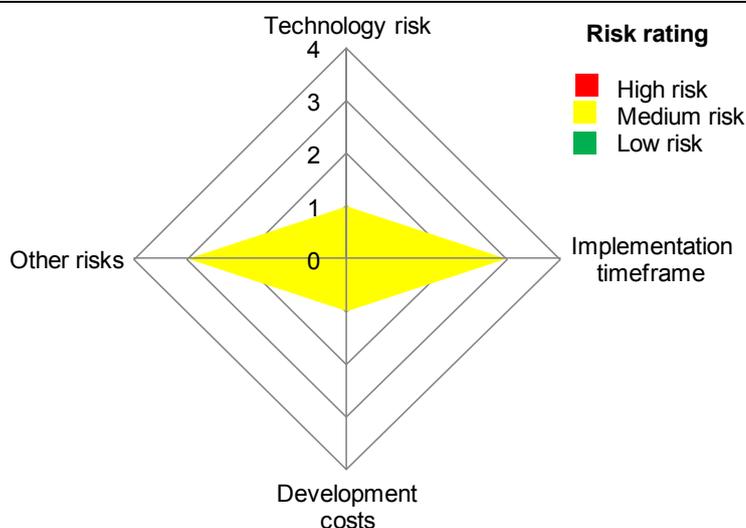
Switching from BF/BOF to EAF involves an entirely new steel plant being built, so capital costs are high. McKinsey (2009) estimate a capital cost difference of €200 per tonne steel annual production capacity. This estimate is for EAF-DRI, but capital costs are expected to be similar. However, the estimate of abatement cost per tonne CO<sub>2</sub>-e for EAF-DRI (in the region of €50) is likely to be a large overestimate for scrap EAF, as EAF-DRI is significantly more expensive. No estimate for scrap EAF could be found.

Switching process technology is only applicable to new build, and is likely to happen as a slow migration as capacity is expanded. It therefore has limited standardisation potential across the industry.

The abatement potential estimated in the IACC for increased steel recycling and switching to EAF is based on GHG emissions from the iron and steel manufacturing process alone. This is actually an underestimate of the true GHG abatement potential of this option, as if viewed on a

<sup>41</sup> The ranges indicate CO<sub>2</sub>-free and coal-based electricity.

life cycle basis, considerably greater savings are achieved. This is because increased steel recycling also reduces the emissions from mining and processing iron ore. On a life cycle basis, 1kg of primary steel (blast furnace) has a GHG potential of approximately 2.5 to 4 times that of 1kg of secondary steel (EAF) (Ecoinvent, 2006). Furthermore, as South Africa's electricity generating mix becomes "greener", so will the abatement potential of this option increase even further.



**Figure : Radar risk diagram: iron and steel - BF/BOF to EAF**  
 Source: Genesis Analytics 2010

Rating criteria	Rating	Explanation
Technology risk	1	Technology long been in use in the iron and steel industry
Implementation timeframe	3	New plant build so greater than 5 years to implement
Development costs	1	No development costs anticipated
Other risks	3	Risk that sufficient steel scrap is available (requires finding ways to increase steel recycling)
Composite risk score	8	
Overall risk rating	Medium risk	

**Table : Risk ratings: iron and steel - BF/BOF to EAF**  
 Source: Genesis Analytics, 2010

### Carbon capture and storage (CCS)

As discussed previously in this report, carbon capture and storage (CCS) is a potential future technology for the sequestration of CO<sub>2</sub> emissions from large emission point sources. In geological sequestration, CO<sub>2</sub> is captured and injected into deep geological formations where it is to be permanently stored. Blast furnaces are the largest source of direct CO<sub>2</sub> emissions in the steel-making process, and are thus the prime candidates for CCS. If blast furnaces were

redesigned to use oxygen instead of enriched air and to recycle top gases, their emissions would be sufficiently rich in CO<sub>2</sub> to enable it to be captured with physical absorbents. However, the oxygen-injection blast furnace is not yet proven. Smelt reduction (i.e. substituting a single process for the ore preparation, coke-making and blast furnace iron-making steps of a traditional ore-based facility) is also an enabling technology for CCS because its off-gases have a higher concentration of CO<sub>2</sub> (provided the process uses oxygen) (IEA 2008). An alternative to the use of physical absorbents is to use chemical reactions to “clean” the exhaust gases of CO<sub>2</sub>. This method would be applicable to conventional blast furnaces, but is more expensive. The carbon capture process requires energy and decreases the energy efficiency of the plant; increasing energy use by about 0.24 MWh per tonne CO<sub>2</sub> separated (McKinsey, 2009).

CCS, used together with oxygen injection, could result in an 85% to 95% reduction in CO<sub>2</sub> emissions (IEA, 2008). McKinsey (2009) estimate that the technology will be suitably developed to allow implementation by 2021, although in South Africa this could be later.

Initial indications are that South Africa has relatively limited storage potential (i.e. that there are only a limited number of geologically suitable sites). The LTMS study considers two scenarios for CCS in the power sector (2Mt and 20Mt). The higher estimate of CCS storage potential is assumed here (20Mt), and it is further assumed that iron and steel would take up approximately 10% of this (it is assumed that power generation will take up the bulk of the CCS storage area available in SA, since emissions from iron and steel processing account for less than 10% of total GHG emissions in SA). This is likely to be an overestimate, since there is potential that more SA steelmaking will switch from BF/BOF to EAF (where CCS is not applicable).

It is very difficult to cost CCS as it is very much still in development. Most sources assume very high costs initially, but predict that these will come down in time. McKinsey (2009) assume capital costs in the region of €600 per tonne new build CO<sub>2</sub> annual abatement capacity, decreasing to €200 in 2030. In addition, they predict overhead costs of 15 € per tonne CO<sub>2</sub> abated, decreasing to €6 per tonne in 2030. These costs apply to new build and they assume slightly higher costs for retrofit – €19 and €8 respectively. Transport costs are estimated at €7 per tonne (in 2030) and storage costs at €12 per tonne.

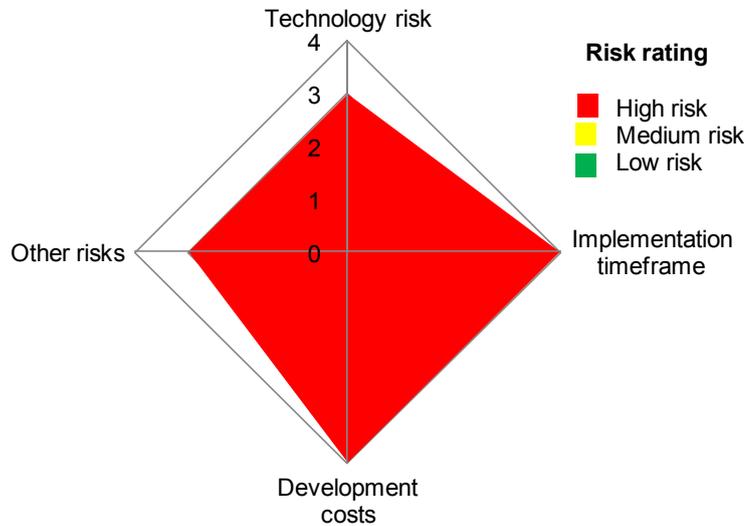
The LKAB experimental blast furnace in Sweden has started testing various CCS configurations for a small-scale blast furnace (with a capacity of only one to two tonnes of iron per hour), with the aim of running a demonstration plant in the period 2015 to 2020. CCS using physical absorbents is likely to be more cost-effective than CCS using chemical absorbents, but blast-furnace gas-reforming and chemical absorption using waste heat is being investigated in Japan, Korea and China (IEA, 2008).

Current expert estimates suggest that CCS for blast furnaces would cost around \$40/t CO<sub>2</sub> to \$50/t CO<sub>2</sub> in capture, transport and storage costs, excluding any furnace productivity changes that could have a significant positive or negative impact on the process economics (IEA 2008). The marginal investment costs would be higher for retrofits than for new builds. McKinsey (2009) predict abatement costs per tonne CO<sub>2</sub>-e of around €40 for new build and €50 for retrofits (McKinsey, 2009). CCS is therefore assigned a “2” in the IACC, as it will be possible to achieve at the individual company level.

The technology is only relevant for steel plants following the BF/BOF processing route, and then only those of sufficient scale (they must be sufficiently large sources of emissions for the

technology to be viable). The plant must also be within reasonable transport distance of suitable storage sites. Retrofit is possible, but McKinsey estimate this is possible at only 40% of plants due to technical constrains (global estimate, particulars not know for South Africa).

CCS is an immature technology that has yet to be proven industrially and commercially viable. In South Africa geologically suitable sites are yet to be found.



**Figure : Radar risk diagram: iron and steel – CCS**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	3	Technology is being tried in pilot phase overseas.
Implementation timeframe	4	Technology will be new with many issues to cover, e.g. finding and securing suitable CO <sub>2</sub> storage sites, so anticipate more than 10 years to implement.
Development costs	4	Considerable development costs required at all phases of the technology (recovering the CO <sub>2</sub> , transport and securing storage sites). Development costs will not be borne by the steel industry alone as CCS has potential in other industries too (e.g. coal-fired electricity and CTL). Public funding and research co-ordination likely to be required.
Other risks	3	Long term storage potential of CCS not completely proven (possibility of high leakage rates). Also CCS as yet untried in South Africa (suitable sites still need to be identified).
Composite risk score	14	
Overall risk rating	High risk	

**Table : Risk ratings: iron and steel – CCS**

Source: Genesis Analytics, 2010

## **7.6.6. OPPORTUNITIES ARISING FROM CLIMATE CHANGE MITIGATION**

The building industry has been a particular player in the movement towards “green” or sustainable materials. Steel, as a very significant construction material, is therefore under scrutiny. Many of the methods developed for assessing “green buildings” employ a life cycle basis. The carbon footprint of steel is therefore likely to play an increasingly important role in competitive export markets. South African steel is already at a disadvantage because of our very carbon-intensive electricity generating mix. There is however, significant potential for abatement in the iron and steel industry through relatively cost effective energy efficiency measures (e.g. co-generation), which, if implemented, will make South African steel more competitive. Furthermore, South Africa already has a high percentage of EAF relative to most developing nations. If steel recycling can be increased further to allow an even higher percentage of EAF, South African steel could become very competitive on its “sustainability” rating.

## **7.7. NON-FERROUS METALS CASE STUDY**

### **7.7.1. SECTOR DEFINITION AND DATA ISSUES**

The non-ferrous metals sector study explores mitigation technology options which fall under SIC code 3520 – the manufacture of basic precious and non-ferrous metals. The metals considered here include nickel, copper, lead, zinc, aluminum, titanium, gold, silver, vanadium, magnesium and the platinum group metals (PGMs)<sup>42</sup>.

As identified above, it is impossible to obtain baseline emissions data for the sector as a whole, due to the aggregation of data within the various reference sources consulted. This is further compounded by sensitivity around proprietary process technology, which results in companies limiting information released into the public domain. Some of the bigger companies release statistics in their environmental reports, but this tends to be company- wide and very aggregated.

With respect to identification of mitigation technologies, unlike some of the other sectors analysed for this study, few sector specific mitigation options were identified. The primary reason proposed for this is that, as identified previously, direct emissions are negligible compared to emissions from electricity supplied to the sector, suggesting that the biggest gains to be made are from accessing cleaner supplies of electricity.

There is little quantitative information on either mitigation potential or costs of mitigation specific to the sector.

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<sup>42</sup> It is noted that there are different interpretations of what falls into the classification of “precious” and “non-ferrous metals”. In particular, although they are included in SIC code 3520 chrome and manganese are almost always considered as ferrous metals, and are thus excluded from this current analysis.

### **7.7.2. SECTOR CONTEXT**

The sector is the fifth largest industrial consumer of energy and emitter of CO<sub>2</sub> internationally and in 2005 accounted for 3% of world industrial energy use and 2% of energy and process CO<sub>2</sub> emissions (IEA, 2008).

According to statistics published by the DME (2008), South Africa holds the world's largest reserves of ores of platinum group metals (88%), gold (40%) and vanadium (32%). It is also prominent in terms of reserves of titanium (18%) and zirconium (19%). Despite South Africa's contribution to the world's mineral supply having diminished in many sectors over the period 1997 to 2007, the country remains the leading producer of platinum group metals (60%), gold (13%) and vanadium (39%). South Africa is also among the top three producers of titanium minerals (18%) and zircon (42%).

The mining and minerals processing sector is a significant contributor to the country's economy. Apart from the direct contribution of approximately 7% contribution to GDP in 2006, there is also an indirect multiplier effect on the gross domestic product. Multiplier effects include goods and services provided to the industry (2.2% of GDP), value added beneficiation of mining outputs (1.7% of GDP – including power generation, production of processed minerals products and manufacture of fabricated materials such as stainless steel); and induced effects through export earnings, consumption multipliers and additional earnings of employees in related sectors (6.4% of GDP). Taking all of these factors into consideration suggests a “real” contribution by mining to GDP of 17.3% in 2006 (Chamber of Mines, 2007). It is noted that these figures refer to the mining and minerals processing sectors as a whole and are included here for illustrative purposes; it has not been possible to separate out from these the contribution of the non-ferrous metals sector.

Various processing routes are available for recovery and purification of these metals from ore bodies. These can broadly be categorised into those which use heat (or pyrometallurgical processes) and those which solubilise metals in a solvent followed by electrowinning (hydrometallurgical processes). Table , based partially on Norgate, Jahanshahi and Rankin (2006) identifies the most common processing routes for a number of non-ferrous metals.

<b>Metal</b>	<b>Process</b>
Nickel	Flash furnace smelting and Sherritt-Gordon refining Pressure acid leaching and solvent extraction/electrowinning (SX/EW)
Copper	Smelting/converting and electro-refining Heap leaching and SX/EW Leaching followed by SX/EW
Lead	Lead blast furnace Imperial smelting process
Zinc	Electrolytic process Imperial smelting process
Aluminium	Bayer refining, Hall-Heroult smelting
Titanium	Becher and Kroll processes
Gold and silver	Concentration or leaching, roasting or bio-oxidation, and smelting Concentration followed by flash smelting

**Table : Non-ferrous metal processing routes**

*Source: Norgate, Jahanshahi and Rankin 2006*

Technological change is slow within the sector, with few major breakthroughs on the horizon. As with mining, technological development is more geared towards making existing processes more efficient than developing whole new processes, in other words there tend to be relatively small, low cost incremental changes. Closed-loop recycling is a potential big breakthrough in the future (i.e. there would be no need for new mining as all metal would be collected and reused), but this will require significant new infrastructure and legislation, included that encapsulated in extended producer responsibility, where producers must take back old product and disassemble to reuse or recycle metal parts. It would also cause significant restructuring of the mining and metals sectors.

Larger companies are more likely to research energy efficiency and clean technology options, but many of the R&D labs have been closed and the research outsourced or consolidated. The reasons for this are varied but include attempts at streamlining activities and a slowdown in growth in the sector. The large companies are also more likely to implement mitigation measures because many are international companies (e.g. with annual environmental or sustainability reports) so have increased pressure to demonstrate a commitment to mitigation, and also because mitigation measures that might be required legislatively in one country they operate in (e.g. Australia) are rolled out to all their operating regions. However, in general there is also huge inertia within the mining and minerals processing sectors, both in the mind-set of the players and also because it is not easy to change technologies once they are in place.

### **Market structure**

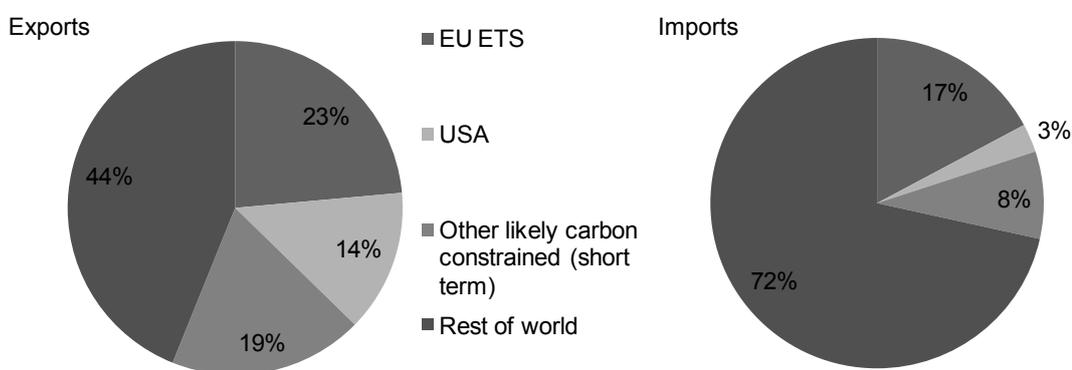
The non-ferrous metals sector in South Africa is structured similarly to the mining sector, with a few dominant players and a few small players, particularly BEE companies. Some of the larger

companies processing non-ferrous metals in South Africa include Anglo American (platinum group metals, gold, nickel, copper, zinc and lead), Exarro (zinc, titanium, and zircon), BHP Billiton (aluminum) and Xstrata (platinum and vanadium), Impala Platinum and Aquarius Platinum. South Africa has two primary aluminum smelters in Richards Bay owned by BHP Billiton. A further 720 000 ton per annum capacity aluminum plant at Coega in the Eastern Cape has been given some consideration although the likelihood of this going ahead is unknown and probably small.

### International trade

The sector is very export-intensive and in 2007, 56% of exports went to countries which either have active carbon policies in place, or are expected to in the near future. This is a concern for South Africa as metals produced in the country are likely to have a high carbon footprint relative to those produced elsewhere, due to the carbon-intensive nature of electricity production and the contribution of indirect electricity emissions to the sector's footprint.

In terms of imports, these are less skewed towards countries who will be concerned about carbon leakage at only 28% of total imports.



**Figure : Concentration of trade in countries with carbon policies (2006): Non-ferrous metals**

Source: TIPS SADC trade database 2009

### 7.7.3. GHG EMISSIONS

Sources of greenhouse gases include CO<sub>2</sub> emissions from furnaces employing coal or coke as a reductant and emissions associated with the electricity and gas consumed in processing. CO<sub>2</sub>, methane and VOCs are also emitted from heavy equipment burning diesel fuel. The IEA (2008) identifies that direct emissions are dwarfed by indirect emissions from power generation, and as such the largest mitigation potential in the sector is going to be from changing to cleaner electricity sources.

Non-ferrous metals accounted for some 9.3% of South Africa's total final electricity demand in 1998 (14 770 GWh) (Blignaut et al 2005), which translates to electricity related emissions<sup>43</sup> of 12.72 Mt CO<sub>2</sub>-e. This work also estimates emissions of 0.053Mt CO<sub>2</sub>-e in 1998 from fuel combustion (crude oil and gas), giving a total emissions of 12.77 Mt CO<sub>2</sub>-e from the sector in 1998. The South African Energy Balance, on which the work of Blignaut was based, reports that electricity consumption in the sector increased to 18 640 GWh by 2006, indicating that emissions would have also risen by about 26% to about 16 Mt CO<sub>2</sub>-e by that year.

DEAT (2009) suggests process related emissions from the "non-ferrous" sector of 3.7 Mt CO<sub>2</sub>-e in 1994. However this figure excludes electricity, and only considers aluminium, lead and zinc.

In addition, Perfluorocarbons (PFCs) and sulfur hexafluoride (SF<sub>6</sub>), greenhouse gases with high global warming potentials, are emitted from aluminium smelters (those employing older technology). Approximately 9% (or 2.18 Mt CO<sub>2</sub>-e.) of the total emissions attributed to metals production in South Africa is attributed to Perfluorocarbons from aluminium production (Winkler 2007). For the base year considered in the LTMS report (2003), aluminium production is calculated to have a GHG emission intensity of 2320 kg CO<sub>2</sub>-e. per ton product.

### 7.7.4. CURRENT SECTOR RESPONSE TO CLIMATE CHANGE

Current mitigation initiatives in the sector are largely around energy efficiency measures. The large multinational mining houses all have sustainability departments which produce environmental reports, and many of these make some effort towards reporting their carbon footprint or GHG emissions. These are primarily released for benchmarking, i.e. to show footprints have declined year on year, and are not particularly useful for other purposes because they tend to be highly aggregated, presenting cumulative greenhouse gas emissions over all products or business units. Some emission reduction initiatives are being driven by overseas legislation (particularly that in Australia), which companies then make efforts to roll out to all of their world wide facilities.

The biggest threats to the sector are the current global economic downturn, international competition (particularly from China with very low environmental, health and safety compliance costs), and resource issues (e.g. water and to a lesser degree land competition). Future opportunities include increasing process efficiency and exploiting low grade ores which is made possible by improved beneficiation technologies.

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<sup>43</sup> This is using an emission factor of 861 kg CO<sub>2</sub>/MWh as calculated in DEAT (2009)

It is noted that no activities towards emissions reductions which fall under the CDM banner have been identified for the sector.

## 7.7.5. SECTOR MITIGATION OPPORTUNITIES

### 7.7.5.1. IACC

The IACC for the non-ferrous sector is shown below. The most significant mitigation opportunity in the sector is that of increased recycling of end-of-life metals, given that recycling uses significantly less energy on a life cycle basis than primary metal production. Increased recycling is a low risk opportunity which represents a cost offset. The second biggest opportunity is that of technology change towards flash smelting (in the case of pyrometallurgical processing) and reduced requirements for ore size reduction (in the case of hydrometallurgical processing). These opportunities may require significant capital investment and some technical development to determine their applicability to different ore types.

A mitigation opportunity unique to this sector is that of PFC capture from aluminium plants. Although the total emissions are small, PFCs have a very high GWP potential. Technologies for reducing their generation are well established (hence the "low" risk rating) and there is currently activity underway in the sector globally, including in South Africa, to reduce these emissions. The other opportunities considered in this sector are energy efficiency, which is also low risk and represents a cost offset, and fuel substitution or demand reduction which is well established but may require some capital investment.

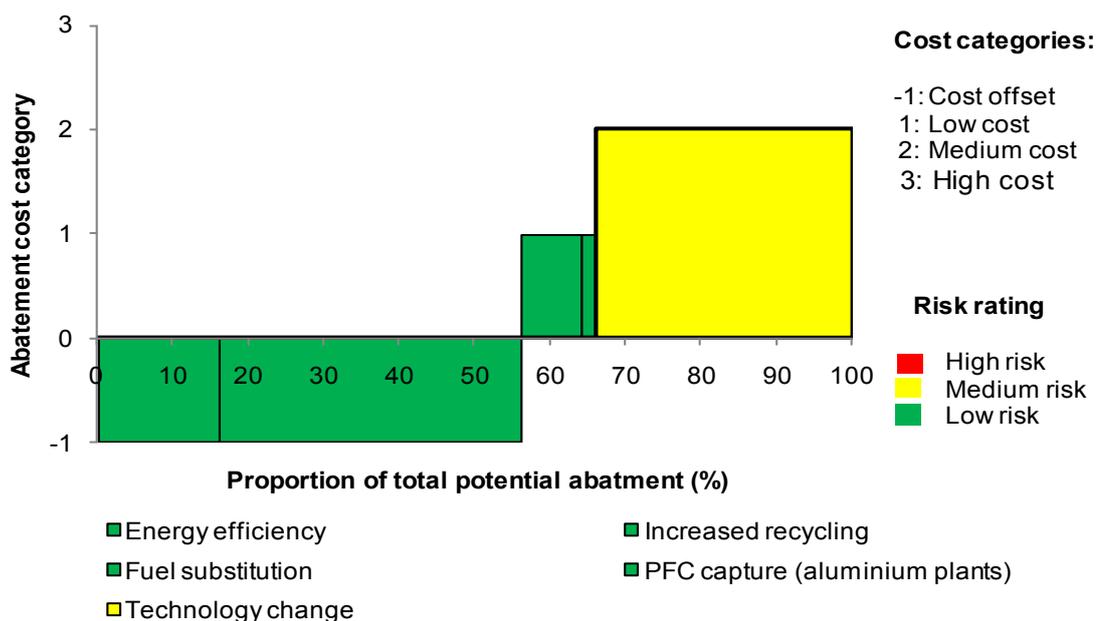


Figure : IACC: Non-ferrous metals<sup>44</sup>

Source: Genesis Analytics, 2010

<sup>44</sup> For details of how to read the IACC, see footnote in section .

## 7.7.5.2. DESCRIPTION OF ABATEMENT OPTIONS

### Energy efficiency

As stated previously, the majority of emissions associated with the non-ferrous metals sector relate to electricity supply to the sector. As such, reducing demand for electricity will contribute to greenhouse mitigation. A number of opportunities are identified for improving energy efficiency in the sector. These include:

- Better preventative maintenance, to ensure equipment is operating as close to optimal conditions as possible;
- Replacement of motors on pumps and fans with more efficient, variable speed, and appropriately rates drives. Installation of power factor correction equipment;
- Efficiency increases in provision of utilities, including upgrading/replacement of burner systems with more efficient equipment; and,
- Maximizing the use of the exothermic energy generated by the reactions within the smelters. This latter opportunity is relatively well optimised in modern flash smelting technologies

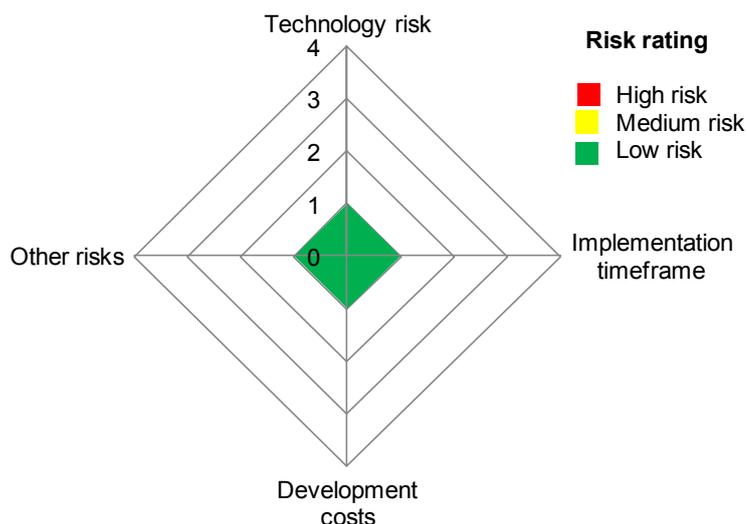
It is impossible to provide the capital costs associated with this broad range of interventions as costs depend on the type of energy efficiency intervention, as well as the type of process and plant configuration. In constructing the IACC however, it is suggested that these interventions are relatively low cost and will have very short payback periods, thus suggesting an indicative cost of “-1”, suggesting they will generate revenues due to savings in a fairly short period of time.

Furthermore, the risk profiles associated with these options are low as they are well established both locally and overseas, require little or no development and will not have any unforeseen other risks. Many of the options can be standardised across the various types of metals and across operating companies.

The actual abatement potential associated with energy efficiency is fairly low compared to the other mitigation technology options presented here.

It is suggested that one of the main reasons why many of the energy efficiency measures available to the sector are not implemented (with the exception of that associated with exothermic energy from reaction in the smelters) is that the economic gains from efficiency measures applied to an existing plant are relatively small compared to overall operating costs, and so are not seen to be worth the effort. Thus there are insufficient pressures or drivers for companies to see the need to implement these. A further limitation is that such initiatives are not core business, and many mining communities tend to just keep on with “business as usual”. New plants are, however, expected to be more efficient.

Co-benefits associated with energy efficiency relate to decreasing other air pollution and solid waste generation impacts normally associated with electricity production.



**Figure : Radar risk diagram: non-ferrous metals - energy efficiency**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Energy efficiency technologies in industrial processing are well established and utilized around the world. As such low technology risk is envisaged.
Implementation timeframe	1	Technologies considered here relate to minor process modifications for which implementation timeframes are short.
Development costs	1	Well-established technologies suggest low or no development costs for implementation.
Other risks	1	No other risks to these technologies are foreseen.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: non-ferrous metals - energy efficiency**

Source: Genesis Analytics, 2010

### Increased recycling

Recycling of metals consumes considerably lower amounts of electricity than production from primary ores as it removes a number of the process steps including mining, size reduction of ores, primary processing and purification – metal species which have not been alloyed can be readily melted and reprocessed with limited energy inputs. Alloys can also be reprocessed, although this is usually back into alloys. South Africa already recycles approximately half of the total aluminium produced, so the infrastructure for recycling is well established.

The following figures give an indication of the savings in kg CO<sub>2</sub>-e of producing 1kg of secondary (recycled) metal versus 1kg of primary metal. These figures are on a life cycle basis, i.e. are from extraction of the primary metal through to disposal and do not just reflect

the difference in the refining process. These figures should be taken as indicative only because they are strongly dependent on the technology used in the primary refinery, and also because in some cases the primary metal refinery is in South Africa whilst the secondary metal refinery is in Europe. Nonetheless the difference is very significant for many metal products (Ecoinvent 2006):

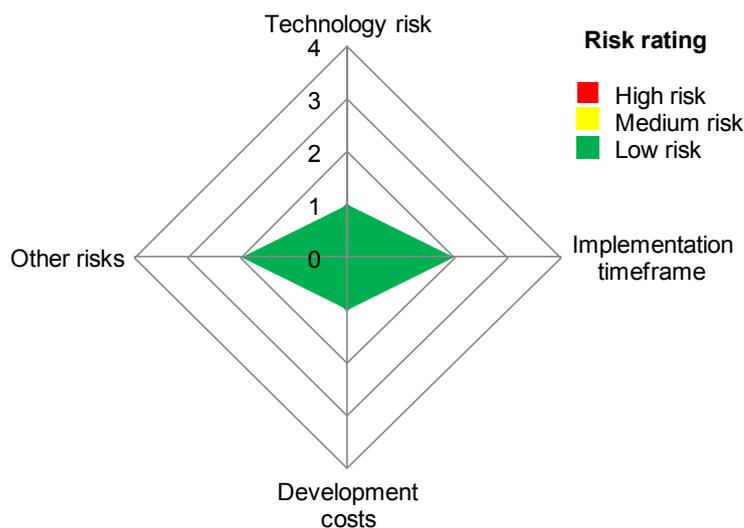
- 1kg of primary aluminium has potential GHG emissions of between 8 and 28 times that of 1kg of secondary aluminium
- 1kg of primary lead has potential GHG emissions of between 2 and 60 times that of 1kg of secondary lead
- 1kg of primary copper has potential GHG emissions of up to 50 times that of 1kg of secondary copper
- 1kg of primary platinum has potential GHG emissions of around 20 times that of 1kg of secondary platinum
- 1kg of primary nickel has potential GHG emissions of between 3 and 6 times that of 1kg of secondary nickel

On this basis, recycling is suggested here to have the largest potential for greenhouse mitigation of all of the options available for the non-ferrous metals sector and represents the majority of the abatement opportunity for the sector. It is reiterated that this is on a life cycle basis – i.e. it includes the mining and size reduction impacts, and that opportunities will differ significantly between the various types of metals considered and production processes used.

Much of the data found on the costs and mitigation potential for recycling considers an aggregated waste stream, which includes paper, plastic, ferrous and non-ferrous metals. Although this data is not directly translated to the non-ferrous metals sector specifically, it is suggested here that the trends will be similar. McKinsey (2008) suggests that recycling reduces emissions by 3.2 tonnes CO<sub>2</sub>-e to 5.1 tonnes CO<sub>2</sub>-e per tonne recycled, depending on the waste composition. Furthermore, it suggests that the cost of abatement in 2030 will be to the order of -€14 per tonne CO<sub>2</sub> mitigated, attributed to the avoidance of significant costs through the use of recycled goods in manufacturing processes and the use of mature, simple technologies for landfills.

Although recycling is desirable from a mitigation perspective, it requires significant efforts to support the reverse logistics for collection of end of life metals, many of which are highly dispersed in the economy. A requirement exists for extensive consumer education in this regard. Producers will also require significant education and possibly legislation, for example, extended producer responsibility programmes, labelling of product components, and design with an eye towards easy disassembly at product end of life.

Co-benefits of recycling include job creation, reduction of wastes going to landfill sites, the reduction in impacts associated with mining and processing of primary ore bodies and lowering of the consumption of non-renewable resources.



**Figure : Radar risk diagram: non-ferrous metals - increased recycling**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	There is low technological risk associated with recycling non-ferrous metals as these technologies have been utilized for many years around the world.
Implementation timeframe	2	Setting up the systems for extensive recycling takes time – in terms of logistics, consumer education, access to markets etc. There is already a recycling sector in the country but this will need to grow significantly to have a high impact on reducing emissions from the sector.
Development costs	1	No technological development is required for recycling.
Other risks	2	Some other risks from the sector include competition for the waste resources to feed into recycling, and making recycling economically viable.
<b>Composite risk score</b>	<b>6</b>	
<b>Overall risk rating</b>	<b>Low risk</b>	

**Table : Risk ratings: non-ferrous metals - increased recycling**

Source: Genesis Analytics, 2010

### Fuel reduction and substitution

Two opportunities for reducing or substituting fuel are identified in the sector:

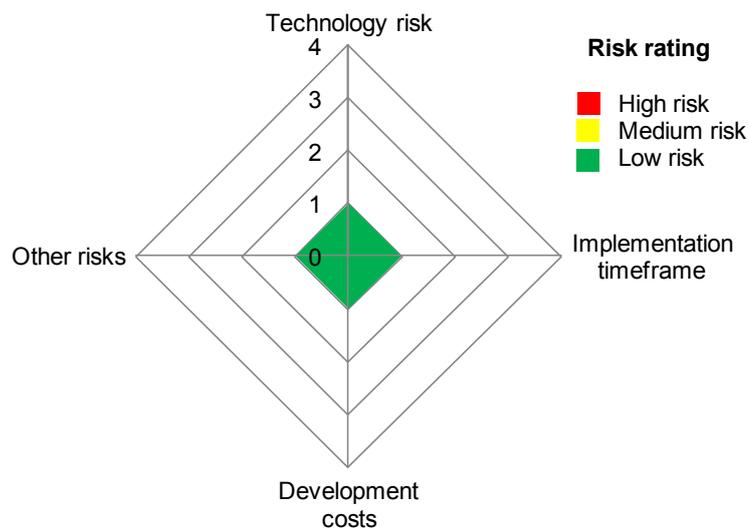
- With respect to pyrometallurgical processing, various options are available for fuel substitution to reduce the emissions associated with coke or coal fed into smelters, depending on the metal being processed. Steam injection into blast furnaces and use of natural gas can be used to reduce coke/coal consumption. Hot process gases can

be used to preheat feed streams going into the smelters, thus reducing energy consumption required to maintain required smelter temperatures.

- Hot process gases can also be used elsewhere on the plant where a heat source is required. Furthermore, biomass can be used to replace coal, coke or gas used in boilers for steam provision. It is noted that no reference has been found to using biomass directly in smelters, so it is unknown whether this is a viable mitigation option.

As with the energy efficiency options, no information was found on cost estimates for fuel reduction and substitution. It is suggested, however, that investment costs are low relative to the remaining options for the sector, although new piping infrastructure will be required. As such this group of mitigation technologies has been allocated an indicative cost of “1”. As such practices are well established both locally and overseas, the risk profile is low.

No other co-benefits were identified.



**Figure : Radar risk diagram: non-ferrous metals - fuel reduction and substitution**  
 Source: *Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	Technologies are used extensively overseas and to a limited degree in South Africa.
Implementation timeframe	1	Short implementation times.
Development costs	1	Low technology option with no significant costs.
Other risks	1	No other risks foreseen.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: non-ferrous metals - fuel reduction and substitution**

Source: *Genesis Analytics, 2010*

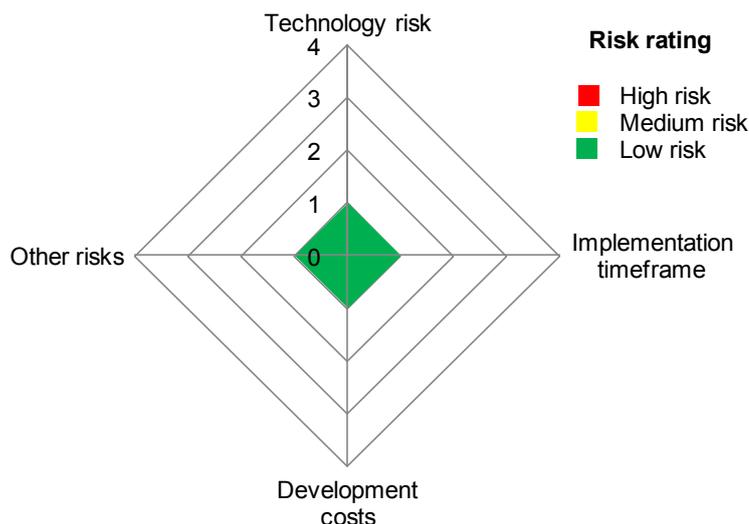
### Reduction in PFC Emissions (Aluminium plants)

Consumption of carbon anodes and perfluorocarbons (PFCs) form the majority of direct greenhouse gas emissions from aluminium refineries. Carbon anodes produce CO and CO<sub>2</sub> during the electrolytic process. During normal aluminium production in an electrolytic cell, emissions of PFCs are negligible, particularly in modern plants. They are primarily produced during upset conditions known as anode effects, where the aluminium oxide levels in the electrolyte are not sufficient and the electrolytic solution itself undergoes electrolysis to form PFCs. The two main perfluorocarbon compounds produced are tetrafluoromethane (CF<sub>4</sub>) and hexafluoroethane (C<sub>2</sub>F<sub>6</sub>), both of which have high global warming potentials and long atmospheric lifetimes (IAI, 2009).

Imposing strict control over anode effects can contribute to ensuring as stable a process as possible and thus minimising production of PFCs. The LTMS also makes reference to capture and destruction of PFCs as a technology which may be employed in aluminium refineries. This is only applicable to old plants, as all new aluminium plants will have negligible emissions of PFCs.

The global aluminium industry has already made significant progress in reducing per tonne of production emissions of PFCs, with reductions of 87% since 1990, from 4.93 to 0.65 t CO<sub>2</sub>-e per tonne (IAI 2009). Winkler (2007) estimate current estimates of PFCs in South Africa to be approximately 2.18Mt CO<sub>2</sub>-e.

It is noted that BHP Billiton, the owner of the two existing aluminium smelters in the country, claims to be making advances in PFC reductions in line with world standards. Furthermore, any new refineries which are built will be built with modern technologies in which emissions are minimised. As such the opportunities for reduction in this area are small; the option was only included here as it is one of the only technologies for the sector highlighted in studies such as the LTMS. The costs of reductions using this technology are negligible, at only R0.16 per tonne CO<sub>2</sub>-e (Winkler, 2007).



**Figure : Radar risk diagram: non-ferrous metals - reduction in PFC emissions**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Technologies for PFC reduction are well established around the world and are claimed to be used in South Africa.
Implementation timeframe	1	Modifications can be achieved in a relatively short turnaround period as they do not require significant plant modifications.
Development costs	1	As technologies are well established, development costs are low.
Other risks	1	No other risks are identified.
Composite risk score	4	
Overall risk rating	Low risk	

**Table : Risk ratings: non-ferrous metals - reduction in PFC emissions**

Source: Genesis Analytics, 2010

### Technology change

Two main groups of technologies are used for metal recovery in the non-ferrous metals sector, being pyrometallurgical and hydrometallurgical processes. The former, which make use of high temperatures to smelt ores, are older technologies. The latter, which recover metal species by solubilising the metals and then recovering them through electrowinning, have in recent years become more popular due to their higher efficiencies in recovery of metal species. Both technologies require ores to be crushed and milled which is in itself also an energy intensive process. Electrowinning is, however, a more energy and hence greenhouse gas intensive process, consuming more energy per tonne of metal recovered than pyrometallurgical processing. For example, electrowinning of nickel emits 16.1kg CO<sub>2</sub>-e / kg product, compared to 11.4kg CO<sub>2</sub>-e/kg from flash furnace smelting and Sheritt-Gordon refining, while copper

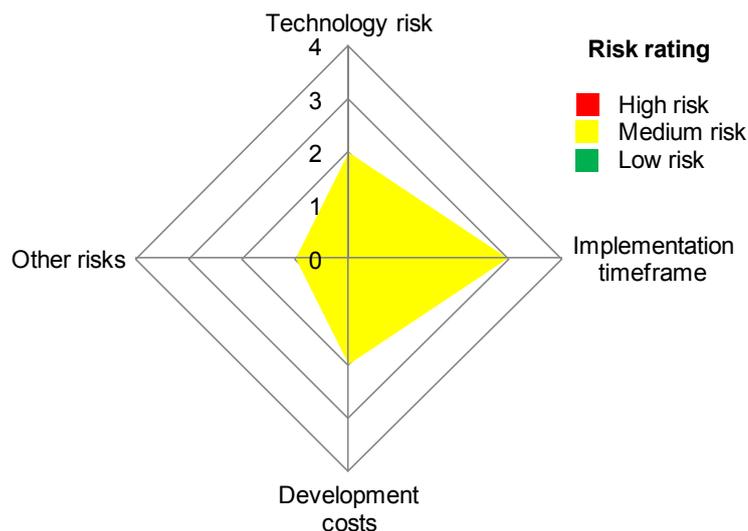
production produces 3.3kg CO<sub>2</sub>-e/kg from pyrometallurgical processing and 6.2 kg CO<sub>2</sub>-e/kg from hydrometallurgical processing (Norgate et al, 2007).

Opportunities thus exist for technological change towards greenhouse gas mitigation in both pyrometallurgical and hydrometallurgical processing. With respect to pyrometallurgical processing, there is already a global shift towards using flash smelting processes instead of the more conventional blast furnaces. Flash smelting is significantly more energy and greenhouse gas efficient than blast furnace technologies.

In terms of technology shifts in hydrometallurgical processing, research towards alternatives which reduce requirements for size reduction of ores (and move towards whole ore processing), and those which do not require an electrowinning step, represent opportunities for abatement of greenhouse gases. Such technologies include cementation, bioleaching and heap leaching.

Both flash smelting and alternative hydrometallurgical processing options are well established internationally, and some are proven in South Africa. There is development risk associated with some of these technologies, as each ore behaves differently and technologies need to be proven before implementation. As such there is not strong potential for standardisation across the sector. Furthermore, there are long timeframes associated with these as they relate to construction of new plants, rather than being retrofitted to existing facilities. As such, technological change is rated as a medium risk option.

Quantitative data on mitigation costs is not easily assigned here, due to the fact that construction of new plants is not done for the purposes of greenhouse mitigation. However the costs of new plant are sufficient to warrant an indicative cost rating of "2".



**Figure : Radar risk diagram: non-ferrous metals - technology change**

Source: *Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	2	Experience with implementation overseas, with some experience in certain technologies locally.
Implementation timeframe	3	Primarily applicable to new developments, so only likely as new infrastructure is being built
Development costs	2	Some customisation of technologies to local conditions and ores will be required.
Other risks	1	No other risks identified.
Composite risk score	8	
Overall risk rating	Medium risk	

**Table : Risk ratings: non-ferrous metals - technology change**

*Source: Genesis Analytics, 2010*

#### **7.7.6. OPPORTUNITIES ARISING FROM CLIMATE CHANGE MITIGATION**

Recycling has been identified as having the biggest potential for greenhouse gas mitigation in this sector, as well as having other environmental benefits. There is opportunity for the sector to position itself further down the value chain and move into the refining space, rather than being producers of primary minerals from ores.

As demand for products with reduced carbon footprints expands around the world, there is potential for early adopters of less carbon intensive processes to access these markets. In the short term this may include those produced with higher recycled content, in flash smelting and processes which reduce the amount of ore processing required. In the longer term competitive advantage may be gained through advances in increased underground processing of ores.

## **7.8. MINING CASE STUDY**

### **7.8.1. SECTOR DEFINITION AND DATA ISSUES**

This report covers the mining industry. In particular, it covers the SIC sectors 21 “Mining of coal and lignite”, 23 “Mining of gold and uranium ore” and 24 “Mining of metal ores, except gold and uranium”. SIC sector 25 “Other mining and quarrying” is not explicitly covered here, however, many of the energy efficiency abatement options are generic, and are also applicable to this sector.

Energy related emissions from mining are relatively easy to ascertain as these can be estimated directly from fuel and electricity consumption records. Direct emissions from mining are generally difficult to monitor, as these tend to be fugitive and dispersed emissions, such as those from blasting, coal-bed methane and spontaneous combustion.

Prediction of emissions from coal mining represents a particular challenge, and receives particular focus here due to the significant contribution of coal mining to emissions from the sector as a whole. There are no established methodologies for prediction of fugitive emissions arising from spontaneous combustion in coal mines, although several are under development. This, coupled with a historical culture of denial by mine management, means that the extent of these emissions are generally vastly underestimated (or not estimated at all). Emissions from spontaneous combustion at coal mines are not included in the GHG inventory of South Africa. Data on methane emissions from coal mines also tends to be very uncertain. This is because they are generally calculated using activity data and emission factors (as is done in South Africa’s GHG inventory). The emission factors are highly uncertain because methane emissions vary considerably between different coal mines (e.g. according to seam depth, mining method, coal type etc.). Continuous methane monitoring is required to obtain more accurate data, but as sensitive, expensive equipment is required, this is seldom employed at South African coal mines.

### **7.8.2. SECTOR CONTEXT**

The minerals and mining industry in South Africa is well-established and resourced<sup>45</sup>. It has a high degree of technical expertise and the ability to mobilize capital for new development. Mining is the second largest industry in the domestic primary sector behind agriculture. South Africa is a leading world supplier of a range of high quality minerals and mineral products. In 2007, 53 different minerals were produced from 1414 mines and quarries, 50 of which produced gold, 31 platinum-group minerals, 96 coal and 344 diamonds, all as primary commodities. The number of operating mines and quarries recorded by the Department of Minerals and Energy increased by 202 from 2006, attributed to the improvement in the quality of data reporting from the mining industry and expansions in the mining industry encouraged by the Minerals and Petroleum Resources Development Act of 2002. South Africa has the world’s largest resources of platinum-group-metals (PGMs) (88% of world total), manganese (80%), chromium (72%), gold (40%) and alumino-silicates. South Africa also accounts for over 40% of the global production of ferrochromium, PGMs and vanadium. It is the world’s leading producer of chrome ore, vermiculite and alumino-silicates, and is among the top three producers of gold, manganese ore, titanium minerals and fluorspar. In 2007, mining contributed

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<sup>45</sup> This brief overview of the minerals sector is summarised from SAMI 2007/2008 (DME, 2008).

R135.6 billion or 7.7% to GDP, an increase of R16.2 billion over the previous year (this figure excludes the value-added contribution of processed minerals which falls under manufacturing). During 2006 the mining industry (excluding exploration, research and development structures and head offices) employed 2.9% of South Africa's economically active population, or 5.1% of all workers in the non-agricultural formal sectors of the economy.

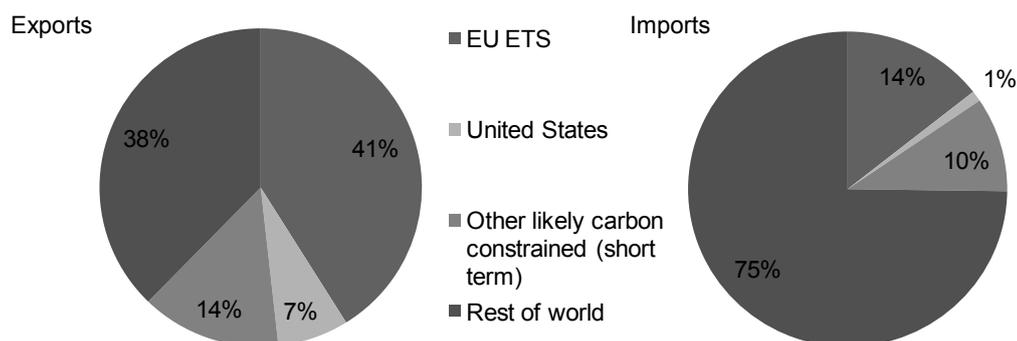
The mining industry in South Africa is dominated by the large international mining houses, e.g. Anglo American, BHP Billiton, Xstrata, etc. Corporate restructuring is an ongoing exercise. Mining houses continue to transform into focused mining companies by typically shedding their non-core industrial holdings. The transformation includes the consolidation of ownership through minority buy-outs, separation of a large diversified company into two or more specialised companies, the transfer of primary listings (and corporate head offices) offshore, as well as the purchase of South African mining assets by foreign companies. The mining industry is placing more emphasis on stimulating black economic empowerment (BEE) and the last few years has seen the emergence of several empowerment companies of substantial size (e.g. Exxaro Resources and African Rainbow Minerals). The Nedcor Securities Junior Mining and Exploration Index (NSJME, an investment opportunity aimed at providing greater visibility for South Africa's junior mining and exploration sector) for the first time reached a market capitalization exceeding R100 billion in 2006. There are also numerous smaller groups and companies which carry out mining and beneficiation activities. These companies contribute towards the creation of employment opportunities by exploiting relatively small mineral deposits, which may not be considered economically attractive to the larger groups. The Small Scale Mining Board (SSMB) was launched in 2005 by the DME with a mandate to assist with the resolution of limitations observed and identified within the small-scale mining sector.

### **International trade**

South Africa's minerals industry is primarily export driven, with 71% of primary mineral sales destined for world markets in 2007 (dti, 2009a; Statistics South Africa, 2009 and Genesis calculations). Mainly primary product is exported, but Government is also trying to stimulate beneficiation (i.e. secondary processing of minerals and metals to add value to the export product) with some success. As shown in Figure 1, a large proportion of exports (62%) are destined for markets where carbon policies are either in place already, or likely to be in place soon which is a concern for the industry. However, there are some factors that are likely to keep South African products competitive. South Africa is among world leaders in mining technology, with many of the large international mining companies either based or originating in South Africa. In addition, South Africa has the largest reserves in the world of several minerals (e.g. PGMs) and significant reserves of many more.

The minerals bureau (DME, 2007) forecasts the value of South Africa's exports of primary minerals to increase by 6.9% per annum (considering the period up to 2011). The sectors with the highest expected growth rates are coal (11.4%), gold (9.2%) and PGM's (7.3%). These figures assume that the major economies of the world expand moderately, providing a stable base for the smaller economies to achieve relatively high growth. However, these predictions were made in 2007 and the current global economic downturn means that these need to be revised significantly downward.

In terms of imports, only around 25% originate in markets where carbon pricing is likely to be an issue. The ratio of the value of imports to the value of sales by domestic firms is around 40% (dti, 2009a; Statistics South Africa, 2009 and Genesis calculations).



**Figure : Concentration of trade in countries with carbon policies (2006): Mining**

Source: TIPS SADC trade database 2009

### 7.8.3. GHG EMISSIONS

Greenhouse gases emitted from the mining sector are primarily CO<sub>2</sub>, methane and Volatile Organic Compounds (VOCs) associated with trucks and other large mining equipment using diesel. Indirect emissions arise from the use of electricity. Underground mines use CFCs, HCFCs and HFCs for refrigeration, but the losses are small. Coal mining represents a significant contributor to emissions from the sector, with underground coal mines emitting methane to varying degrees (generally linked to the depth of mine), as do coal dumps and stockpiles (to a lesser degree). Furthermore, spontaneous combustion of coal dumps, stockpiles and opencast workings emit CO<sub>2</sub> and other partial combustion products.

Mining is not reported as a sector in the GHG inventory of South Africa, with coal mining falling under Energy, and other mining split between mineral products and metals production (falling under Industrial Processes and Product Use). The only direct figure that can be obtained from the GHG inventory is that of fugitive emissions from coal mines, which contributes some 40 391 kt CO<sub>2</sub>-e (13% of total emissions from the energy sector).

Mining accounts for around 8% of the total energy consumption in South Africa (Blignaut et al., 2005), with coal mining responsible for 1.1%, gold 3.7% and other mining making up the balance (3.3%). This translates to non-electricity energy-related GHG emissions of 965 kt CO<sub>2</sub>-e from coal mining, 1157 kt CO<sub>2</sub>-e from gold mining and 3726 kt CO<sub>2</sub>-e from the rest of mining. This amounts to a total of 5848 kt CO<sub>2</sub>-e non-electricity, energy-related GHG emissions from the mining sector, or 1.7% of South Africa's total energy-related GHG emissions (Blignaut et al, 2005).

Gold mining uses 0.9% of the total demand for coal, 1.2% of the total demand for petroleum and 12.1% of electricity demand. Coal mining accounts for some 1.7% of South Africa's total demand for petroleum, and 1.9% of electricity demand. Other mining activities account for 4.7% of total demand for coal, 1.9% total demand for petroleum and 4.5% of electricity demand (Blignaut et al, 2005).

However, it is clear that energy-related emissions do not account for the full GHG emissions from the mining sector as a whole. Looking at the data from Blignaut et al (2005) (for energy related emissions) and the national GHG inventory data (for methane emissions) together suggests that fugitive emissions from coal mines are some 40 times larger than energy-related

emissions from coal mining, and nearly 7 times larger than the energy-related emissions from the mining sector as a whole. This figure includes only coal mine methane and does not include other sources of fugitive emissions, e.g. spontaneous combustion, which are estimated to be even more extensive. It is noted that, at the time of writing this report, a study has been initiated to calculate the overall GHG emissions from coal mining. This study will provide further insights into emissions from the sector (Beukes et al, forthcoming).

#### **7.8.4. CURRENT SECTOR RESPONSE TO CLIMATE CHANGE**

Current greenhouse gas mitigation efforts within the mining sector are primarily around energy efficiency. The now replaced Department of Minerals and Energy (DME) set a 15% energy demand reduction target for the mining sector, to be met by 2015 (DME, 2005). Efforts are voluntary, and the DME has signed an energy efficiency accord with 32 mining and industrial companies, whereby they have agreed to achieve the targets set out. A technical committee has been established where process, progress and reporting mechanisms are being addressed. A number of the mining houses, including Anglo American, Anglo Platinum, AngloGold Ashanti, BHP Billiton, De Beers, Exxaro, Implats and Xstrata, have signed up to the Energy Efficiency Accord. Some of these mining houses have achieved their targets under the Accord, while others have increased their energy intensity (as measured in GJ/product output).

In addition to those interventions being driven nationally, many mining companies are undertaking energy efficiency programmes across their international operations. In some cases these are being driven by requirements in a single country such as Australia.

CDM activity in the mining sector is largely limited to coal mine methane projects, of which there are a relatively large number (29 in China), but none in South Africa. Beatrix Gold Mine has applied for registration of a methane capture project under the Clean Development Mechanism of the Kyoto Protocol (Le Roux, 2007), although this could not be verified on the UNFCCC CDM website.

#### **7.8.5. SECTOR MITIGATION OPPORTUNITIES**

The following sections look at abatement options in the mining sector. To cover the very wide range of minerals mined in South Africa, mining is looked at generically in terms of mining method. The further minerals processing stages for ferrous and non-ferrous metals are considered in separate sectoral reports.

##### **7.8.5.1. IACC**

The Indicative Abatement Cost Curve for the mining sector is shown below. The prevention and extinction of spontaneous combustion on coal mines is estimated to hold the most significant potential for GHG mitigation in the sector, accounting for around 65% of the total abatement potential for the sector. This figure is estimated by assuming that emissions from spontaneous combustion are around 3 times larger than emissions of coal mine methane for the sector (in CO<sub>2</sub> equivalents) and that 80% of the emissions could be abated. This estimate is extremely rough, as methods to quantify fugitive emissions from coal fires are very uncertain, but an attempt is made here so that the significant mitigation potential of preventing coal fires can be made apparent for the sector. Costs of mitigation are expected to vary considerably with the extent and aspect of the fire, and extremely little information on the costs of preventing and managing coal fires can be found in the literature. Prevention is expected to be relatively

inexpensive and well proven (cladding with soil) but requires continuous maintenance. Spontaneous combustion is therefore designated as medium cost in the indicative abatement cost curve for the mining sector.

The next greatest GHG mitigation potential for the mining sector is reducing emissions of coal mine methane. Methane capture from coal mines is calculated to offer about a quarter of the abatement potential for the mining sector. The emissions estimate from the national GHG inventory is used to arrive at this figure, assuming that 70% of the methane emitted could be captured. It should be noted that this figure is quite uncertain as estimates of the methane emissions from South African coal mines vary quite widely, and are very mine dependent. Coal mine methane mitigation is designated as high cost in the indicative abatement cost curve, following the high cost estimates in the LTMS study. However, coal mine methane projects are successfully and economically employed around the world, so further research on local costs is needed.

Significantly lower relative GHG mitigation potentials are assumed for energy efficiency and technology change measures, contributing approximately 2.5% each. The potential for energy efficiency measures is estimated by assuming a 15% reduction in energy use is possible (the DME's current energy target), and comparing the resultant reduction in GHG emissions with those estimated as being achievable by capturing coal mine methane and preventing spontaneous combustion (coal mine methane emissions are estimated to be 7 times greater than those of energy emissions (on a CO<sub>2</sub>-e basis). Energy efficiency measures are grouped into low cost and medium cost options. All are well proven technologies, with the former including such options as installing variable speed drives on pumps and compressors, and general good housekeeping measures (e.g. switching off lights and equipment when not in use). Medium cost options include switching from diesel to electric equipment, utilising the hydraulic head in underground mines through installation of 3-pipe chamber systems, installing turbines on shaft infrastructure, switching from pneumatic to hydraulic equipment, and improving the efficiencies of compressed air systems.

The biggest technological change option available to the mining industry is conducting some of the primary processing of ores underground, with the aim of reducing the amount of rock hauled to the surface. This has the potential to reduce around 36% of total energy use on underground mines at moderate cost, but is applicable only to new build and suitable ore bodies.

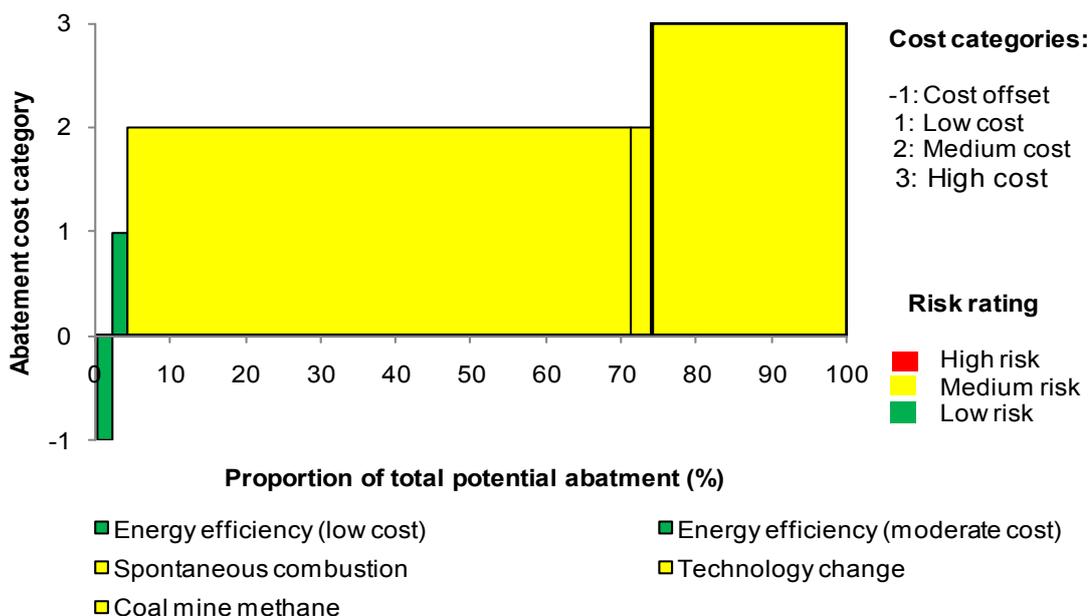


Figure : IACC: Mining<sup>46</sup>  
 Source: Genesis Analytics, 2010

## 7.8.5.2. DESCRIPTION OF ABATEMENT OPTIONS

### Energy efficiency

A number of opportunities are identified for improving energy efficiency in the mining sector. Opportunities differ between underground and opencast mines. Underground mines are more energy intensive than opencast mines, with the primary emissions originating from consumption of electricity associated with ventilation, cooling, haulage of ore out of the mines, movement of people in and out of the mines, lighting and conveyor systems. Diesel is also used underground for transport of people and ores.

Energy related emissions from opencast mines arise from electricity consumption, primarily from draglines, and from burning diesel in trucks, the relative contribution of which depends on the mine and the material being extracted.

In exploring energy efficiency options, a distinction was made between low cost options (which fall into the indicative cost category of “-1”) and those moderate cost options which fall into the cost category of “1”. These opportunities are shown in the table below.

<sup>46</sup> For details of how to read the IACC, see footnote in section .

Low cost options	Moderate cost options
<b>Underground mining</b>	
Increasing energy efficiency on fans, cooling and ventilation systems. Air handling equipment for maintaining adequate air quality and temperature underground is required, representing a significant energy requirement and hence greenhouse emissions. Electricity savings of 30% or more are possible through efficient compressed air systems and installation of variable speed drives	Shifting from diesel to electric transport vehicles and motors in underground operations, as electric vehicles are, in general, more efficient in terms of greenhouse emissions. This shift is often motivated by the associated improvements in air quality
Installation of variable speed or more energy efficient drives on pumping systems for water, slurries etc	Utilising the hydraulic head in underground mines through installation of three pipe chamber systems
Improving drilling efficiency	Installing turbines on shaft infrastructure
Reducing consumption due to lighting through energy efficient light bulbs and switching off lights in areas of the mine which are not in use	Switching from pneumatic to hydraulic equipment
	Improving efficiencies of compressed air systems
<b>Open cast mining</b>	
In "truck and shovel" operations there is considerable potential to reduce diesel use through more efficient diesel motors and through improved driving practices, such as switching off engines when not moving	Where trucks are used to remove ore from the pit there is potential to reduce diesel consumption by utilising electric power on the up-ramps (i.e. by connecting to overhead power cables). This generally results in significant cost savings for the mine and lower energy emissions overall. There is also the potential to switch other heavy machinery to electric power wherever feasible
Installation of variable speed or more energy efficient drives on pumping systems for water, slurries etc	Greater and more efficient use of conveyors running on electricity rather than trucks for haulage
Install day/night switches on lighting circuits, and installation of more efficient lighting systems	Increased use of draglines in preference to diesel trucks for haulage of material in open cast mining (where mine conditions are suited). Only applicable to new mines/new mine sections
Switching off unused equipment	

**Table : Breakdown of energy efficiency options in the mining industry**

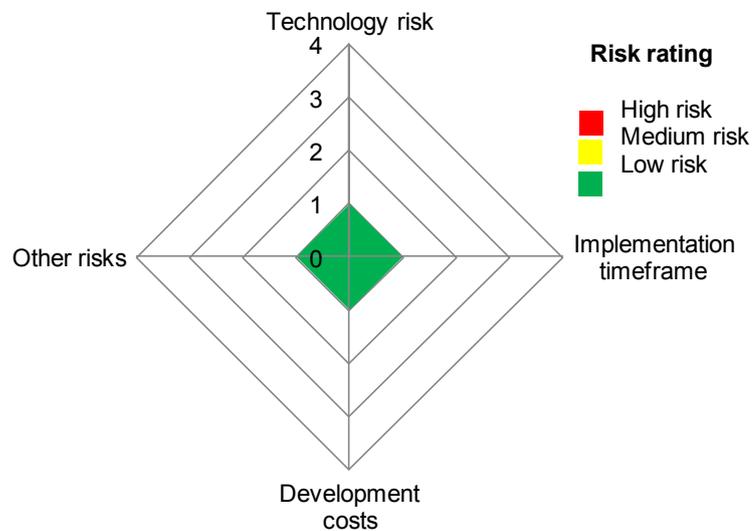
Source: Genesis Analytics, 2010

A broad range of opportunities is identified above, and it is impossible to provide quantitative capital costs or emission reduction potential associated with each and every one of these as they will apply to different types of mines. Although absolute savings associated with these options is high, on the cost curve the low and moderate energy efficiency options are each allocated a 2.5% contribution to abatement potential in the sector. This figure is estimated by

assuming a 15% reduction in energy use is possible (the DME's current energy target), and comparing the resultant reduction in GHG emissions with those estimated as being achievable by capturing coal mine methane and preventing spontaneous combustion (see below). The abatement potential of energy efficiency measures comes out rather small because, for the data available on national GHG emissions (DEAT, 2009 and Blignaut et al, 2005), coal mine methane emissions are some 7 times those of energy emissions (on a CO<sub>2</sub> eq. basis), and 70% of coal mine methane emissions compared to 15% of energy emissions are assumed to be reduced. Emissions from spontaneous combustion are estimated to be even more extensive than coal bed methane, and 80% reductions are assumed possible.

With respect to risk profiles associated with these options, all are well established both locally and overseas, and hence present low technology and development risks and no other risks are foreseen. Many of the options can be standardised across the various mines and operating companies.

Co-benefits associated with energy efficiency relate to decreasing other air pollutants and solid waste generation impacts normally associated with electricity production. Switching to electric mining equipment improves air quality and thus the occupational health and safety of the miners.



**Figure : Radar risk diagram: mining - energy efficiency**

*Source: Genesis Analytics, 2010*

Rating criteria	Rating	Explanation
Technology risk	1	Energy efficiency technologies in mining processes are well established and utilized around the world including by many of the companies located in South Africa. As such low technology risk is envisaged.
Implementation timeframe	1	Technologies considered here relate to behavioural changes, minor process modifications, installation of new equipment or purchase of new vehicles, for all of which implementation timeframes are short.
Development costs	1	Well-established technologies suggest low or no development costs for implementation.
Other risks	1	No other risks to these technologies are foreseen.
<b>Composite risk score</b>	<b>4</b>	
<b>Overall risk rating</b>	<b>Low risk</b>	

**Table : Risk ratings: mining - energy efficiency**

*Source: Genesis Analytics, 2010*

### **Spontaneous combustion**

Spontaneous combustion refers to a burning or smouldering coal seam, coal storage pile or coal waste pile. Spontaneous combustion or “coal fires” occur because adsorption of oxygen at the outer and inner surface of coal results in an exothermic oxidation reaction. This leads to an increase in temperature within the coal seam or stockpile, and if the temperature gets high enough (approximately 80°C) the coal can ignite and start to burn. Spontaneous combustion processes occur naturally but are accelerated through human impact, where mining operations expose formerly covered coal to oxidation processes and lead to the accumulation of large coal waste piles and stockpiles. Besides the economic loss (coal reserves lost), spontaneous combustion causes significant environmental impacts (amongst which are emissions of GHGs).

Spontaneous combustion occurs in opencast mines where the overburden has a high carbonaceous content and/or where the opencast mining intersects old underground workings. The extent of spontaneous combustion and resulting emissions are very hard to estimate. Consensus in the literature is that there is no simple method to estimate emissions as so many factors play a role. State-of-the-art methods using thermal imaging show potential, but require extensive and on-going surveying at the mine to be workable. Whilst the importance of this source of fugitive emissions is recognised in the IPCC emission estimation manuals, no estimation technique is recommended. Reflective and thermal indicators can be derived from satellite data to develop early warning- or risk assessment strategies and to implement priority schemes for coal fire extinguishing activities. However these methods are not yet capable of predicting emissions, i.e. they can warn that the problem is occurring but they cannot provide actual emission numbers. Spontaneous combustion is thus generally not included in National GHG inventories, even though it is such a large source of GHG emissions in many countries (e.g. USA, China, Australia, India, South Africa etc.)

China has received significant international attention lately because of their extensive coal fires. According to recent estimates, coal fires in China contribute about 0.1 - 0.2% of the

annual human induced CO<sub>2</sub> emissions globally (12% of all Chinese coal-based carbon emissions) (Kuenzer et al, 2007). However, others put these even higher, at 1 - 2% (Prakash, 2007). No estimates of emissions from spontaneous combustion could be found for South Africa in the open literature, but indications are that emissions from spontaneous combustion are vastly under-reported. Spontaneous combustion does not occur at all opencast coal mines as the right conditions have to be present. When it does occur, spontaneous combustion is estimated to account for 20 - 85% of all GHG emissions from the mine (estimates from the authors own consulting experience in the mining industry and thus cannot be cited).

Coal stockpiles and coal waste piles are also significant sources of spontaneous combustion. Fires on coal stockpiles can cause significant damage to plant equipment, e.g. conveyors, and thus represent a significant economic loss to the mine (as well as the loss of valuable product). Careful attention is therefore paid to minimising their occurrence through good stockpile management practices. Smouldering discard dumps were an extensive problem in South Africa, but indications are that these have decreased significantly in recent years. The most recent update of the Discard and Duff coal inventory undertaken by the DME reports 8% of dumps burning, and 17% partially burned (down from 30%) (DME, 2001).

Approaches to mitigating surface coal fires arising from spontaneous combustion are well established, and essentially involve cladding the combustible material under at least a metre of soil to prevent oxygen ingress. In certain cases, e.g. on steep slopes, the area may be excavated entirely and carried away by truck and submerged in a suitable water body (e.g. community sewerage). Underground fires are more challenging and can be managed by injecting a water-mud slurry into cracks created by subsurface burning or by drilling a series of holes into underground shafts, drifts, and slopes and pumping in the slurry to smoulder the flames. The surface is then covered with thousands of tons of soil to prevent oxygen from circulating back into the ground and rekindling the fire (Stracher and Taylor, 2004). Spontaneous combustion is often a particular problem where opencast mining meets old underground mine workings. Here it can be somewhat avoided through careful mining, but this is often not done because it can reduce ore recovery.

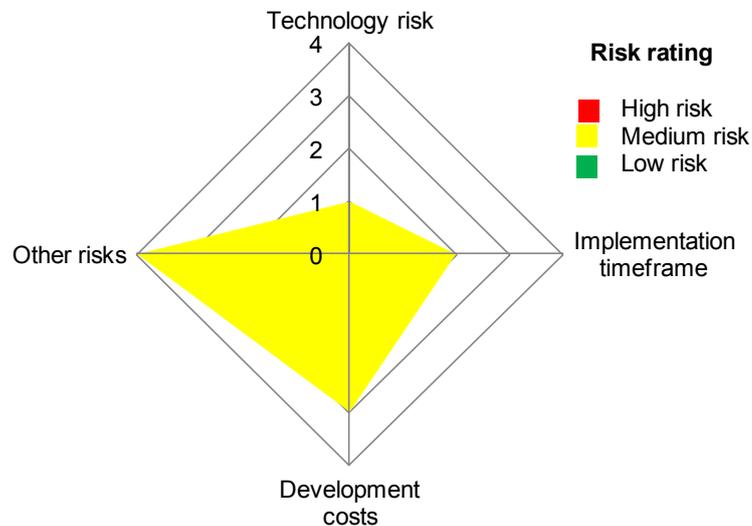
Preventing and extinguishing coal fires is surmised to have the most significant GHG abatement potential for the mining sector, and is estimated to account for around 65% of the total abatement potential for the sector. This figure is estimated by assuming that emissions from spontaneous combustion are around 3 times larger than emissions of coal mine methane for the sector (in CO<sub>2</sub> equivalents) (extrapolated up from research done on individual coal mines) and that 80% of the emissions could be abated. This estimate is extremely rough, and an attempt is made at quantifying emissions from coal fires so that its significant potential impact for the sector can be made apparent.

Costs are expected to vary considerably with the extent of the fire. Extremely little information on the costs of preventing and managing coal fires can be found in the literature. Prevention is expected to be relatively inexpensive (cladding with soil) but requires continuous maintenance. Surface fires are also comparatively inexpensive to manage, but the cost will depend on the extent and also the aspect of the fire (e.g. steep overburden strata will be more expensive and difficult to control). Extinguishing underground fires has been labelled "cost prohibitive" (Stracher and Taylor, 2004). Spontaneous combustion is therefore assigned a "2" (medium cost) in the indicative abatement cost curve for the mining sector. This is estimated to represent the average costs of prevention and management of coal fires. Extensive underground fires are more likely to incur high costs and require some sort of public funding to assist in their management. Furthermore, it should be noted that costs of preventing

spontaneous combustion are at a net cost to the mine (although spontaneous combustion does sometimes have some further costs to the mine depending on the scale of the problem, e.g. lost saleable reserves and damage to conveyor belts).

Spontaneous combustion does not occur at all mines, and is primarily associated with opencast coal mines. It therefore has somewhat limited standardisation potential across the sector, although the management of discard (coal wastepiles) and stockpiles has good standardisation potential. In some cases, fires are associated with abandoned mines and wastepiles and mitigation might fall to local or national public bodies rather than private mining companies.

A co-benefit of preventing and reducing coal fires is improved regional air quality. Spontaneous combustion has considerable negative environmental impacts in addition to GHG emissions. These include emissions of noxious gases (nitrogen oxides (NO<sub>x</sub>), nitrous oxide (N<sub>2</sub>O), carbon monoxide, hydrogen sulphide (H<sub>2</sub>S) and sulphur dioxide (SO<sub>2</sub>)) and particulates. Coal fires lead to the degradation of their direct surrounding area through significant aerosol input to water sources and agricultural areas, and the toxic fumes released pose a threat to the health of the local inhabitants. Furthermore, land subsidence can occur due to the loss of volume underground, when a coal seam, supporting several layers of overlying strata, turns into ash. The resulting slow or very sudden subsidence can be a threat to infrastructure, local inhabitants and miners (Kuenzer et al, 2007).



**Figure : Radar risk diagram: mining - spontaneous combustion**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	1	Preventing and managing surface coal fires arising from spontaneous combustion is straightforward and has been successfully implemented on many South African mines. Underground fires (and certain surface fires) are more challenging but not technically difficult.
Implementation timeframe	2	Prevention is immediate (short time frame), while very extensive fires will require constant attention over a few years to ensure success (and ongoing maintenance).
Development costs	3	Relatively high development costs, not in the abatement technology itself (which is relatively easy and well established) but significant research is required into how to quantify emissions.
Other risks	4	It is very difficult to quantify spontaneous combustion emissions and thus any abatement will be very difficult to "police". Requires significant development in how to quantify these emissions before it will be possible to enforce their reduction. Furthermore there is a reluctance to abate emissions that are not currently being counted in GHG inventories (i.e. no year on year improvement is registered for the efforts which is what mining companies and governments want to show)
Composite risk score	10	
Overall risk rating	Medium risk	

**Table : Risk ratings: mining - spontaneous combustion**

*Source: Genesis Analytics, 2010*

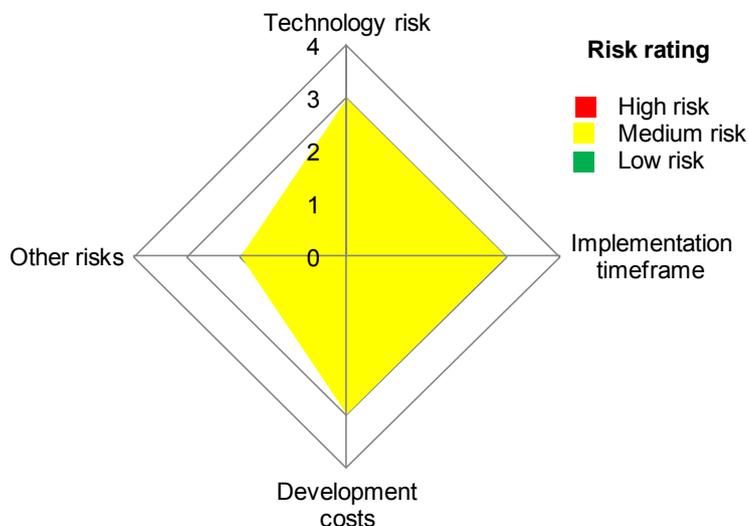
### Technological Change

The biggest technological change option available to the mining industry relates to conducting some of the primary processing of ores underground, with the aim of reducing the amount of rock hauled to the surface. Although underground processing has been used in a few mines overseas (most notably uranium), its wide scale deployment does, however, require significant technological advances to be made. Little information was found on the overall cost and greenhouse mitigation potential associated with this option, although given that haulage represents a significant contribution to the cost of underground mining (depending on the depth of the mine), underground processing can save up to 90% of this cost – much of which will be associated with electricity consumption. Once again, however, although the absolute greenhouse savings associated with this technology change could potentially be significant, as with energy efficiency its contribution to overall abatement relative to spontaneous combustion and methane emission capture would be small. In constructing the cost curves an allocation of 2.5% of overall mitigation potential was thus allocated to technological change.

Costs fall within the indicative cost category of “2” which relates to construction of new mines, as well as the development costs associated with the option of underground processing.

There is limited opportunity for standardisation across the sector, as different metals, ore bodies and mines will have different processing requirements.

This option has the significant co-benefit of reducing the amount of waste material which needs to be managed on the surface.



**Figure : Radar risk diagram: mining - technological change**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	3	Some underground processing installations internationally e.g. in uranium processing, however not yet demonstrated in any other types of mines
Implementation timeframe	3	Long development times, and only applies to new mines or new sections of mines
Development costs	3	High development costs are expected prior to technology being considered viable for large scale deployment
Other risks	2	Will require a mindset shift in the industry
Composite risk score	11	
Overall risk rating	Medium risk	

**Table : Risk ratings: mining - technological change**

Source: Genesis Analytics, 2010

### Coal mine methane

Coal mining contributes 8% of total global anthropogenic methane emissions. Methane is a component of underground coal seams that is adsorbed onto the surface of coal and may accumulate in interstitial spaces. It is released during coal-mining operations. Many factors

affect the quantity of methane released, including the gas content of the coal, the permeability and porosity of the coal seams, the method of mining used, and the production capacity of the mining operation. More than 90% of fugitive methane emissions from the coal sector come from underground coal mining (IEA, 2008). South African coals are generally low in methane (Lloyd and Cook, 2005), although significant variability is seen between different seams and different depths. In underground coal mines, methane is removed for safety reasons, which is achieved using large-scale ventilation systems that move massive quantities of air through the mines. These ventilation systems release large amounts of methane into the atmosphere at very low concentrations.

There are a variety of profitable uses for coal mine methane (CMM). CMM end-use options include injection into natural-gas pipelines, electricity generation, co-firing in boilers, district heating, vehicle fuel, and manufacturing and industrial uses (such as feedstock for carbon black and methanol and dimethyl ether production). For low-concentration methane in mine ventilation air, oxidisation technologies have been developed that produce thermal energy for heat, electricity, and refrigeration (IEA 2008). The latter option is expected to be the only one open to South African coal mines. A large number of coal mine methane projects have been successfully implemented around the world, with over two hundred coal mine methane recovery and utilization projects operating, in development, or planned around the world (CMM Projects, 2009). The technology is therefore low risk, although there are additional challenges and possibly some development still required to implement it to capture South Africa's low concentration methane. There are currently no coal mine methane projects in South Africa, although The Beatrix Gold Mine has applied for registration of a methane capture project under the Clean Development Mechanism of the Kyoto Protocol (Le Roux, 2007).

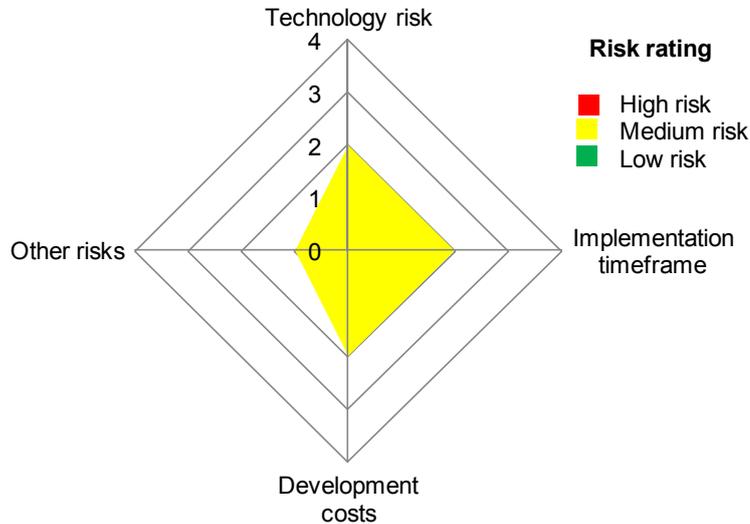
The national GHG inventory estimates methane from coal mines at 40.4Mt CO<sub>2</sub>-e. The LTMS estimate a revised figure for the base year of the study (2003) of 6.55Mt CO<sub>2</sub>-e (29kg CO<sub>2</sub>-e per tonne product) (Winkler 2007). Assuming that roughly 70% of the methane emitted could be captured (the LTMS study assumes only 50%); methane capture from coal mines is calculated to offer about a quarter of the abatement potential for the mining sector. This figure might be a fair overestimate, as Lloyd and Cook (2005) claim these sources overestimate emissions from South African coal mines, and put the figure at a much lower 1.5Mt CO<sub>2</sub>-e(72kt methane per annum). Of this figure, only 0.86Mt CO<sub>2</sub>-e is present in mine ventilation air, with the balance being emitted from the coal after it has left the mine (i.e. only 64% is present in ventilation air and thus available for capture). Whilst these figures might be more accurate for the Witbank coalfields, certain coalfields in South Africa are deeper and "gassier", particularly those expected to be increasingly exploited in the future, e.g. the Waterberg basin (M2M 2008). The higher abatement potential estimate proposed here is therefore deemed to be warranted.

The above estimates only include coal mine methane, although methane has been venting from the Free State goldfields for decades (le Roux, 2007). No estimates are available on the quantity of this source of methane emissions although they are appreciable (for example, at the Harmony Gold Mine in the Orange Free State, the kitchen stoves and bath houses were fuelled by methane coming from the mine shafts for over 20 years) (M2M 2008).

The LTMS study costs a scenario for destroying methane emissions using thermal oxidisers (assuming 50% methane capture). The costs for this mitigation option were amongst the highest of all the LTMS scenarios considered (R346 per ton CO<sub>2</sub>-e). The reasons for these very high costs are not made clear in the LTMS study. Coal mine methane is therefore assigned a "3" (high cost) in the indicative abatement cost curve for the mining sector.

However, the fact that CMM projects are successfully and economically employed around the world calls these high costs into question, and further research on local costs is needed.

Coal mine methane capture is applicable to underground coal mines only, so the option has limited standardisation potential across the sector. Capturing coal mine methane has significant co-benefits, these include enhancing economic growth, strengthening energy security, improving air quality and improving industrial safety (M2M 2008).



**Figure : Radar risk diagram: mining - coal mine methane**

Source: Genesis Analytics, 2010

Rating criteria	Rating	Explanation
Technology risk	2	Technology demonstrated commercially in many projects around the world (10 in Australia, 40 in China, 21 in Poland etc.). Technology demonstrated in gold mines in South Africa, but the differences in methane concentration may make this not directly transferable to coal mines (but it should help with the learning curve).
Implementation timeframe	2	Projects can be implemented in relatively short timeframes (between 2 and 5 years).
Development costs	2	Some development costs anticipated to adapt technologies to South African conditions (low concentrations of methane).
Other risks	1	None identified.
Composite risk score	7	
Overall risk rating	Medium risk	

**Table : Risk ratings: mining - coal mine methane**

Source: Genesis Analytics, 2010

## **7.8.6. OPPORTUNITIES ARISING FROM CLIMATE CHANGE MITIGATION**

Capturing coal mine methane (CMM) has potential for significant co-benefits, such as enhancing economic growth and strengthening energy security. Opportunities for utilising CMM in South Africa have historically been thought to be limited, but improved technology for thermal oxidation of low concentration methane, coupled with the deeper, “gassy” nature of coalfields likely to be exploited in the future, means this might no longer be true. The potential end uses for CMM in South Africa include electric power generation, boiler fuel, transportation fuel and petrochemical feedstocks. CMM could offset or reduce growing requirements for gas imports to meet increasing gas demand. It could also provide an effective fuel substitute for coal and firewood. Where mines are shallow and less gassy, collected CMM could be used for local heating purposes, but infrastructure would be required (M2M, 2008). Furthermore, both coal bed methane projects and spontaneous combustion prevention have the significant co-benefit of improving industrial safety on the mines.

Underground processing of ores is a new technology that could offer significant potential to underground mines in South Africa to become leaders in this technology. Underground ore processing has significant environmental and cost benefits, associated with bringing less rock out to the surface (which reduces both the energy investment and disposal requirements).

Energy efficiency measures are all associated with cost savings, with the particular time to repay the investment depending on the particular measure implemented. Many of the energy efficiency measures also have significant health and safety aspects (e.g. improvements in air quality when changing from diesel to electric equipment).

## **7.9. SECTOR CASE STUDIES: CONCLUSION**

### **7.9.1. GENERAL CONCLUSION**

A consistent picture emerged from the sector case studies that indicated that data on GHG emissions, abatement opportunities and mitigation costs is not readily available in South Africa. Furthermore, the data that does exist has predominantly been generated for the purposes of compliance with the national inventory requirements of the United Nations Framework Convention on Climate Change, or for economy level modelling in the LTMS. This information is too high-level to effectively inform policy development, which requires data at an individual process and SIC code level in order to consider issues of alignment with other policies and to evaluate the impact of climate policies on individual sectors. In order to support the development of climate policies, it is therefore important that a detailed national GHG emissions inventory is developed which is in line with Statistics South Africa’s Standard Industrial Classification system. Additional detailed primary research is also required on the mitigation opportunities available to individual sectors<sup>47</sup>.

Detailed information is not only required for the development of effective climate policies, but can play a crucial role in identifying how best South Africa can capitalise on the opportunities offered by GHG mitigation in order to build international competitiveness. There may well be a first-mover advantage for developing countries that are quick to adopt a strategy to combat

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<sup>47</sup> See <http://www.climatefruitandwine.co.za> for a useful example of how the deciduous fruit and wine industry in South Africa is attempting to generate the detailed emissions information that is required to inform climate policy.

climate change in terms of access to international markets and the development of environmental goods and services. In the shorter term, if South African firms and industries can brand themselves as a “green” alternative, this could prove a substantial competitive advantage in developed country markets where consumers are much more discerning on sustainability issues.

## 7.9.2. KEY OBSERVATIONS

A number of key observations (which will inform the analysis in subsequent sections) emerge when the 7 IACCs in this section are considered together:

- In only 2 sectors (Liquid fuels and Chemicals) are a significant amount (10 percent or more) of potential abatement reliant on high risk technologies (**few high-risk options**)
- In all but 2 sectors (Electricity supply and generation and Mining) there are a number of low risk options available with negative or low cost ratings (**many low cost low risk options**)
- In only 3 sectors (Chemicals, Iron and steel and Non-ferrous metals) do negative cost options make up more than 10 percent of total potential abatement (**few negative cost options**)
- Only 1 high cost abatement option was identified (in the mining industry)<sup>48</sup> (**only 1 high cost option**)
- 2 sectors face significantly poorer abatement opportunities than the rest. They are Electricity generation and supply and Mining. All the options available to it and the bulk of its options available to the Electricity generation and supply sector are medium cost and the bulk of them are classified as medium risk. By definition, the fact that all its options are medium costs means that this sector will need to find new ways of harnessing all potential energy sources in order to function effectively in a carbon constrained world (see section for definition of ‘medium cost’). More than 95 percent of abatement potential in the Mining sector is linked to options that are either medium or high cost and are relatively risky (**2 sectors face particularly unattractive set of abatement options**)

## 7.9.3. RECOMMENDED SECTOR ACTIONS

This section highlights actions that individual sectors can take effectively engage in the climate change debate, and identify the opportunities offered by climate change mitigation (or at least reduce the effort required to mitigate GHG emission reductions).

### 7.9.3.1. AGRO-PROCESSING

The Agro-processing case study suggested that climate change is not currently considered a business imperative in this sector. A considerable amount of effort is thus recommended to raise awareness of climate change issues and the particular risks and opportunities it poses for the food industry. In order to develop and implement an awareness programme, research is

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<sup>48</sup> „High cost’ is defined as so costly that a sector, should it not be able to pass on costs, will not be able to continue function in its current form and may need to shut down if it can’t reinvent itself (see section ).

required to determine quantitative estimates of energy use and GHG emissions. This initiative needs to have buy-in from key food industry players and complement existing GHG inventory processes within national government and the private sector. Specific research is required to determine how competitors in other countries are assessing climate change as a competitive advantage in terms of new product development and promotion of low carbon footprint products.

The lack of availability of data illustrates that a review of GHG emissions on a sector-wide and sub-sector-wide basis is an imperative for the Agro-processing sector to meaningfully engage in any debate on GHG mitigation and to provide input into the development of GHG mitigation strategies for this sector. In summary no significant action can be taken by the food industry unless clarity is obtained on what baseline GHG emissions are. A constraint in this sector is lack of industry bodies or action taken jointly on various trade issues.

### **7.9.3.2. ELECTRICITY GENERATION AND SUPPLY**

The electricity supply sector differs from the other sectors considered in this study in that it is currently dominated by a single utility, although it is acknowledged that there is some potential for independent power producers to enter the market. Although Eskom is already undertaking various activities in exploring renewable energy, the utility is faced with an imperative to build new base load supply to meet the growing demand in the country. Meeting this growing demand, at least in the medium term, will be done through building new coal fired power stations. It is likely that IGCC (a “cleaner” coal technology) will eventually be used in South Africa, although the next power stations to be built will use supercritical coal.

Eskom will be responsible for achieving a large proportion of any emission reduction efforts undertaken by South Africa in response to both internal efforts to combat climate change (including the renewable energy target), and international treaties such as the Kyoto Protocol. This suggests a need for ongoing and increased efforts in building renewable energy capacity, in addition to using cleaner coal technologies. Research is required into the most efficient ways of exploiting renewable energy. The electricity supply case study suggested wind, nuclear and solar CSP as the most promising technologies (with medium abatement and low to medium implementation risks, and the potential to contribute 20% or more to the sector’s overall greenhouse mitigation). It is noted that in order to ensure grid stability, a range of responses is required; no single technology presents an overall solution for the sector.

### **7.9.3.3. CHEMICALS**

As was the case for the other focus sectors, the chemical sector case study revealed that South Africa does not have any reliable GHG emissions data for the Chemicals sector. According to the modelled data contained in the LTMS the production of nitric acid, carbide and ammonia generates more emissions than any other chemical production. Following the LTMS, there is an opportunity to initially focus the development of a GHG emissions inventory for this sector on facilities and processes that produce these chemicals. However, it is possible that there are other processes that are major sources of GHG emissions.

Electricity constitutes a significant proportion of the chemical industry’s overall energy spend and roughly 40% of all energy consumed. Energy efficient technologies are thus likely to become a significant source of competitive advantage for companies that are able to pass on energy savings to their downstream customers. Significant revenue growth for specialty chemical firms may also be derived from the development and marketing of chemical products

which help to reduce energy consumption (e.g. advanced catalysts, insulation materials and light weight materials for vehicles), as well as materials for new energy technology (e.g. solar photovoltaic cells and fuel cells). The industry needs to be encouraged to include renewables in their energy consumption mix. In response to the electricity supply crisis of 2008, some firms set aside discretionary funding to improve energy efficiency. Companies should also set aside discretionary funding to undertake energy savings audit of their operations, including the determination of the status quo and the benchmarking of their energy utilisation performance against those of similar industries.

With respect to more direct actions at operations level, firms can identify high priority energy saving projects such as refraining from running equipment under no load, improving the Power Factor Correction (PFC), installing bearing technologies that are geared to reduce friction; improving the motor electrical efficiency by carefully assessing the practice of rewinding of motors; and exploring if replacement motors can be of a smaller size.

#### **7.9.3.4. LIQUID FUELS**

It is apparent from the Liquid fuels case study that there is a long way to go to achieve the level of information transparency required for optimal policy design. To get a better understanding of possible ways to cut emissions, the cost of available technology options, and the reductions that each technology could achieve, the liquid fuels sector needs to undertake plant level investigations of major sources of emissions and map the opportunities to reduce (or abate) those emissions.

Based on the analysis in the sector case study, the abatement potential and costs of emissions reduction in the South African liquid fuels sector will depend on the industry's ability to capture CHP, reduce flaring and implement energy-efficiency opportunities, as well as on the future feasibility of carbon capture and storage. Sasol's strategic incorporation of natural gas into its feedstock mix has already demonstrated what the shift from coal to gas can achieve. It is imperative that alternative fuel sources such as natural gas are considered and supported by other liquid fuel companies.

If improved planning could be undertaken through consultation with staff closer to the operations, the planning process could be used to promote beneficial changes by creating a sense of ownership. Strategically, improved planning is the key to improved implementation and operation.

Because emissions reduction information in this industry tends to be project specific, it is also highly proprietary and where available is presented in a way that is not useful for policy analysis. Initiatives are required in the industry to generate comprehensive climate change mitigation information in a format that can inform policy development. Responsible Care has clearly shown that voluntary mechanisms can work if there is co-operation.

It is public knowledge that the CTL technology is both energy and emissions intensive. Given South Africa's current "lock-in" on CTL as a guarantor of national fuel security, further research to develop alternative processes to retrofit CTL should also be considered.

#### **7.9.3.5. IRON AND STEEL**

Driving towards more energy-efficient processes has been and should remain one of the main focuses of the iron and steel industry. Recent work to identify attractive energy-reduction

options has consistently shown that significant potential, typically in the order of 10 to 15% of total energy costs, can be captured with payback of less than two years. The primary barriers to realising these opportunities are typically organisational (McKinsey 2009). Incentives to overcome these organisational barriers may be useful.

Most companies already understand the rationale of switching to different approaches to cast and roll some specific steel products, e.g. direct casting. However such technology changes imply high switching costs and some level of risk, particularly if market conditions are uncertain and credit tight (McKinsey 2009). These projects generally have positive returns over the long term, allowing a gradual migration to these technologies, e.g. new build only. Incentives will need to be considered to encourage these more extensive energy efficiency options to be implemented more quickly.

Increased steel recycling and shifting technology from the blast furnace route to the electric arc furnace offers the most significant mitigating potential. On a life cycle basis, 1kg of primary steel (blast furnace) has a GHG potential of approximately 2.5 to 4 times that of 1 kg of secondary steel (EAF) (Ecoinvent database v2). However, this shift is somewhat constrained by the availability of scrap metal required by the EAF. Whilst possibilities do exist to replace the scrap (e.g. gas), these are higher cost. An important mitigation option is therefore to increase iron and steel recycling in the SA economy.

#### **7.9.3.6. NON-FERROUS METALS**

The non-ferrous metals case study identified that sector specific data is almost non-existent on the costs and emission reduction potentials associated with the various abatement options. Furthermore, indications are that those options that have received attention, e.g. PFC reduction from aluminium, are relatively insignificant for the sector. In order to better be able to engage with government, there is a strong need for the industry to establish baselines in terms of both emissions from the sector and the costs and emission reduction potentials associated with the various technologies identified here. Statistics on recycling are also very poor, which makes it difficult to assess the potential for increased recycling, and the consequent large abatement potential this carries.

#### **7.9.3.7. MINING**

Globally mitigation opportunities within the mining sector have tended to focus on coal mine methane projects (e.g. as seen by the large number of these projects taking place under the auspices of the Clean Development Mechanism). However, South African coal mines have relatively low concentrations of methane, and projects to capture and utilise the methane have generally been thought not to be economically viable (i.e. in South Africa methane capture/flaring will be at a net cost to the mine and not generate a positive income). Whilst this is true for many of South Africa's mines, it might be less true in the future as deeper "gassier" coalfields are exploited. Furthermore, technological advancements may make this feasible even in low concentration mines. Nonetheless, fugitive emissions from coal mines are a very significant source of GHG emissions in South Africa (higher than emissions from energy use in manufacturing industries and construction, higher than emissions from energy use in transport, and higher than emissions from commercial and residential energy use). It is therefore an essential area to target, even though these projects are likely to prove costly. It is therefore recommended that the sector invests greater research into this area so that a better understanding of methane project costs is achieved, so as to see if these costs really are prohibitive in South Africa.

Whilst easier to achieve and with an economic incentive to the mines, energy efficiency mitigation opportunities will yield relatively minor results. These should still be pursued as many have significant health and safety benefits (air quality), and their GHG savings are still significant in absolute terms. However, many of these measures are not routinely implemented on South African mines. The reasons for this need to be investigated and measures and incentives put in place to encourage their uptake (e.g. overcoming inertia, and educating sector members as to the opportunities that exist).

Spontaneous combustion does not occur at all opencast coal mines, but depends on the mining method and the nature of the overburden (its carbonaceous content). It is also a significant problem on waste dumps and abandoned mines, often with the problem that no one can be held responsible. Low technology mitigation measures are reasonably successful, although fairly costly. It is puzzling why such a major environmental hazard as coal fires arising from spontaneous combustion is largely overlooked by the international community. Some reasons for the rather low levels of concern (Prakash, 2007), that are thought to be also relevant to South Africa, are:

- Ignorance of the magnitude of the problem
- Scattered nature of the information/data on coal fires
- Secrecy and reluctance on the part of related organisations to even acknowledge the occurrence/magnitude of the problem
- Side-tracking of the issue by the funding agencies/policy makers in preference to other issues which have already gained international attention
- Limited research groups focusing on the problem (also related to limited funds available for such research)

These factors urgently need to be addressed so that this very significant source of GHG emissions (and local air pollution) can be prevented. The coal mining sector needs to be proactive in this regard (e.g. through collaborative research projects), rather than reactive when the issue eventually receives wider attention (as it is likely to do, as GHGs become an ever bigger issue).

## 8. IMPACT OF CLIMATE POLICIES ON INDIVIDUAL SECTORS

### 8.1. INTRODUCTION AND THEORETICAL CONSIDERATIONS

Climate change policies, and economic instruments in particular, alter the relative cost structures of sectors within an economy and internationally by putting a price on carbon that effectively makes carbon “a factor of production that needs to be paid for in the same way as labour or raw materials”<sup>49</sup> (Smale et al., 2006:33; Wooders et al., 2009). It is mainly through these relative changes in production costs that climate policies impact the competitiveness of industries, and it is the economy’s vulnerability to these impacts at a sectoral level that is the focus of this section.

Over the medium to long term, putting a price on carbon will lead to a structural change within economies from carbon-intensive goods and services to less carbon-intensive goods and services (Australian Government, 2008a). This structural change to the South African economy will be vitally important if the economy is to remain competitive in a carbon-constrained world (Winkler, 2008). In the short- to medium-term, however, it is important to identify the extent to which particular sectors are exposed to competitiveness issues as a result of climate change policies for two reasons. Firstly, carbon-intensive manufacturing currently constitutes a large part of the economy, attracts significant local and foreign investment, and contributes disproportionately to exports (Winkler and Marquard, 2007). The transition to a carbon-constrained economy will have implications for employment and the allocation of resources in the economy, and may also alter the comparative advantage of the economy (Australian Government, 2008b). Given that investment and employment decisions in these sectors were made in response to past government policies that provided different incentives, assistance to carbon-intensive sectors during the transition to a low-carbon economy is justified (Australian Government, 2008b). Thus, in order to reduce the adjustment costs to the South African economy of moving towards a more environmentally sustainable growth path, vulnerable sectors should receive support in order to ease the move towards production processes that produce fewer GHG emissions. Secondly, in the absence of an international price on carbon, concerns exist that having to internalise the cost of GHG emissions in production processes may reduce the international competitiveness of sectors and that carbon leakage<sup>50</sup> could lead to a disproportionate reduction in local economic activity, employment and tax revenues (Demailly, 2008; Neuhoff, 2008).

The impact of climate change policies varies widely between sectors, and there are usually a minority of sectors in a country that will be significantly affected by climate change policies

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<sup>49</sup> Although they are generally harder to quantify, climate change policies other than economic instruments, like product, technology and energy efficiency standards, also increase production costs (Reinaud, 2009; Wooders et al., 2009).

<sup>50</sup> Carbon leakage refers to a relocation of production activities to jurisdictions with less stringent climate change policies as a result of, for instance, a shift in consumption of carbon-intensive goods from local production to cheaper imported products (Van Asselt, Brewer and Mehling, 2009). Carbon leakage thus refers to a situation where the competitiveness of firms are reduced as a result of a price on carbon existing in some countries, but not in others (Garnaut, 2008). See Section for a discussion of carbon leakage.

(Neuhoff and Mathes, 2008). Carbon costs can lead to firms becoming less competitive and contracting as a result of either losing domestic demand due to consumers switching to less costly domestic or imported substitutes, or losing export market share to products from countries with less stringent climate change policies in place (Graichen et al., 2008). The risk of economic instruments employed to reduce carbon emissions negatively impacting on a sector is largely determined by: the carbon-intensity of the production process (relative to other domestic sectors and across economies); the tradability of goods or services in question; the extent of trade with non-carbon-constrained countries; the size of the carbon cost that needs to be internalised; the overall increase in production costs (as a percentage of value-add or revenue); the ability to pass on production cost increase to consumers; market structure; the price elasticity of demand of products or services; the level of product differentiation; the availability and cost of abatement/mitigation options; and climate policies implemented abroad (Australian Government, 2008a; Graichen et al., 2008; Mohr et al., 2009). These factors determine the ability of the firms in the sector to pass on carbon costs to consumers without losing a significant portion of their market share, and this, ultimately, is what determines the impact of carbon policies on a sector (Mohr et al., 2009).

## 8.2. INTERNATIONAL PRECEDENTS

Although there are a number of factors that influence the ability of a sector to pass on cost increases to consumers, the tradability or trade intensity of a sector is commonly used in the literature on climate change and competitiveness as a proxy for the ability to pass on cost increases to consumers (see for instance Demailly, 2008; EC, 2008a; Graichen et al., 2008; Mohr et al. 2009; Neuhoff and Mathes, 2008; Reinaud, 2009)<sup>51</sup>. The combination of an indicator of the extent to which a sector is traded in a country (as a proxy for the ability to pass on carbon costs to consumers), with an indication of the potential cost increase as a result of climate policies, provides a useful indication of the expected impact of climate policies on the competitiveness of a sector (Graichen et al., 2008). This is the approach used by both the European Union and the Australian Government to identify sectors that are vulnerable to a reduction in competitiveness as a result of climate change policies (see Appendix for details of the EU and Australian approaches). Both parties employ a two-stage process consisting of a quantitative analysis followed by a qualitative analysis to identify sectors that may be at risk of reduced competitiveness and carbon leakage (Australian Government, 2008b; EC, 2008a and 2008b).

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<sup>51</sup> Both EC (2008a:1) and Graichen et al. (2008) find that while a more sophisticated approach involving demand elasticities may be appealing, methodological and data issues indicate that the use of trade data to approximate the ability of sectors to pass on carbon costs is "a more practical way forward offering sufficiently robust results". Australian Government (2008b) considered the use of price elasticities or correlations with international parity prices (i.e. the use of either import or export parity pricing by local producers) as alternative measures of the ability of firms to pass on costs. It concluded that the estimation of price elasticities is a "subjective exercise" that required the use of "too many contestable assumptions to form the basis for policy decisions" (Australian Government, 2008b:12-28). With respect to the use of pricing outcomes, it was found that the use of contracts and a lack of transparent international prices may complicate the assessment of pricing outcomes. Furthermore, it was mentioned that factors other than the absence of international competition, like local market structures, may lead to short-term deviations between domestic and international prices.

### 8.3. METHODOLOGY

In accordance with the European Commission and the Australian Government approaches, the vulnerability of the focus sectors to climate change policies will be analysed using a quantitative and qualitative approach. The methodology is outlined in the sections that follow.

#### 8.3.1. QUANTITATIVE ANALYSIS

The quantitative approach uses three graphs to assess the vulnerability of the focus sectors to cost increases as a result of climate policies. The first graph closely mirrors the approach of the Australian Government, and compares the emission intensities and trade shares of the sectors in question.

**Emissions intensity** is defined as the ratio of total emissions of the sector (including direct emissions and indirect emission linked to electricity usage) to the total value of sales by domestic firms (including exports).

**Trade intensity** is defined as the ratio of imports plus exports to the total sales of domestic firms (which includes exports).

Because of data issues<sup>52</sup>, it is unclear how much confidence can be assigned to the results from the first graph. As a result, two additional proxies for exposure to carbon costs are combined with trade shares to analyse the vulnerability of sectors to climate change policies. The two proxies for exposure to carbon costs are energy intensity (obtained from Devarajan et al. (2009)) and electricity as a proportion of total costs (obtained from Altman et al. (2008)).

**Energy intensity** is defined as the ratio of energy expenditures to total value added by the sector.

**Electricity as a proportion of total costs** is the contribution of electricity costs to total costs in each sector.

#### 8.3.2. QUALITATIVE ANALYSIS

The qualitative analysis will focus on what Hourcade et al. (2007) believe is, in addition to carbon-intensity and the ability to pass on carbon costs, the main issue that influences the impact of climate change policies on the competitiveness of sectors, namely the availability of abatement options.

In addition to the abatement options available in each market, the sector case studies in section highlighted some of the factors that may affect the ability of sectors to pass on carbon costs as outlined in Section above. Given that there is no “practical, transparent or robust test” to assess the ability of firms to pass on costs, these factors are not analysed in this section of the report (Australian Government, 2008b:12-27). This information may, however, be useful for future research on the impact of climate policies on individual sectors<sup>53</sup>. A detailed qualitative

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<sup>52</sup> See Appendix and Appendix .

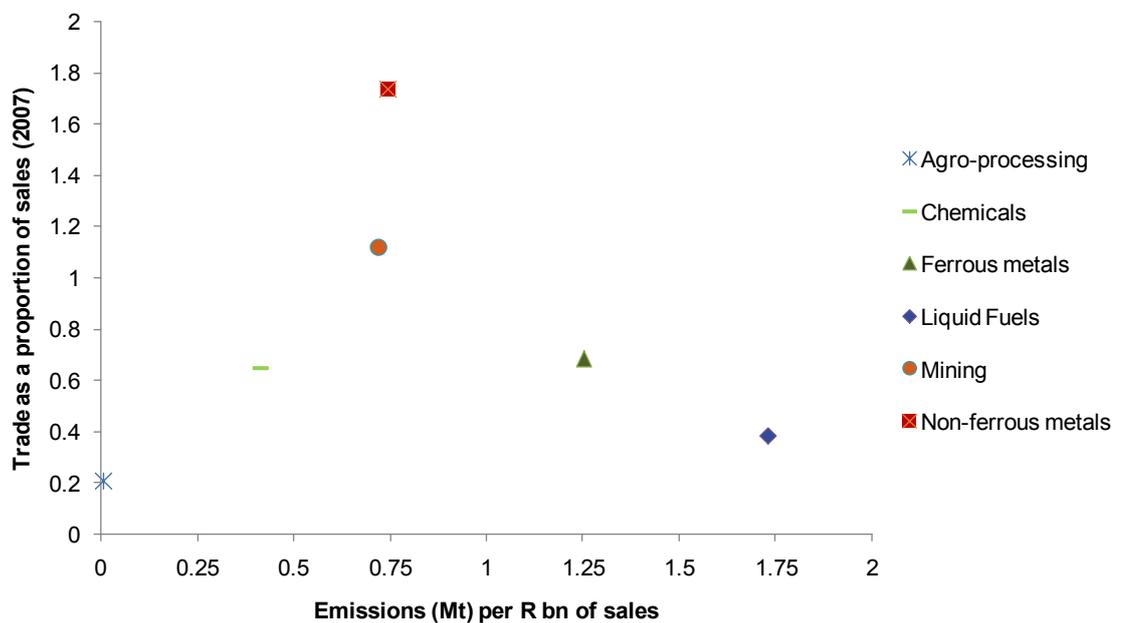
<sup>53</sup> An example of how this information can be used to inform the impact of climate policies on individual sectors is provided in Section with respect to the trade structure of sectors.

analysis of the potential impact of climate policies on competitiveness of a sector for policy formulation purposes should also look at the general international competitiveness of sector. Sectors with a strong general competitiveness advantage may easily be able to absorb carbon costs without adverse effects. As part of this process, the availability and cost of abatement options in export and import markets should also be considered.

## 8.4. IMPACT ON FOCUS SECTORS

### 8.4.1. QUANTITATIVE ANALYSIS

Figure shows that while liquid fuels is the most carbon-intensive sector, non-ferrous metals is the sector most exposed to trade. Based on the Australian Government's threshold to qualify as trade-intensive of 10%, all the focus sectors can be considered trade intensive. Most of the sectors shown (with Agro-processing being the exception) are very exposed to international trade. Converting the Australian Government's thresholds for emission intensity to emissions (Mt)/R1bn of revenue (in 2000 Rand) provides thresholds of 0.3 for emissions intensive and 0.6 for very emissions intensive sectors<sup>54</sup>. This indicates that all the sectors with the exception of Agro-processing can be considered emissions-intensive. Furthermore, with the exception of chemicals (which would be considered emissions intensive), all the other sectors can be considered very emissions intensive.



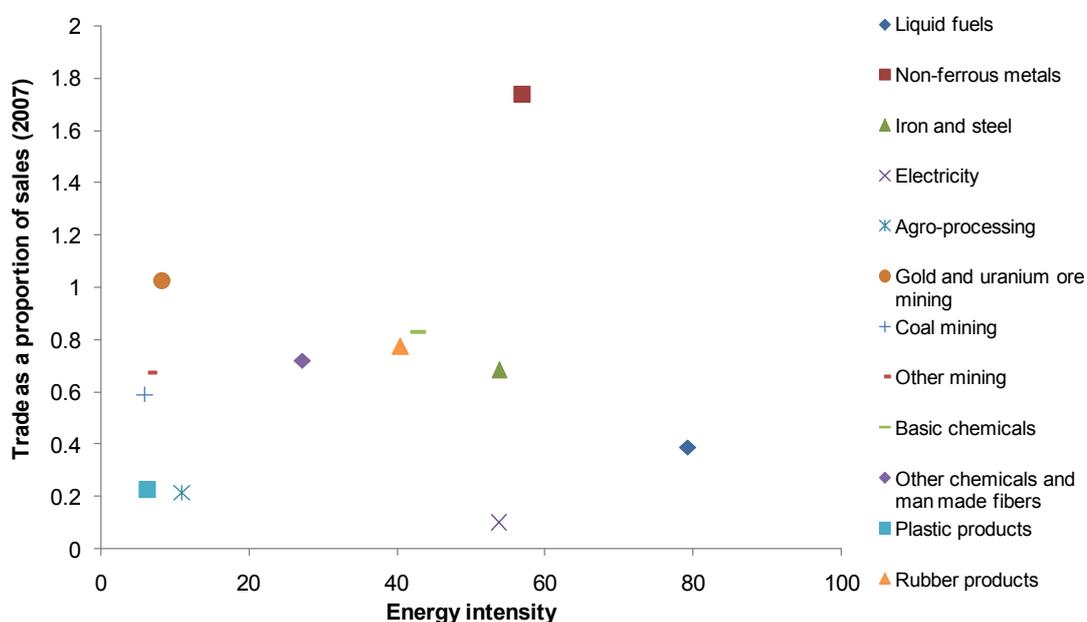
**Figure : Emissions intensity relative to trade share**

Source: *Genesis Analytics, 2010*

<sup>54</sup> The Australian dollar was deflated by Australian CPI (source: [www.abs.gov.au](http://www.abs.gov.au)) to obtain a value for 2000 Australian dollar. It was further translated to Rand at the average 2000 exchange rate (source: <http://www.resbank.co.za>) before being restated as emissions (Mt) per R1bn.

No monetary value for electricity sales could be obtained for 2000. This number was calculated using data on total domestic production in 2000 (in GWh) from Statistics South Africa, and data on the average price of electricity sold in 2000 (in cents/kWh) from a country case study on the South African energy sector by the International Solar Energy Society (ISES, 2001). It is unclear how accurate this calculated value is, and hence its comparability with the other sectors is questionable. As a result electricity generation and supply was not included in the graph. Had it been included, it would have had an emissions intensity of 4.7Mt CO<sub>2</sub>-e per billion rand of sales, and would thus have been by far the most emissions intensive sector. With a trade share of 9.8%, it is the only focus sector that (very narrowly) does not qualify as trade exposed based on the Australian Government's cut-off.

Figure shows that all the sectors with the exception of mining and Agro-processing are very energy intensive, with ratios of energy expenditures to total value added of more than 20%. While liquid fuels is by far the most energy intensive sector, with energy expenditures amounting to almost 80% of the sector's value added, non-ferrous metals and iron and steel seem particularly vulnerable given high energy intensities combined with high trade shares. The basic chemical and rubber sub-sectors also seem relatively vulnerable due to a combination of high energy intensities and trade shares.



**Figure : Energy intensity relative to trade share**

Source: Genesis Analytics, 2010

Using the third proxy of exposure to carbon costs, namely electricity as a proportion of total costs (shown in Figure ), two sectors seem to be significantly more vulnerable to climate change policies than the other focus sectors. Non-ferrous metals and gold and uranium mining not only have the highest trade shares, but electricity also makes up the largest proportion of their total costs of all the sectors considered (with the exception of electricity generation and supply – which should be relatively isolated from increases in electricity costs).

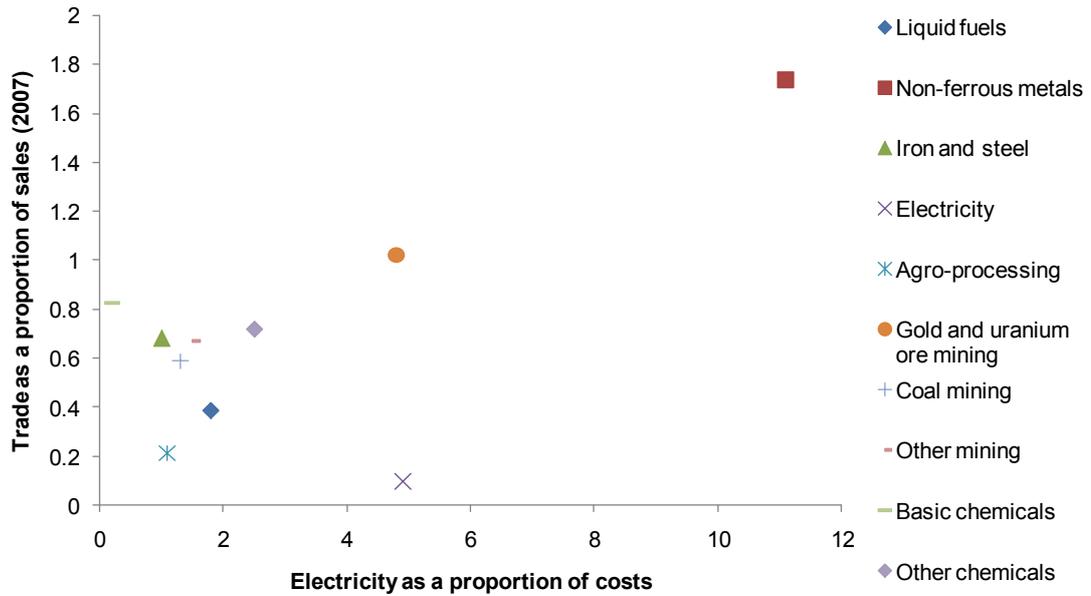


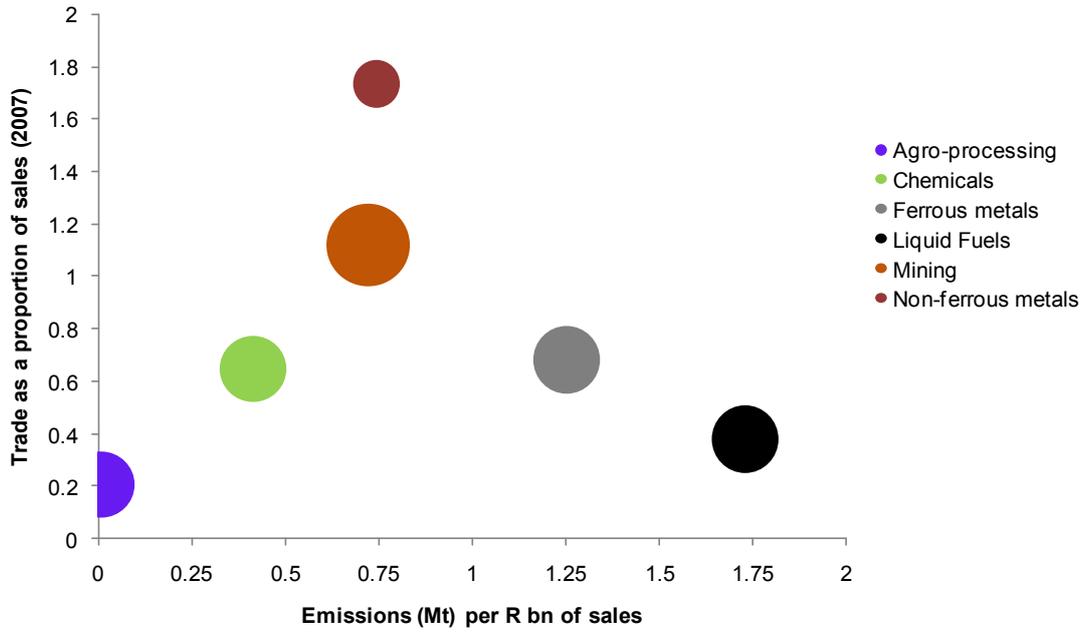
Figure : Electricity as a proportion of costs relative to trade share

Source: Genesis Analytics, 2010

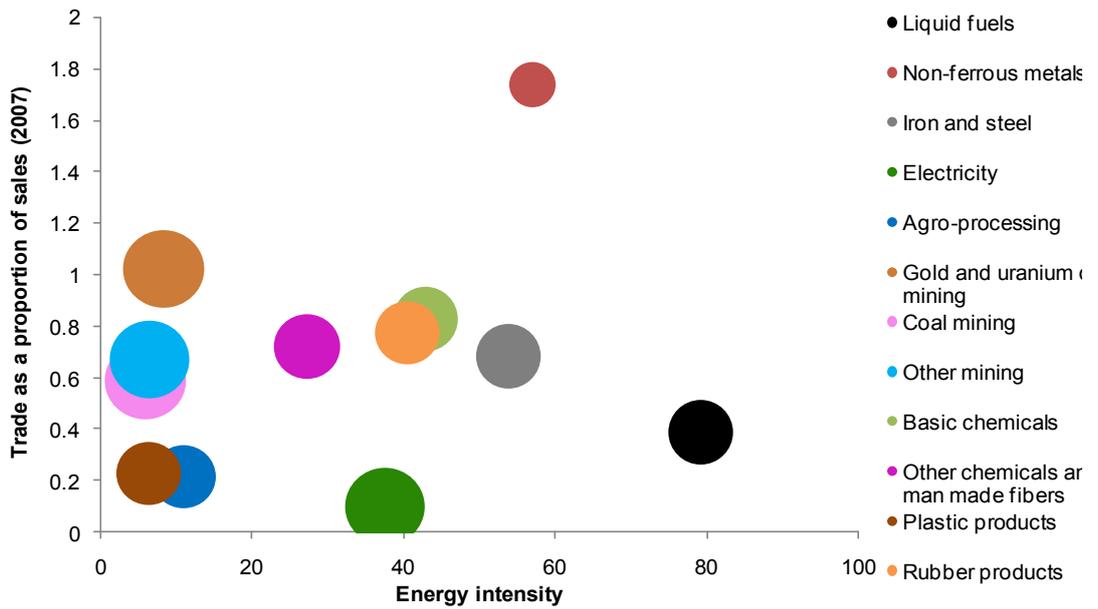
## 8.4.2. QUALITATIVE ANALYSIS

The size of the bubbles in the three graphs that follow represents the attractiveness of the available abatement options in the sector, as summarised in the Indicative Abatement Cost Curves shown in Section . Sectors were given a ranking of poor, average or attractive, depending on the relative cost and riskiness of the abatement options identified for that sector, and this translates into a small, medium or large bubble. A large bubble therefore indicates a sector where the majority of identified potential abatement comes from relatively expensive and risky abatement options, whereas a sector with a small bubble has mostly cost-offset or low cost options which are also relatively low risk. This analysis is based on a qualitative assessment of the attractiveness of the various abatement options available.

Figure provides an interesting picture. Non-ferrous metals may be the most traded sector, but it also has relatively attractive abatement opportunities available to it. Liquid fuels, on the other hand, is the most emissions intensive sector and faces less promising abatement prospects. Ferrous metals, which is more emissions intensive but less trade intensive than mining, has moderately attractive abatement options available to it. Mining's abatement options are more limited. It would thus seem that, based on the indicators under consideration, that mining may be more vulnerable to climate change policies than ferrous metals. Electricity generation and supply, which was not included in the graph for reasons outlined in Section , was deemed to face average abatement prospects.



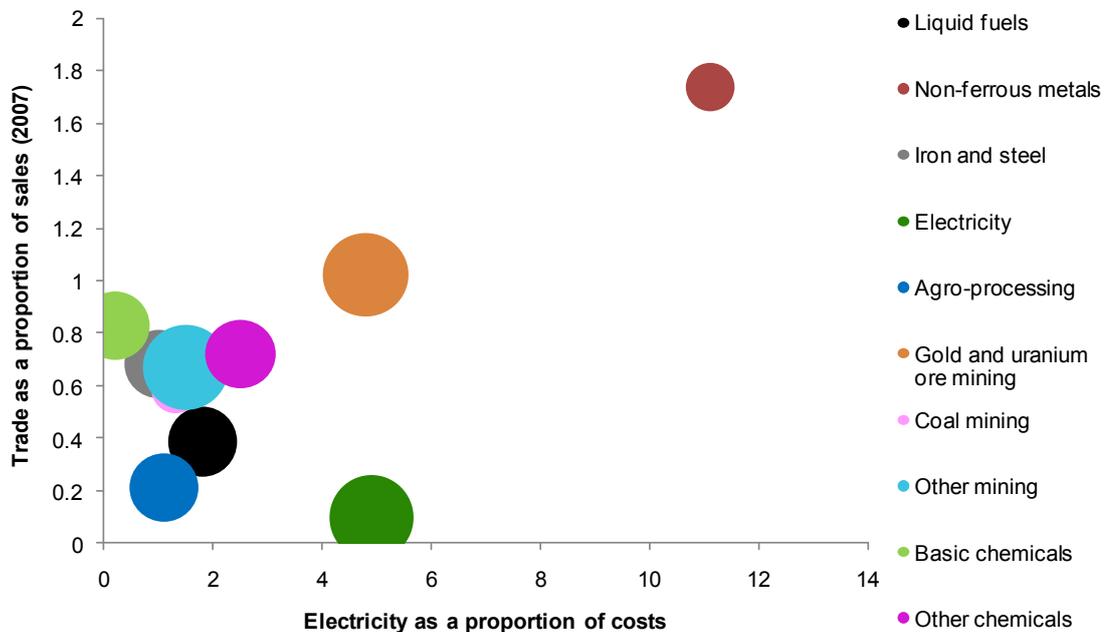
**Figure : Availability of abatement options combined with quantitative analysis (emissions intensity)**  
 Source: Genesis Analytics, 2010



**Figure : Availability of abatement options combined with quantitative analysis (energy intensity)**  
 Source: Genesis Analytics, 2010

Figure combines attractiveness of abatement options with the energy intensity indicator and tells a similar story to Figure with respect to non-ferrous metals and liquid fuels. Otherwise, however, including an indicator of attractiveness of abatement options does not change the

analysis too much, since the sectors with the least attractive abatement options open to them are also the least energy intensive.



**Figure : Availability of abatement options combined with quantitative analysis (electricity intensity)**  
 Source: *Genesis Analytics, 2010*

Figure shows that non-ferrous metals may be less vulnerable to climate change policies than is indicated by comparing its trade share to its electricity intensity (see Figure ) because of relatively attractive abatement options open to the sector. This does not, however, mean that the sector won't be significantly affected by the introduction of carbon costs. The situation is however not expected to be as severe as is indicated by the quantitative analysis alone. The second most vulnerable sector based on trade exposure and the importance of electricity as an input cost, gold and uranium ore mining, faces unattractive abatement options. The results from the quantitative analysis would thus seem to hold, and this sector seems to be relatively vulnerable to climate policies.

## 8.5. CONCLUSION

Climate policies impact sectors by affecting their relative cost structures and competitiveness internationally and relative to other sectors domestically. This section presented a methodology to evaluate the vulnerability of the 7 focus sectors to negative competitiveness impacts as a result of production cost increases linked to climate policies. The methodology is based on the international precedents set by the European Commission and the Australian Government. It was adapted to South African circumstances based on data availability. In order to test the robustness of results, three proxies for exposure to carbon costs, namely the carbon-intensity of production, the energy intensity of production, and electricity as a percentage of total costs, were combined with the trade intensity (which serves as a proxy for the ability of firms to pass through carbon costs to customers) of the focus sectors to evaluate each sector's potential vulnerability to climate policies. In order to gain further insights into the vulnerability of sectors

to climate change policies, the three combinations of quantitative indicators were in turn combined with a qualitative assessment of the attractiveness of available abatement options.

Based on the Australian Government's threshold to qualify as trade-intensive of 10%, all the focus sectors can be considered trade intensive except Electricity generation and supply. Most of the sectors shown (with agro-processing being the exception) are very exposed to international trade. Based on the Australian Government's thresholds, all the sectors with the exception of agro-processing can be considered emissions-intensive. Furthermore, with the exception of chemicals (which would be considered emissions intensive), all the other sectors can be considered very emissions intensive. All the focus sectors with the exception of agro-processing can thus be considered emission-intensive and trade-exposed based on best available data.

The quantitative analyses showed that the proxy chosen for exposure to carbon costs can have a significant influence on the outcome of the analysis. The liquid fuels sector was found to be the most emissions intensive (emissions per unit of revenue) and the most energy intensive (energy costs in relation to value-added), while the non-ferrous metals sector was the most electricity intensive (electricity cost as a proportion of total costs) and also the most exposed to international trade. Mining was also heavily traded and gold and uranium mining was found to be very energy and electricity intensive. The basic chemicals, rubber products and ferrous metals sectors also appear to be relatively vulnerable to carbon costs as a result of a combination of high energy intensities and significant exposure to international trade.

Combining the quantitative analysis with a qualitative assessment of the attractiveness of abatement options available to sectors highlights the importance of considering the abatement options available to sectors when investigating vulnerability to climate change policies. The analysis indicates that the quantitative indicators alone potentially overestimate the vulnerability of the non-ferrous metals and ferrous metals sectors to carbon costs, while underestimating the vulnerability of the liquid fuels and mining sectors.

Overall the findings of this analysis is consistent with international evidence (see section ) that the likely impact of climate policies vary significantly between sectors, and that there are usually a few sectors that are expected to be disproportionately impacted.

## 9. INCENTIVES TO DEAL WITH CLIMATE CHANGE

This section of the report looks in more detail at the types of incentive programmes that can be used to support greenhouse gas emissions reductions in South Africa. The paper aims to provide an overview of current government support programmes and incentives relating to greenhouse gas mitigation. A range of mechanisms are already in place to provide stimulus for investment in energy efficiency, renewable energy and clean technology and the report aims to catalogue and review these, as well as commenting on their likely effectiveness.

The first section will provide insight into the rationale for using incentives to aid the transformation to a low carbon economy. Then South Africa's existing incentives will be discussed and evaluated, particularly in the light of other policy recommendations made in this study. Recommendations will be made for further suitable incentive structures that could be introduced going forward. Finally, a brief section will consider some of the incentives that are in place in other countries and whether these have any relevance for South Africa.

### 9.1. TYPES OF INCENTIVES

There are three main types of incentive:

- *Subsidies* provide direct financial assistance to firms or individuals to support certain investments or behaviour. This can be in the form of grants, matched funding or a guaranteed price for the firm's output.
- *Tax incentives* provide firms or individuals with a tax allowance or deduction which reduces their tax liability, and can be offered for any kind of activity that policymakers wish to encourage. They are similar in effect to a subsidy, where the subsidy amount is equal to the amount of the allowance multiplied by the relevant tax rate.
- *Soft loans* are loans provided at a below-market or zero interest rate to investors in order to make financing more affordable and encourage investment in climate-friendly projects.

### 9.2. RATIONALE FOR CLIMATE CHANGE INCENTIVES

It was noted in section of this study that incentives can be used to encourage investment in environmentally friendly technology and processes but are not always as efficient as other market-based instruments. Incentives also place a direct burden on the fiscus. In some circumstances, however, a strong argument can be made for the use of incentives on two grounds; either to correct a market failure, or as a transitional mechanism to support firms during the adjustment to a lower carbon trajectory. The latter can be an important means of supporting the implementation of a carbon price through a carbon tax or trading scheme. Both have been implemented internationally.

## 9.3. INCENTIVES TO CORRECT MARKET FAILURE

### 9.3.1. THEORETICAL BASIS

Various kinds of market failure may prevent investment in researching and deploying low carbon technologies. Although the pollution externality can be effectively corrected by the imposition of a carbon price, further market failures may remain. McKinsey (2009) find that some of the key technologies for a transition to a low carbon economy are extremely expensive and require big up-front costs which make them too expensive for the private sector to fund as the costs are too great for individual firms to bear. The authors argue that these technologies will not be deployed at a large scale without financial incentives, and governments need to support their development if they are to contribute to abatement in future. They believe that the four areas of regulation key to achieving low-cost emissions reduction are: regulation to overcome market imperfections; a stable carbon price; *“Providing sufficient incentives and support to improve the cost efficiency of promising emerging technologies [emphasis added]”* (McKinsey, 2009: 19); and making sure that opportunities in forestry and agriculture are capitalised on.

The UK Department for Business Innovation and Skills (2009) notes that, although the introduction of a carbon price can make existing technologies more commercially viable and increase the incentive for innovation in low-carbon technologies, there may still be too little innovation if:

- There is uncertainty about the future level and direction of the carbon price and the policy environment. This is especially true in the case of highly risky investments with long lead times.
- The private returns to innovation are still lower than social returns since benefits cannot be fully captured by firms as knowledge that the firm has generated spills over into the rest of the economy.
- Uncertainty and information asymmetries prevent investment in developing low carbon products. This is particularly an issue for early stage research and development since in general low carbon innovations will be in new areas where markets for the products developed are uncertain

Neuhoff (2008) agrees that the inability of firms to appropriate the full returns from innovation can be a major deterrent. The author suggests that the type of industry where this is particularly problematic is where there is a largely undifferentiated product, patents are easy to circumvent and most of any reduction in costs is expected to come from mass production. One industry which has these characteristics, according to Neuhoff, is the energy industry. In such a situation, incentives may be required in order to ensure that the optimal level of research and innovation takes place.

The sector case studies earlier in this report found that information asymmetries and organisational inertia were major factors in preventing firms from taking up cleaner technologies. In particular in the iron and steel and mining sectors, the difficulty of achieving behavioural change was cited as a major reason for potentially cost-reducing energy efficiency interventions not taking place. Here an energy efficiency incentive with a limited time horizon could be useful to encourage initial uptake of the technology. Where technologies are relatively cheap, or even zero cost (as is often the case with energy efficiency), it may be difficult to

justify the use of incentives. In such circumstances regulation or a carbon price may be better suited. There is a much stronger case for incentives when the cost for implementing a technology is still prohibitively high as a result of, for instance, a lack of economies of scale.

Another reason for providing incentives for research and development is suggested by the US Climate Task Force (2008). The authors argue that increasing the incentive to conduct research and development may lead to discoveries which could significantly reduce the cost of abatement and which would not otherwise have taken place. This will then lower the cost to the economy of adapting to climate change policies by enabling a less costly transition path and potentially leading to a different mix of production technologies than would have been a tax or trading scheme alone.

### 9.3.2. INTERNATIONAL EXAMPLES

A broad range of climate change incentives have been implemented around the world across a variety of sectors over the past two decades. In this section, the different types of incentives are explored and some examples are given of where they have been implemented in practice. At this stage, with climate change a fairly recent addition to the policy agenda, it is hard to say much about the effectiveness of such schemes since most have not been in place for long). The following discussion thus serves more as an illustration of the type of interventions that are possible. Ultimately, South Africa will have to consider its own emissions profile and where there is greatest “bang for buck”, as resources will not exist to implement full range of incentives.

Below are some international examples of each of these incentives, grouped into sectors<sup>55</sup>.

#### Energy

- The UK's *Innovation Funding Incentive* – Government will provide up to up to £6 million of funding to support early stage development of trials of key technologies consistent with a vision of smart electricity grids in the UK.
- Brazil's *PROFINA incentive programme for renewable energy* – System of feed-in tariffs combined with preferential financing for renewable energy projects offered by BNDES, the Brazilian National Development Bank.
- Australia's *Renewable Energy Development Programme (REDP)* – The REDP provides large grants to fund non-solar renewable energy power generation demonstration projects for up to one third of the eligible expenditure on each project. The grants support the commercialisation and deployment of large scale, grid feeding, renewable energy projects.
- The USA's *Loan Guarantee Programme* – The government will issue loan guarantees to eligible low carbon energy project in order to enable them to access cheaper financing.

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<sup>55</sup> Information gathered from the International Energy Agency's (IEA's) Climate Change Policy Database and various government websites for individual countries.

## Industry

- The UK's Enhanced Capital Allowance Scheme - Enhanced tax relief for spending on equipment that has an environmental benefit, i.e. energy saving equipment, water efficient equipment and low carbon cars.
- *Clean Business Australia* - A partnership between government and business aiming to increase energy efficiency and sustainability in Australian industries. It is made up of a number of programmes in which applicants compete for limited grant funds, based on the merit of their application. The following grants are available:
  - *The Climate Ready Programme* – to support research and development, proof-of-concept and early-stage commercialisation activities to develop solutions to climate change challenges.
  - *Re-tooling for Climate Change* – to help small and medium sized Australian manufacturers reduce their environmental footprint, through projects that improve the energy and/or water efficiency of their production processes.
  - *The Green Building Fund* - to reduce the energy consumed in the operation of existing commercial office buildings by supporting their retro-fitting and retro-commissioning, and by providing grants to develop the knowledge, skills or capability of those involved in their operation to improve energy efficiency and reduce emissions.
  - *Green Car Innovation Fund* – to provide assistance to Australian companies for projects that enhance the research and development and commercialisation of Australian technologies that significantly reduce fuel consumption and/or greenhouse gas emissions of passenger motor vehicles.
- The UK's *interest free loan scheme for SMEs* - this provides financial assistance to help SMEs acquire and install energy efficient technologies by providing interest free loans. Since the scheme began the Trust has offered over 800 loans to SMEs, worth over a total of GBP 30m, saving an estimated 88,000 tonnes CO<sub>2</sub>-e per annum.

## Transport

- The UK's *Consumer Incentives Programme* - A £250 million scheme of consumer incentives for the purchase of electric vehicles.
- Belgium's *tax reduction for purchase of low emissions vehicles* – fiscal incentives for the purchase of low carbon vehicles, particularly diesel vehicles equipped with a particle emission filter.
- Finland's *incentive programme for the development of technologies for the production of transport biofuels*. Discretionary State aid granted for eligible projects focused on piloting and demonstrating second generation biofuel production technologies and chains.
- France's *scrapping bonus* – For vehicles over 10 years old.

### Residential/Commercial buildings

- China's *efficient light bulbs programme* - To subsidise 50 million low-energy bulbs onto the market. Individuals pay half of the price agreed by manufacturers and the government, while businesses pay 30% of that price.
- Ireland's *Low Carbon Housing Programme* - Aims to support the development of new low-carbon and energy efficient housing through providing capital grants to developers. The programme invites proposals for housing developments incorporating design and technology features that lead to a reduction in CO<sub>2</sub>-e emissions from energy use in a typical new home by at least 70% relative to a baseline.
- Ireland's *Green Loans Programme* – Provides households with detailed household sustainability assessments and low interest loans to help homeowners install solar, water saving and energy-efficient systems and products.

## 9.4. INCENTIVES TO PROVIDE TRANSITIONAL ASSISTANCE

### 9.4.1. THEORETICAL BASIS

In theory, the introduction of a carbon price through either a carbon tax or an emissions trading scheme would lead firms to immediately respond to the price signal and invest in abatement technologies. However, in reality this may not be possible and, in the short term at least, firms may instead reduce output or even go out of business. This is particularly true of industries with large fixed investments such as power generation for example where it would not be immediately feasible to close down a coal fired power station and invest in renewables or nuclear. Even in industries where the means to retrofit existing facilities are available, this may be very expensive or take a long time. The provision of targeted transitional assistance to firms may therefore lower the adjustment cost to the economy, which will also help to build political consensus. If the cost of adaptation is perceived to be too high, then it is less likely that policy will be implemented. These factors are stressed in the Australian White Paper for the Carbon Pollution Reduction Scheme which also suggests that transitional assistance is necessary since firms made their investment decisions based on previous policy regimes, before a carbon price was introduced. Therefore it is not an equitable outcome for investors to bear the full adjustment cost (Australian government, 2008b).

Incentives can therefore be useful in supporting the imposition of a carbon price through one or other economic instrument. They may also be put in place in advance of the introduction of a tax or trading scheme in order to encourage firms to begin the adjustment process and so reduce the cost of abatement once the instrument is in place.

A study by Goulder (2002) models the impact of compensating heavily affected industries (fossil fuel industries) in the USA for loss of profits due to a carbon tax or an auctioned emissions trading scheme. The author finds that for a carbon price of \$25 per tonne increasing at 9% per year until it reaches \$50 per tonne, the efficiency losses of compensation are relatively small. For example, under a trading scheme the study concludes that 87% of permits can be auctioned and only 13% need to be freely provided in order to prevent losses of profit to fossil fuel industries. Under a tax regime, including minor exemptions to the tax or providing modest corporate income tax relief can achieve the same result. The author also finds that widening the compensation to downstream firms also has only modest cost implications since in these industries most of the cost to climate change policy is anyway passed on to consumers. This study was carried out for the USA and results will obviously differ in the South

African context, however, it does suggest that providing assistance to the worst-affected firms may not be prohibitively expensive. Nevertheless any cost reduces the government resources which can be spent elsewhere, in particular on offsetting any negative distributional effects of carbon pricing, or of the transitional assistance itself (Australian Government, 2008).

However, the Australian Government's Carbon Reduction Scheme Green Paper (2008) suggests some important principles for transitional assistance. Assistance measures should not be intended to sustain industries indefinitely without adjustment – ultimately all industries need to reduce their emissions and structural change will be necessary in order to move to low carbon economy. Artificially keeping industries going which need to adjust will cause a higher overall cost to the economy in the long run. The idea of coordinated climate change policy should be to incentivise the change which needs to occur but to provide targeted assistance in the short-run to industries which bear the highest burden of adjustment.

#### **9.4.2. INTERNATIONAL EXAMPLES OF INCENTIVES TO PROVIDE TRANSITIONAL ASSISTANCE**

##### **Australia**

###### *Support for Emissions Intensive Trade Exposed (EITE) Industries*

The Australian scheme seeks to provide assistance to industries with legitimate concerns about facing a carbon price before their competitors, which are defined as “emissions intensive trade exposed (EITE) industries”. The aim of this assistance is to prevent carbon leakage, but also to provide transitional assistance based on the rationale discussed above, in order to support continued growth in EITE industries.

The key principle underlying the design of the assistance scheme is “to support production and investment decisions that will be consistent with a global carbon constraint, by ensuring that assistance to EITE industries is provided in a way that maintains the carbon price signal” (Australian Government, 2008b:12-6). In practice this has been translated into offering support on the same basis (historical industry-wide emissions intensities) to all entities conducting a given activity. The Australian Government believes that this will preserve the carbon price signal by providing relatively greater support to more efficient entities and thus provide a strong incentive for less efficient entities to reduce their emissions. Further benefits of structuring the assistance in this way is that early action is rewarded, new investment which is generally more efficient receives more generous support, and it precludes the need to determine complex allocation rules for new EITI investments (Australian Government, 2008b).

Factors identified by the Australian Government as influencing the need for transitional assistance are: the emissions intensity of firms compared to competitors; their ability to pass on costs; the abatement opportunities available to them; and, the price elasticity of demand for their products. EITE industries are defined as Emissions Intensive based on emissions intensity (average emissions relative to million dollars of value-added) and trade exposure (ratio of traded share relative to domestic production). For detail on the actual thresholds used, see Appendix .

### *Assistance to Strongly Affected Industries*

The Australian White Paper also allows for assistance to industries which are not trade-exposed but which are nevertheless likely to be strongly affected by the imposition of a carbon price. The main rationale for this type of assistance is where competitive pressures will prevent carbon costs from being passed on to consumers (Australian Government, 2008b). The characteristics of a “strongly affected industry” are the following: being non-trade-exposed; being highly emissions-intensive; facing significant reductions in asset values due to the inability to pass on carbon costs; large sunk capital costs; and, a lack of significant economically viable abatement opportunities. The White Paper finds that only the coal-fired power generation industry has the characteristics of a strongly affected industry but that it may be appropriate to provide other forms of assistance to a number of other industries with some of the characteristics in order to reflect their particular circumstances.

## **9.5. INCENTIVES IN SOUTH AFRICA**

A range of direct and indirect support mechanisms for investment in the development and deployment of clean technologies already exist in South Africa. Each is discussed in detail below and Table provides a summary of the discussion.

In order to assess the likely effectiveness of each measure, a framework suggested by Deutsche Bank (2009) is useful. The authors perform a risk assessment of incentive policies in a variety of countries based on the following criteria:

- Is there policy certainty during the implementation timeframe? (i.e. is the benefit stable?)
- Is the policy well-aligned with the overall target?
- Can the policy be successful in current market conditions?
- Is the policy accessible to outside investors?
- Will the policy unlock substantial private capital?

The following section reviews each identified incentive against the criteria above.

### **Tax incentives: Direct**

A number of tax incentives exist or have recently been introduced for research or investment which will reduce the country’s GHG emissions.

#### *Section 12K of the Income Tax Act of 1962*

The Income Tax Act was amended in 2009 to make income from carbon credits or Certified Emissions Reductions (CERs) exempt from income tax. This will apply to all Clean Development Mechanism (CDM) projects registered on or before 31 December 2012. However, up-front investment in CDM projects has not been made tax-deductible (Deloitte, 2009). This amendment is seen as positive since South Africa’s take-up of the CDM has been poor to date (see section ), and the clarification of the tax status on income from the sale of CERs increases the level of investor certainty which should help to unlock private investment capital for CDM projects.

However, a range of other problems have also contributed to the low rate of CDM project registration in South Africa according to Little (2006). Based on a range of interviews with all kinds of CDM stakeholders, the author cites the following difficulties as crucial to the slow progress of CDM in South Africa: a complex and bureaucratic process leading to high transaction costs; uncertainty about the international regime post-2012; a volatile carbon price; the availability of cheap energy; and, a lack of understanding of the mechanism in industry. This suggests that although the clarification of the tax status of CER income is a helpful development, it may not be enough to significantly increase the number of registered CDM projects in the country given current market conditions.

#### *Section 12L of the Income Tax Act of 1962*

A further amendment to the Income Tax Act in 2009 was to insert section 12L which introduces an incentive for proven energy efficiency savings. The allowance due is based on the formula  $A \times B \times 50\%$ , where A is the amount of energy savings made in kWh equivalent and B is the lowest renewable energy tariff (REFIT) available. The purpose of the allowance is to allow firms to appropriate the full benefits or increased profit resulting from investments in energy efficiency, without being taxed on that profit. Energy Efficiency Savings must be certified by the South African National Energy Development Institute (SANEDI). The start date for the incentive has not yet been finalised but its expiry date is January 2020 which should give sufficient certainty to investors. The incentive is well-aligned with the target laid out in the National Energy Efficiency Strategy (DME, 2005) to reduce final energy demand by 12% from the 2005 baseline by 2015.

Currently the incentive translates into a tax allowance of 45c/kWh of energy saved (the lowest REFIT is 90c/kWh). At a corporate tax rate of 28%, this provides a subsidy for investment in energy efficiency of 12.6c/kWh saved. Looking at statistics from the Energy Efficiency Accord (EEA) spearheaded by the National Business Initiative (NBI) gives an illustration of what this means in practice. Between 2005 and 2007, participants invested R9.933 billion in energy efficiency measures. The 15 Accord members who provided information on their electricity energy demand reduction saved 2405 GWh in the 2007 financial year (NBI, 2008). Had the incentive been in place, they would have received an allowance of R1.082 billion or a total benefit of R303 million for that year. This amounts to around 3.05% of the investment costs recouped in the first year alone. It is difficult to assess up front how successful the incentive will be, however, it does seem that the low value to firms relative to their investment outlay in the short term may limit its ability to unlock substantial private capital. However, the programme's stated aim of ensuring that firms capture the full benefit of their energy efficiency investment is likely to be met.

#### *Section 12I of the Income Tax Act of 1962*

The proposed amendment to Section 12I of the Income Tax act would provide incentives for investments which correspond to industrial policy objectives. Additional tax allowances of 35% or 55% are available against investments of R30 million to R1.6 billion according to a points system where up to 10 points can be scored based on performance against a series of criteria. This includes a potential two points for investments in technology which will result in increased energy efficiency and cleaner production.

Although the inclusion of energy efficiency and cleaner production criteria in the tax incentives package is welcome, a maximum score on this criteria can only provide two of the five or eight points needed in order to gain the 35% and 55% allowances respectively, so investments in

green technology will have to meet some of the other criteria in order to qualify. These are: innovative processes; general business linkages; acquiring goods and services from small, medium or micro enterprises; direct employment creation; and, skills development. In addition, there is no direct link with GHG emissions reduction, only with energy efficiency. Thus the policy is not directly aligned with climate change policy aims.

*Section 11D of the Income Tax Act of 1962*

This gives a tax allowance of 150% of expenditure incurred in respect of technological research and development. As such R&D expenditure on clean technology could qualify for support but the incentive has no specific application to climate change. While it would thus reduce the cost of new R&D related to climate change mitigation technologies, it is unlikely to incentivise firms to divert resources from other R&D activities into this area and as such is not well-aligned with climate change goals.

*Section 13 of the Income Tax Act of 1962*

This section of the Income Tax Act provides a tax allowance for the improvement of commercial buildings. Landlords can deduct the cost of any improvements made against rental income. However, the China Council for International Cooperation on Environment and Development (2009) argue that this is not enough to incentivise landlords to make energy efficiency improvements. There is an inherent misalignment between the cost and benefits of energy efficiency investments in rented buildings, since the cost of improvements falls to landlords whilst the full monetary benefits (in terms of energy savings) accrue to tenants. Therefore a specific tax or other incentive to encourage energy efficiency upgrading in rental properties, and to ensure energy efficiency in new developments, may be appropriate.

**Subsidies: Direct**

*Renewable Energy Feed-in Tariffs (REFIT)*

In April 2009, the National Energy Regulator of South Africa (NERSA) published feed-in tariffs for a range of renewable energy technologies in an attempt to improve progress towards government's target of 10 000 GWh of renewable energy contribution to final energy demand by 2013. The list of qualifying technologies was subsequently extended in a second phase in June 2009 which was approved in August 2009. A feed-in tariff is a guaranteed price at which each kWh of energy will be bought in order to feed in to the main grid supply. It represents a subsidy for renewable energy since the price is higher than the average price of electricity produced currently. The price is calculated based on the cost of generation plus a "reasonable profit" in order to incentivise investment (NERSA, 2009). The REFIT power purchase agreements are agreed for 20 years, with the tariffs subject to review every year for the first five years and every three years thereafter with new tariffs only applicable to new projects.

Feed-in tariffs are a popular means of encouraging the growth of renewable power generation worldwide and have now been implemented by more than 36 countries (NERSA, 2009). They have been found to have been successful at stimulating the sector and also at reducing the cost of renewable power generation over time (Renewable Energy World, 2009b).

The tariffs currently guaranteed by NERSA are the following:

	Technology	Tariff (Rand per kWh)
REFIT	Wind	1.25
	Small hydro	0.94
	Landfill gas	0.90
	Concentrated solar power trough plant with 6 hours storage	2.10
REFIT II	Concentrated solar power trough (without storage)	3.14
	Large scale grid connected PV systems	3.94
	Biomass (solid)	1.18
	Biogas	0.96
	CSP tower with storage of 6 hours per day	2.31

**Table : Approved renewable energy feed-in tariffs for REFIT I & II**

Source: NERSA 2009

In general these elements of the guidelines seem to have met with stakeholder approval and the tariffs are widely held to be sufficient to unlock private capital, providing tariffs which in some cases are greater than those offered in Germany, the leading proponent of the Feed-in Tariff approach (Engineering News, 2009; Renewable Energy World, 2009a). There is significant private sector interest in the programme (Dewey and LeBoeuf, 2009) which was reflected in the high number of comments received by NERSA on the draft guidelines and on the strong attendance at stakeholder consultations.

However, there are still a number of problems with current market conditions which are causing concern to potential investors. The first is power procurement as the guidelines do not make clear whether there will be limits on the amount of power that will be purchased and whether the procurement will be on a first come first served basis or through a tender process. Both methods have been used internationally, with the "first come first served" model having the benefit of rewarding first movers and encouraging quick uptake (Dewey and LeBoeuf, 2009). The second key issue from an investor's perspective is the question of who the buyer of the power will be. In the guidelines it is stated that the Renewable Energy Purchasing Agency (REPA) will buy the power and that REPA is to be housed in Eskom's Single Buyer Office. This is a decision of some concern to investors, not least since Eskom has failed to sign a single Power Purchase Agreement (PPA) to date. The Energy Minister, Dipuo Peters, recently called for an independent power purchasing operator to be created. Unless there is clarity on the procurement and institutional arrangements, the renewables sector is unlikely to take off, despite the generous feed-in tariffs. Financing of projects will remain difficult to secure whilst uncertainty on these issues remains.

#### *Solar Water Heater Grant*

As part of the Demand Side Management programme, Eskom offers a rebate of 15 to 30% of the purchase price of solar water heaters. Geysers typically cost in the range of R12 000 - R30 000 depending on their size (Eskom, 2010).

Although the geysers lead to electricity and therefore cost savings for consumers, the high upfront costs result in a relatively long payback time of five to ten years (Eskom, 2010) so take-up has been slow and the programme has not met its targets so far (Altman et al, 2009).

Additional problems reported which have prevented broader take-up are the high price of geysers and the lack of suppliers and skills in South Africa which further increase the cost to consumers (Eskom, 2010). Therefore, in current market conditions the policy seems unlikely to be successful. However, Eskom believes that the programme is gaining traction, and the Department of Energy has targeted the roll out of solar water heaters to 1 million homes over the next five years (Engineering News, November 2009). This would relieve peak demand on the grid by around 630 MW, or 1.6% of current capacity. It has been reported that Eskom is soon to increase the rebate, roughly doubling the allowance available, in order to incentivise wider uptake (Engineering News, January 2010). This should help to unlock further private investment.

#### *Energy Efficient Motors Programme*

Another feature of the Demand Side Management programme is Eskom's subsidy for the replacement of industrial motors with energy efficient motors. The subsidy is between R400 and R3500 depending on the size of the motor (the programme covers motors from 1.1kW to 90kW) (Eskom, 2010). Eskom estimates that replacing 5000 standard motors with energy efficient motors would result in an electricity saving of 2 482 MW and that programme overall could save up to 10 GW (current generation capacity is roughly 40GW). Energy efficient motors are on average around 20% more expensive than ordinary motors (see section [ ]) and the subsidy reduces this disparity somewhat. According to Altman et al (2009), however, the subsidy amounts are too small relative to the cost installing a motor and this explains the poor uptake of the subsidy. The programme seems unlikely to effectively leverage large amounts of private capital under these circumstances.

#### *Renewable Energy Fund*

The Renewable Energy Fund is funded by the Department of Energy and administered by the Renewable Energy Finance and Subsidy Office (REPSO). It offers support of R250 per kW for renewable energy investment projects of at least 1MW in size and requiring total investment not greater than R100 million. To-date the Fund has awarded six subsidies with a total installed capacity of 23MW (DME, 2010), including small scale hydro, biogas to electricity, wind energy and landfill gas to electricity. Altman et al (2009) suggests that if R200 million of funding is available each year, this will result in 800MW of installed generating capacity. The Fund offers substantial support for renewable energy investments but given the current institutional constraints (see the REFIT discussion above) this may not be enough to unlock significant private investment.

#### *Energy Efficiency Stimulation Programme - Proposed*

An Energy Efficiency Stimulation Programme has been proposed by the dti as a means of stimulating investment in energy efficiency (Altman et al, 2009). The programme amounts to an investment grant of up to 50% of the value of the qualifying investment costs for projects in the manufacturing, mining and commercial sectors. Investment projects smaller than R5 million qualify for a grant equal to 50% of their investment costs payable over three years. Projects greater than R5 million qualify for between 30 and 50% payable over two years and the grant cannot exceed R30 million. Grant payment is subject to the project achieving certain energy efficiency requirements. Altman et al (2009) note that it is not clear if the grant is taxable or not and that initial comments on the proposal suggest that the investment size limits should be extended in both directions, and the scope of the programmes extended to other sectors. This indicates that the potential to incentivise investment is not as high as it could be. However,

Altman et al believe that the programme can be effective, and calculate that if 1000 projects are supported annually with an average grant amount of R5 million over two or three years, then an energy saving of 2.5GWh per year could be achieved at a cost of R1.5 billion per year. However, it remains at a proposal stage.

### **Subsidies: Indirect**

#### *DTI's Critical Infrastructure Programme (CIP)*

The CIP's objective is to incentivise infrastructure projects that are critical to support economic development. The programme provides a cash grant covering between 10 and 30% of the cost of qualifying infrastructure. Co-generation and renewable energy generation could qualify for a grant from the CIP (Deloitte, 2009), however, the incentive is not directly aligned with climate change objectives.

#### *Technology and Human Resources for Industry Programme (THRIP)*

The THRIP is a partnership programme administered by the National Research Institute, which aims to facilitate business and government joint funding of innovative research in South Africa (dti, 2010). The programme aims to assist projects that promote and facilitate scientific research and technology development and diffusion by sharing the cost and risk of developing commercial technology. The dti provides R1 of funding for every R2 provided by industry but the dti's support may be doubled if a project supports other priorities such as the promotion of SMMEs or increasing the number of women in technical and engineering careers. The programme has been used to fund research in the energy industry before, and could be utilised as a source of funding for the development of clean technology (Altman et al, 2009), but again is not directly intended to support climate policy objectives.

#### *Support Programme for Industrial Innovation (SPII)*

The SPII is a small fund administered by the IDC which can be used to fund innovative technology and therefore potentially new clean technology. SPII is focussed on the phase that begins at the conclusion of basic research up to the point where a pre-production prototype has been produced. Three types of financing are possible under the Product Process Development Scheme, the Matching Scheme and the Partnership Scheme, depending on whether the initiative is being pursued by a small firm, large firm or industry respectively (SPII, 2010). This may be a useful incentive for the development of clean technologies in South Africa but once more is not specifically a climate change incentive, and will therefore not incentivise climate-friendly technologies above other kinds of innovation.

Type	Incentive	Description	Effectiveness/likely effectiveness	Cost
<b>Tax incentive</b>	Section 12K Income Tax Act	Income from CERs from CDM projects registered before 31 December 2012 tax-exempt	Helpful but there are other barriers to the uptake of CDM	Foregone tax revenue
	Section 12L Income Tax Act	Income tax allowance for energy savings. Allowance = $A \times B \times 50\%$ . Where A = amount of energy savings in kWh equivalent and B = lowest renewable energy tariff (REFIT), currently R0.90c.	Phase 1 of EEA participants invested R9.933 billion and saved 2405 GWh of electricity which would have earned them R303 million or 3.05% of their investment costs	12.6c/kWh foregone tax revenue
	Section 12I Income Tax Act	Additional 35% or 55% tax allowance on investments which correspond to industrial policy objectives including energy efficiency and cleaner technology	EE not the only objective and not directly targeting GHG emissions.	Unknown
	Section 11D Income Tax Act	Tax deductions for expenditure on technological R&D. Tax allowance of 150% of expenditure incurred.	No specific application to climate change.	Unknown
<b>Subsidy</b>	Renewable Energy Feed-in Tariffs	Guaranteed price at which different types of renewable energy will be bought to feed into the grid	Price sufficient but institutional constraints still present problems	None to government (except administrative costs) - all to electricity users
	Solar Water Heater grant	Rebate from Eskom for the purchase of solar water heaters.	100 000 geysers offset 300 MW or around 63 MW during peak periods. Long payback time and rebate relatively small – programme has not achieve targets	Funded from electricity tariffs and cheaper than building more generation capacity
	Energy Efficient Motors Programme	Subsidy from Eskom for the purchase of new energy efficient motors.	Replacing 5000 standard motors with energy efficient motors would result in a saving of 2 482 MW. Estimated that programme overall could save up to 10 GW. Small benefit in relation to the cost of installing a motor so take-up has been slow (HSRC).	Funded from electricity tariffs and cheaper than building more generation capacity
	Renewable Energy Fund (REPSO)	Support of R250 per kW available for renewable energy projects from 1MW in size for projects up to R100 million.	HSRC calculation – could increase installed capacity by 800MW per year.	R200 million per year (for 800MW)
	Energy Efficiency Stimulation Programme	Proposed by the DTI - investment grant of up to 50% of value of qualifying investment costs over two or three years subject to project achieving EE performance requirements.	HSRC calculation - if 1000 projects are supported annually with average grant amount of R5 million over 2 or 3 years will lead to saving of 2.5GWh per year. Tax status not clear and stakeholders would like the programme to be extended.	R1.5 billion annually (based on projected figures given)

Type	Incentive	Description	Effectiveness/likely effectiveness	Cost
	DTI Critical Infrastructure Programme	Non-refundable cash grant available to approved beneficiaries on completion of infrastructure project. 10 - 30% of development costs.	No specific application to climate change.	Unknown
	Technology and Human Resources for Industry Programme	Partnership programme to facilitate business and government joint funding of innovative research in SA. Administered by National Research Institute	No specific application to climate change.	Unknown
	Support Programme for Industrial Innovation	Small fund administered by IDC	No specific application to climate change.	Unknown
	National Industrial Participation Programme	Small fund administered by DTI	No specific application to climate change.	Unknown

**Table : Catalogue of available incentives for investment in clean technology**

*Source: Genesis Analytics, 2010*

## 9.6. CONSIDERING CURRENT AND FUTURE INCENTIVES IN SOUTH AFRICA

Incentives are only one a number of policy instruments which can be used to meet the Cabinet's Peak, Plateau and Decline mitigation trajectory and climate change policy vision. From an economic theory and fiscal affordability perspective they should play a supportive as opposed to a central role. Currently, the use of incentives dominates the suite of existing climate change policy instruments, and it is argued that not all of these incentives are appropriate.

Theory suggests that incentives should be used to smooth the transition from one policy environment to another, or to address market failures. The energy efficiency incentives currently in place are aimed at addressing the market failure caused by underpriced electricity. This market failure is likely to be automatically addressed as the electricity price inevitably rises in South Africa. However, there are other reasons (behavioural, cultural, and institutional) for the high levels of energy inefficiency which characterises the South African economy. Existing energy efficiency subsidies do not appear to provide significant cost incentives, and their uptake has been relatively poor. Energy efficiency is a cost-negative mitigation option as modelled by the LTMS<sup>56</sup>. This, together with the future increase in the electricity price argues against the use of incentives to improve uptake, and suggests rather that information, cultural, or institutional issues need to be addressed through alternative policy mechanisms.

There are no existing direct incentives for R&D in any specific low emissions technology, rather general incentives which only cover low emissions R&D indirectly. Given the prevalence of risky mitigation options with high potential abatement identified in the case studies in section , there appears to be substantial room for incentives which *target the creation of a competitive advantage in a particular technology* with a view to capturing the market for this technology internationally (eg. centralised solar thermal power generation). This type of incentive is anticipated to play an important role in realising medium to long term emission reductions to meet the Plateau and Decline portion of Cabinet's trajectory. It is unlikely that the fiscus has the resources to incentivise R&D in all of these opportunities, but should rather focus on one or two more likely candidates (see footnote ).

A second suggested use of R&D incentives is to *adapt existing low emissions technology for application in the South African environment*, such as fine-tuning solar water heater design for the country's climate, manufacturing skills and natural resources. Many similar opportunities exist which have the potential to address additional policy challenges, such as the clearing and disposal of alien vegetation (in decentralised biomass power generators), and the creation of jobs in the manufacture of low technology cookstoves.

Given the *Clean Business Australia* example mentioned earlier in this section, a challenge fund model seems particularly well suited to channelling funds to R&D aimed at developing and

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<sup>56</sup> It should be noted, however, that the sector case studies cast doubt on the validity of this assumption (see section ). A significant proportion of energy efficiency opportunities may be low cost. This does not change the conclusion above since a) low cost options can still be more effectively incentivised (across may sectors) by a low-level carbon price and b) the bulk of the current low cost energy efficiency options may become cost neutral or negative cost options as the price of electricity moves to cost-reflective levels in SA.

commercialising new abatement technologies and adapting existing technologies to South African conditions<sup>57</sup>.

The REFIT holds out considerable promise as an effective and appropriate incentive instrument for supporting emerging technologies, but only once the institutional and market issues currently hampering its use are resolved. Similarly, should the other barriers to the CDM be removed, and the mechanism be implemented at scale in the country, the tax exemption is anticipated to provide significant incentive to these projects, the CDM itself being an emerging technology.

There are no incentives in place to smooth the transition to a low carbon economy for vulnerable sectors yet, but it is anticipated that this is likely to be crucial for an economy which is so dependent on highly energy intensive exports, and has many vulnerable sectors which are currently drivers of economic growth and employment (see sections and ). Temporary partial or full temporary exemption from policies that implement a carbon price may provide temporary room for industries to increase their carbon efficiency. Subsidies and soft loans for energy and carbon efficient technologies are likely to play a role in assisting these industries to increase their GHG-emission efficiency. Export rebates can be used to temporarily protect exporters against international carbon prices and border adjustment measures, but this approach is likely to not be WTO compliant and will also be a drain on the fiscus.

The incentive package is strongly focused on energy, with no incentives in the transport sector at all, although transport plays an important role in medium to long term emission reductions. South Africa is developing a competency in the electric car, and has an automotive sector which may be able to support the creation of a competitive advantage in this mitigation technology. Incentives would be very appropriate to support this emerging industry.

The indirect incentives appear to be too unfocused to provide significant incentives, especially in the absence of other strong low carbon policy instruments such as carbon pricing and regulation. However, within the context of such a low carbon policy regime, the existing indirect incentives may achieve greater uptake as the low emissions component becomes increasingly attractive to potential project developers.

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<sup>57</sup> The „Challenge Fund’ is an effective and versatile financing mechanism to channel grant funding to catalyse innovation and investment. Challenge funds explicitly target partnerships with established private firms to incentivise, on a risk- and cost-sharing basis, R&D, innovation and investment in specific target areas. The strength of a challenge fund lies in its ability to be focused, entrepreneurial, opportunistic and cost-effective, and through the mechanism of competition, to maximise private sector innovation. It functions as a temporary market development catalyst that stimulates competition, innovation and risk-taking to help companies discover new ways of working where the returns and risks are uncertain or unknown. An example of a challenge fund operating in South Africa, aimed at incentivising profitable projects that have a significant impact on poverty reduction, is the Business Trust-funded Shared Growth Challenge Fund (<http://www.sgcf.co.za>). A challenge fund aimed at incentivising projects around the development, commercialisation and local adoption of GHG reduction technologies would have the added advantage that it would be able to fund the most promising projects utilising a number of different technologies. This would overcome the need (as a result of fiscal constraints) to focus R&D incentives on a limited number of pre-determined technologies.

## 10. CONCLUSION: THE WAY FORWARD

### 10.1. TIMEFRAMES

As a developing country, South Africa has been able to delay its emissions peak to 2020, whilst retaining credibility in the international arena. In order to meet this peak, the LTMS shows that the country must embark immediately on an aggressive energy efficiency programme (the Start Now) scenario, whilst preparing the way for including a significant level of renewables and nuclear generation into the electricity grid, together with mitigation technologies in transport (electric cars), liquid fuels (carbon capture and storage) and others.

Therefore, apart from a few notable exceptions, the country has time to develop an optimal mitigation policy package to drive the implementation of the remaining LTMS wedges from 2020. These exceptions include ensuring the success of an aggressive energy efficiency drive, identifying areas where the country can capture new sources of international competitiveness, avoiding lock-in to technologies and new industries which will hamper emissions reduction into the future, and ensuring that policy, the regulatory environment, institutions, data, financing and technologies are in place to begin the implementation of low carbon options come 2020 if not before.

### 10.2. POLICY DEVELOPMENT GUIDELINES: USE OF ECONOMIC INSTRUMENTS

In order to achieve the optimal level of GHG emissions abatement on a continuous basis, the cost of emissions must be incorporated into the price signals of the international economy. Economic theory tells us that this is most efficiently done through the use of a broad based economic or price instrument. A range of appropriate regulatory and incentive instruments will be important to support the emergence of a carbon price over time. These should be used to:

- accelerate investment in clean technologies whilst the carbon price is still too low to counteract their risk;
- in areas where non-price barriers exist which are more appropriately targeted through a non-price mechanism and before a significant carbon price comes into effect; and
- support vulnerable sectors to transform to a low carbon economic environment.

The LTMS scenario which comes closest to the medium and long term ambitions of the Peak, Plateau and Decline trajectory is „Use the Market’, which models the imposition of an escalating carbon price. At present, however, there is *insufficient information available regarding GHG emissions and abatement options at a sectoral level in South Africa to accurately determine what the impact of a given carbon price will be on individual sectors*. The timeframe discussion above, together with the analysis of optimal policy design outlined earlier in this report recommends that climate policy development be approached slowly, with an emphasis on getting correct data, building consensus, and providing long, loud and legal policy signals so that the private sector has sufficient policy certainty to ensure optimal investment planning.

It is anticipated that the South African climate policy suite will eventually comprise a number of policy instruments, tailored to the country's specific circumstances. The components of this suite of policies will be the outcome of a policy development process that is likely to include extensive stakeholder engagement. The sections that follow thus provide possible policy options which could be considered for inclusion in the eventual suite of policies. These sections build on Section by incorporating the analysis from subsequent sectors.

### **10.2.1. GENERATE DATA**

It is strongly evident in the sector case studies that there is a critical lack of data at a sectoral level in the country. In a sector like Agro-processing, for instance, it is almost impossible to draw any firm conclusions on the impact of climate policies on the sector because of the lack of available data. Gathering data must be prioritised in order to avoid inappropriate and potentially damaging policy. A delay in mandatory policy may be negotiated as an incentive for firms to disclose verified emissions data.

### **10.2.2. PURSUE ENERGY EFFICIENCY**

An aggressive energy efficiency programme must be pursued, which could be supported by a white certificate scheme, with the steep electricity price escalation acting as a natural stimulus, and technology standards supporting the adoption of mature and standardised energy efficiency technologies. Attention will need to be paid to potential carbon leakages from an indirect policy instrument like a white certificate trading scheme. The sector case studies indicated that negative or low cost energy efficiency options were available to most of the sectors. The relative abatement potential of energy efficiency options, however, varies widely between sectors. The evidence from the sector case studies does question the assumption used in the LTMS that energy efficiency options are negative cost options. In only 2 of the 7 sectors do negative cost energy efficiency measures (including more energy efficient industrial motors) make up more than 10% of identified abatement potential.

### **10.2.3. SUPPORT TECHNOLOGY DEVELOPMENT AND ADOPTION**

Subsidies and incentives for R&D in strategic low carbon areas are required in advance of the introduction of a carbon price to develop a competitive advantage for the country, and to ensure the development of suitable technologies for South Africa's low carbon future. The REFIT is a good example of an appropriately applied subsidy, although the issues surrounding policy in the energy sector need to be resolved to enable the REFIT to be implemented. There are no existing direct incentives for R&D in any specific low emissions technology in South Africa. Low emissions R&D is indirectly covered by general incentives. Given the prevalence of inherently risky abatement options (an indication that the technology has not matured yet – leaving scope for further R&D) with high abatement potential in the case studies in section , there appears to be sufficient justification for incentives which target the creation of a competitive advantage in a particular technology with a view to capturing the market for this technology internationally (eg. Centralised solar thermal power generation). It is unlikely that the fiscus has the resources to incentivise R&D in all of these opportunities, but should rather focus on one or two more likely candidates which offer the best immediate prospects for abatement. The current incentive package is strongly focused on energy, with no incentives in the transport sector at all, although transport will play an important role in medium to long term emission reductions. South Africa is developing a competency in the electric car, and has an automotive sector which may be able to support the creation of a competitive advantage in this

mitigation technology. Incentives would be very appropriate to support this emerging industry. A second suggested use of R&D incentives is to adapt existing low emissions technology for application in the South African environment, such as fine-tuning solar water heater design for the country's climate, manufacturing skills and natural resources.

#### **10.2.4. ALIGN CLIMATE AND INDUSTRIAL POLICIES**

Climate and industrial policies should be aligned, ensuring low carbon criteria are incorporated in all industrial policy projects and decisions, and that climate change opportunities are exploited directly, with environmental goods and services prioritised as a sector for development.

#### **10.2.5. UTILISE VOLUNTARY MEASURES**

Voluntary mechanisms like reporting or emissions reduction agreements can build consensus on upcoming mitigation policy, introduce firms to the idea of reporting and verifying emissions, and generate much-needed data to inform the policy design process. The systematic exploitation of CDM opportunities (particularly programmatic CDM) could also provide access to substantial amounts of funding for abatement activities in South Africa at very little cost to government (the cost of unlocking blockages). Sector case studies identified opportunities for CDM projects in all the focus sectors apart from Non-ferrous metals.

#### **10.2.6. CONSIDER IMPLEMENTING A CARBON PRICE**

The sector case studies showed that a relatively low cost carbon price would incentivise the uptake of emissions reduction technologies and lead to significant GHG reductions in all but two sectors, namely the Electricity generation and supply and Mining sectors (these are the only sectors where low cost abatement options does not account for at least 60 percent of available abatement opportunities). The two economic instruments available to implement a broad-based carbon price in South Africa are a carbon tax and an ETS. Theoretically it is also possible to implement these two instruments together.

A **carbon tax** could be gradually introduced, preceded by, or in parallel with a voluntary data disclosure scheme with an incentive such as tax rebates for the first few years as a reward for full disclosure. The impact of the tax will be optimal if it is aimed at emissions at source. The tax could generate significant fiscal revenues and could ensure that the overall bundle of climate change policies is revenue neutral (i.e. it could offset the cost of other climate change policies). Targeted government transfers could be used to offset the impact of a carbon tax on the poor.

A mandatory **ETS** would benefit from an initial voluntary phase to generate data and familiarise participants with the mechanics of emissions trading. An ETS should have broad coverage to maximise efficiency. Initially permits may be grandfathered, but a relatively fast move to full auctioning is suggested to ensure fiscal, environmental and economic efficiency and to address equity concerns and potential barriers to entry. Market power and a lack of liquidity are likely to significantly impact any local ETS as a result of South Africa's emissions profile. A local ETS should thus either be linked to an accredited international ETS, or be designed to minimize the risk of disproportionate market power. It is important to consider the effect that a reduction in coverage to address market power may have on the scheme's efficiency. If this is not taken into consideration, the rationale for having an ETS in the first place may not be

adhered to. The benefits of design features to reduce price volatility must be considered against their impact on emissions reduction certainty and increased administrative complexity.

#### **10.2.7. PROVIDE TRANSITIONAL ASSISTANCE**

As carbon prices or international discrimination based on carbon intensiveness of exports is introduced, transitional incentives can be used to ease the transition for vulnerable or trade intensive sectors. These are best used temporarily, and not to support highly emissions intensive industries in the long term. At present there are no incentives in place to smooth the transition to a low carbon economy for vulnerable sectors. This is anticipated to be crucial for an economy which is so dependent on highly energy intensive exports, and has many vulnerable sectors which are currently drivers of economic growth and employment. Partial or full temporary exemption from policies that implement a carbon price may provide temporary room for industries to increase their carbon efficiency. Subsidies and soft loans for energy and carbon efficient technologies are likely to play a role in assisting these industries to increase their GHG-emission efficiency. The analysis in section indicated that, consistent with international experience, there is likely to be a minority of local sectors that will be disproportionately affected by climate change policies. The Non-ferrous metals and liquid fuel sectors, in particular, seem highly vulnerable to competitive concerns. The sector case studies also showed that the attractiveness of available abatement options vary significantly between sectors, and that there are a minority of sectors that will find it particularly difficult to reduce their GHG emissions. These two factors seem to indicate that targeted transitional assistance will be justified in South Africa. Sectors which may benefit from this type of assistance include Non-ferrous metals, Liquid fuels and Mining

#### **10.2.8. CONSIDER PERFORMANCE AND TECHNOLOGY STANDARDS**

Performance and technology standards in general are not economically efficient and do not lead to lowest cost abatement. They may, however, be useful policy instruments to meet a given emissions target in the event of other policies proving to be less effective than initially anticipated. In South Africa there are 2 instances where standards may be warranted under these conditions. Technology standards supporting the adoption of mature and standardised energy efficiency technologies can be useful to support energy efficiency – provided that the technologies mandated are expected to lead to cost benefits or only negligible cost increases. Furthermore, in order to meet the Peak, Plateau trajectory, negotiated performance standards between Eskom (and other potential electricity sector players) and government, may be an effective instrument to ensure the necessary shift in generation mix

#### **10.2.9. CONSIDER TRANSPORT EMISSIONS**

Transport has been specifically excluded from this study, but being a significant source of emissions in the future warrants careful attention. Appropriate policy instruments for transport will be particularly important.

### **10.3. SECTOR ACTIONS TO PREPARE FOR POLICY DEVELOPMENT**

Based on the sector case studies presented in section , a number of key actions can be highlighted that will enable focus sectors to engage constructively in the climate change debate and to assist them with moving towards low-carbon production (see section for more detail regarding sector actions).

#### **10.3.1. AGRO-PROCESSING**

There is a dearth of information regarding climate mitigation opportunities and emissions data in the Agro-processing sector. Baseline emissions data does not exist, and quantitative estimates of the viability of only 4 abatement technologies could be obtained as part of the current study. In addition, the study found that awareness of climate change issues and the particular risks and opportunities it poses for the Agro-processing industry need to be raised. Substantial research is required therefore to determine quantitative estimates of energy use and GHG emissions and to identify, quantify and consolidate the abatement potential offered by all potential abatement options in this sector.

#### **10.3.2. ELECTRICITY GENERATION AND SUPPLY**

The lack of policy co-ordination and the contested policy space in the energy sector is currently hampering effective policy development needs to be addressed before climate policy can be considered. The case study analysis in Section indicated that the medium cost profile of all the abatement options in this sector meant that this sector will need to find new ways of harnessing all potential energy sources in order to function effectively in a carbon constrained world. There are no low or no cost options available to this sector. Since electricity supply dominates carbon emissions and thus determines the carbon profile of most other industry, and given that assets in this sector are long lived and expensive, addressing the organisational issues in this sector should be a climate mitigation policy priority. Solar CSP appears to represent a potential source of competitive advantage for the country, and should be proposed for significant national incentive funding. The way forward on nuclear also needs to be clarified, with a plan for capturing technological competitive advantage (pebble bed), or releasing funding for more promising technologies.

#### **10.3.3. CHEMICALS**

Reliable disaggregated GHG emissions data for the Chemicals sector needs to be generated. Electricity constitutes a significant proportion of the chemical industry's overall energy spend and energy efficient technologies are thus likely to become a significant source of competitive advantage in this industry. At an operational, level firms should identify high priority energy saving projects such as refraining from running equipment under no load, improving the Power Factor Correction (PFC), installing bearing technologies that are geared to reduce friction; improving the motor electrical efficiency by carefully assessing the practice of rewinding of motors; and exploring if replacement motors can be of a smaller size. Significant revenue growth for specialty chemical firms may also be derived from the development and marketing of chemical products which help to reduce energy consumption as well as materials for new energy technologies like solar photovoltaic cells and fuel cells). The Chemical sector is a potentially vulnerable sector to climate mitigation policies, and should therefore prioritise data collection and early action in energy efficiency to motivate for transitional subsidy protection in the future.

#### **10.3.4. LIQUID FUELS**

Plant level investigations of major sources of emissions need to be undertaken to get a better understanding of the availability and cost of available abatement technologies and the reductions that each could achieve. Because emissions reduction information in this industry tends to be project specific, it is also highly proprietary and where available is presented in a way that is not useful for policy analysis. Initiatives are required in the industry to generate comprehensive climate change mitigation information in a format that can inform policy development. Based on the analysis in the sector case study, the abatement potential and costs of emissions reduction in the South African liquid fuels sector will depend on the industry's ability to capture CHP, reduce flaring and implement energy-efficiency opportunities, as well as on the future feasibility of carbon capture and storage. It is imperative that alternative fuel sources such as natural gas are considered and supported. Strategically, improved planning is the key to improved implementation and operation. Given South Africa's current "lock-in" on CTL as a guarantor of national fuel security, further research to develop alternative processes to retrofit CTL should also be considered. The sector should promote CCS as a potential recipient of R&D incentive financing, with decision points identified for the viability of the technology. The sector faces large potential competitiveness impacts due to be very energy and emissions intensive. It will probably need to make a case for transitional assistance and should thus start generating required data in a timely fashion.

#### **10.3.5. IRON AND STEEL**

Driving towards more energy-efficient processes has been and should remain one of the main focuses of the iron and steel industry. Recent work to identify attractive energy-reduction options has consistently shown that significant potential, typically in the order of 10 to 15% of total energy costs, can be captured with payback of less than two years. The primary barriers to realising these opportunities are typically organisational and should be addressed. Increased steel recycling and shifting technology from the blast furnace route to the electric arc furnace offers the most significant mitigating potential. However, this shift is somewhat constrained by the availability of scrap metal required by the EAF. An important mitigation option is therefore to increase iron and steel recycling in the SA economy. As a sector potentially vulnerable to climate mitigation policies, this sector will need to justify the use of transitional subsidies, and therefore early action on energy efficiency may stand the sector in good stead.

#### **10.3.6. NON-FERROUS METALS**

Sector specific data is almost non-existent on the costs and emission reduction potentials associated with the various abatement options. Furthermore, indications are that those options that have received attention, e.g. PFC reduction from aluminium, are relatively insignificant for the sector. In order to better be able to engage with government, there is a strong need for the industry to establish baselines in terms of both emissions from the sector and the costs and emission reduction potentials associated with various abatement technologies. Statistics on recycling are also very poor and need to be improved. Without these statistics it is difficult to assess the potentially large abatement potential from increased recycling. As a particularly vulnerable sector to climate policies (highly traded and emissions intensive), it is strongly in the sector's interests to provide the data which justifies potential transitional subsidies.

### **10.3.7. MINING**

Globally mitigation opportunities within the mining sector have tended to focus on coal mine methane projects (e.g. as seen by the large number of these projects taking place under the auspices of the Clean Development Mechanism). However, South African coal mines have relatively low concentrations of methane, and projects to capture and utilise the methane have generally been thought not to be economically viable. It is thus important to investigate technology advancements that could make methane projects feasible even in low concentration mines. It is also important to gain a better understanding of methane project costs to confirm that costs really are prohibitive in South Africa at present. Energy efficiency mitigation opportunities will yield relatively minor results, but their GHG savings are still significant in absolute terms. Since many of these measures are not routinely implemented on South African mines, it is important to investigate the reasons for this. Depending on the nature overburden and mining method and the nature, spontaneous combustion in coal mines can be a significant issue. It is also a significant problem on waste dumps and abandoned mines. Low technology mitigation measures are reasonably successful, although fairly costly in avoiding coal fires arising from spontaneous combustion. The issue of spontaneous combustion in coal mines is largely overlooked and the reasons for this needs to be investigated and addressed. Similarly to metals and chemicals, mining is an emissions and trade intensive sector, and will have to justify the use of transitional subsidies.

# 11. APPENDICES

## 11.1. APPENDIX : DATA ISSUES

In general, good data on GHG emissions is not available in South Africa at a sectoral and sub-sectoral level. For each sector the best available information from the 2000 GHG inventory (DEAT, 2009) and the LTMS (Winkler, 2008) was collated and where necessary supplemented with imputed estimates of GHG emissions from energy usage from a paper by Blignaut et al (2005). International estimates of the emissions-intensity of the sector were also considered. The specific difficulties related to emissions data in each sector are elaborated on in the case studies.

In order to determine the mitigation potential and costs from the various mitigation options in each sector, consideration was given to a number of data sources, including the Long Term Mitigation Strategy (LTMS) (Winkler 2007), the McKinsey study on pathways to a low carbon economy (McKinsey 2008), the IEA's Energy Technology Perspectives (IEA 2008) and a study conducted by the Energy Research Centre at the University of Cape Town which builds on the LTMS study (Marquard et al, 2008). A number of considerations make it difficult to extract the data from these studies and to compare the data between sources. These are the following:

- In the LTMS, mitigation potentials for technologies are determined within the context of a "scenario", or in other words mitigation potential is not calculated for individual technologies, but rather in scenario groupings. Within these groupings a number of underlying assumptions have been made, including likely technology mixes in the future and the maximum possible contribution of a technology to the overall grid. Many of these assumptions are not readily unpacked from the study.
- Time periods differ between studies. The LTMS presents cumulative mitigation over the period to 2050, during which the relative contribution of the various technologies changes, while the McKinsey study presents abatement curves set in the year 2030. Furthermore the reference year for which costs are presented varies between information sources.
- Much of the data in both the IEA and McKinsey studies incorporates global averages, while potential for abatement from mitigation technologies varies around the world depending on climatic, economic and other considerations.
- Finally, and perhaps the most important consideration which limits cross comparison between technologies, are the underlying assumptions used in financial modelling to obtain levelized mitigation costs<sup>58</sup>. These include cost of capital, interest rates, exchange rates, output/availability of technology, life of plant, discount rates. These considerations coupled with significant variability in technology costs over the past few years (influenced by economic climate, technology advances and the price of raw materials) make it nearly impossible to unpack and cross compare technology costs.
- Furthermore, the relevant time frame influences the cost of implementing mitigation technologies. Even if sufficient data was available to build abatement cost curves for

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<sup>58</sup> Levelised costs reflect a cost per tonne of CO<sub>2</sub> abated, taking into account both capital costs (which have been allocated over the life of the plant) and operating and maintenance costs associated with the technology.

the relevant sectors in South Africa, it would be necessary to assume implementation timeframes in order to understand abatement costs. The national process of allocating emission reduction targets or deliverables from individual sector has not yet been undertaken. Given that this is beyond the scope of the study, the compilation of accurate abatement cost curves for individual sectors in South Africa is not possible.

## **11.2. APPENDIX : EMISSIONS TRADING VERSUS A CARBON TAX: SA PERSPECTIVE**

Much policy debate worldwide has focused on a comparison of the merits of emissions trading versus a carbon tax.

As noted in Section , under conditions of certainty, a tax and a fully-auctioned ETS will deliver the same environmental outcome, at the same cost to the economy (abstracting from administrative costs etc) and with the same fiscal/distributional outcomes. In the real world, however, information on both the volume of emissions and the cost of abatement is scarce and this uncertainty has been the basis for a number of economic analyses differentiating between the two instruments. A seminal analysis by Weitzman (1974) showed that under uncertainty about the true abatement cost curve, a price-setting instrument (i.e. a tax) is more efficient than a quantity-setting mechanism (i.e. cap and trade). The essence of this argument is that the cost of abatement increases more steeply with each extra unit abated than does the benefit gained from the abatement. This is due to the nature of the damage caused by GHG emissions where each extra unit of emissions is argued to have a relatively small impact on the volume of emissions in the atmosphere. Weitzman shows that under these conditions there is a greater cost to society from choosing the wrong quantity target than from choosing the wrong carbon price.

Newel and Pizer (2003) expand on this, arguing that GHGs are a stock variable, i.e. damage is caused by the build up of GHGs in the atmosphere over time rather than by each individual unit of GHG released. This being so, it is abatement over time which matters for avoiding damage to the environment and not hitting an emissions target in a given year. As noted in the earlier discussion, taxes give firms the flexibility to vary emissions over time periods whereas an ETS implies a strict limit on emissions in each period. In an emissions trading scheme, firms could choose to emit more and buy more permits in a given year, but this would tend to push up the permit price and the overall emissions target would still have to be met, or else firms would face heavy penalties. This makes taxes less costly to the economy over time than a trading scheme.

Modelling done by Pizer (1999, 2002) based on simulating 1000 emissions scenarios for 2010 worldwide found that cost outcomes under a carbon tax are much more narrowly distributed than under an ETS. The net cost of a tax by 2010 amounted to between 0.2% and 0.6% of global GDP versus 0 to 2.2% of global GDP for a trading scheme. On average the tax also achieved a greater reduction in emissions. Overall the simulations suggest that the net benefit of a tax would be 5 times greater than a pure ETS. However, a hybrid scheme which operates like a trading scheme until the permit price reaches some trigger price at which government will sell unlimited permits (essentially a carbon tax) performed marginally better even than the optimal tax scheme.

However, the key advantage of a tax over a trading scheme is the ability of a tax to give firms complete price certainty. This is critical from the perspective of encouraging investment in abatement and innovation. Without price certainty firms may delay investment in emissions-

efficient technology as future payoffs are unclear (Parry and Pizer, 2007). In a trading scheme, like any market, the price of permits fluctuates, and can vary substantially according to the stage in the economic cycle, problems in the underlying product market and expectations of future government policy (US Congressional Budget Office, 2008). This has been made all too clear by the experience of the EU ETS. A tax represents a stable carbon price, providing consistent incentives to firms to change their behaviour and allowing them to plan more accurately for the future. This enables them to adapt at a pace which suits them best which is a more efficient option in a scenario where an emissions target only exists in the very long term, and where variations in emissions year to year in the short term are less important. Policy and price certainty is vital to minimising the cost to the economy of the required adaptation, and this can be provided more easily by a tax.

A tax is less administratively complex than a trading scheme which is an advantage in South Africa where capacity to implement a complex scheme could be an issue. Taxes are also more transparent to consumers whereas under an ETS the price paid for permits will vary over time, and consumers cannot tell how heavy a burden the scheme has really placed on firms. As noted in Sections and , a grandfathered scheme necessarily results in windfall profits for some polluting firms and is a process very open to capture by strong interest groups. An auctioned scheme or a tax by contrast would not reward big polluters nor require the complicated and lengthy process of assigning baseline emissions to sectors or firms.

In the South African context, it is clear from the analysis in Section and Section that the issue of market power is a major problem for the effective functioning of an ETS. A tax on the other hand would provide the same incentives to all firms, and would not be open to manipulation by those with a greater share of permits within an ETS. With more than 50% of emissions made up by only 2 institutions, it seems very unlikely that a South African ETS could generate the level of liquidity and efficiency necessary for effective abatement, and any scheme instituted would likely be yet another cause of distortion in product markets (particularly given that emissions concentration within any potential ETS is likely to be much higher because of excluded sectors). Given the amount of distortions in the underlying product markets, the electricity market in particular, overlaying a trading scheme is likely to exacerbate problems rather than solve them. This makes a tax more likely to be effective.

One way problem could be addressed without compromising of the coverage of a potential local ETS (i.e. excluding Eskom and Sasol) and hence potential environmental effectiveness would be if the South African scheme could be linked to a larger scheme in another country or countries. This prospect seems relatively distant still, however, and would come with its own potential difficulties<sup>59</sup>. Another option for addressing the issue of market power is to implement a trading scheme downstream that excludes Eskom and potentially Sasol's process emissions (potentially combined with other instruments like green or white certificate trading schemes and performance or technology standards) that will reduce liquidity and market power issues. This will, however, significantly reduce the coverage of a local ETS and reduce economic efficiency (see Section ). Given the large upfront fixed costs of establishing a trading scheme, reducing the coverage of an ETS will also increase the cost of implementing such a scheme relative to the amount of emissions reduction achieved. Other solutions to the problems of market power and liquidity in SA have been put forward, but the implications of these solutions have yet to be

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<sup>59</sup> The issue of international ETS and international climate agreements is addressed in more detail in the second last paragraph of this section

fully unpacked. Eskom and Sasol could, for instance, each be split into a number of individual carbon trading units each with its own emissions cap (Goldblatt mentioned in ESKOM AND SASOL FORGE A DUOPOLY IN EMISSIONS, 2009).

Sin et al (2005) find that for individual countries acting in the absence of an international agreement on climate change policy, a tax is the more efficient instrument, whereas if an international permit market exists, it may become optimal for the country to also introduce an ETS. The reason for this is that the quantity target imposed by the cap is effectively relaxed, since firms can choose to comply by purchasing permits from other countries and no abatement need happen in South Africa at all. Every permit purchased by a South African firm will be offset by an equal amount of abatement in another country. Sin et al (2005) argue that in this case, a tax and an ETS would have the same environmental outcome but the trading scheme would be more efficient since the price of permits would adjust to any market developments whereas a tax stays fixed over a given time-period. Intuitively it seems that an international trading scheme would be desirable, since it would equalise the marginal cost of abatement over the whole range of countries, thus ensuring that the cheapest abatement is undertaken, whatever the distribution across countries. An international permit market would not suffer from liquidity or market power problems, since there would be so many participants and no firm should be large enough to influence permit price.

The issue of international agreement therefore represents a dilemma for countries, but suggests that in the short to medium term it may be better to implement a carbon tax which can later be transformed into a permit system if and when a worldwide trading scheme becomes effective.

Von Essen (2009) mentions that it is possible (and quite easy) to combine a carbon tax and an ETS in a country. The carbon tax can either be used to incentivise emissions reductions in firms not covered by an ETS, or the systems can be fully integrated with an ETS serving as the basis for a differentiated carbon tax where firms covered by an ETS is exempted from the standard carbon tax and rather pay a targeted tax calculated on the amount of emissions permits held by a firm (Von Essen, 2009).

In South Africa, the question of which instrument can deliver abatement at the least overall cost to society remains open. While the balance of arguments seems to tend more towards a carbon tax, at least in the short to medium term, the debate is far from over<sup>60</sup>.

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<sup>60</sup> The National Treasury, for instance, is planning to start work on a policy paper in 2010 that will investigate the role of emissions trading schemes in establishing a comprehensive carbon pricing regime in South Africa .

### 11.3. APPENDIX : ADDITIONAL AGRO-PROCESSING INFORMATION

Industry	Data availability
SA Fruit & Vegetable Canning Association	Currently no GHG emission & energy demand data
Rooibos Tea Council	Research completed on Impacts of Climate Change on Rooibos Tea Industry Currently no comprehensive GHG emission data set for SA Rooibos Tea Industry
Deciduous Fruit Producers Trust	Methodology for calculating GHG emissions for SA Wine and Fruit Industry is being developed GHG Mitigation Strategy will be developed for wine & fruit industry upon completion of Methodology Currently no comprehensive GHG emissions data set for SA Fruit & Wine Industry
Distell	Energy consumption & GHG emission data collected by voluntary Integrated Production of Wine (IPW) programme for wine cellars Above-mentioned data is not available for public consumption
National Cleaner Production Centre	Initial interest in including carbon foot printing as part as existing work on waste minimisation
Energy Research Centre	SA GHG National Inventory used aggregated GHG emission data from DME Energy Balances No comprehensive GHG emission data set is available on SA Agro-processing & sub sectors
Sugar Milling Research Institute	Research currently being undertaken to investigate GHG Emission Reduction opportunities No comprehensive GHG emission data set is available for SA Sugar Milling
Grain Milling	No comprehensive GHG emission data set is available for SA Grain Milling
Dairy	No comprehensive GHG emission data set is available for SA Dairy

**Table : Availability of GHG emissions and energy demand data in the South African food industry**

*Source: Genesis Analytics, 2010*

<b>Institution</b>	<b>Contact Person</b>	<b>Quantitative estimates of Energy Saving / GHG emission reduction for Mitigation options</b>
Centre for Renewable & Sustainable Energy Studies	Professor Wikus Van Niekerk	It is not plausible to determine quantitative estimates on energy savings / GHG emission reductions for the whole sector Quantitative estimates are required on a case by case basis
Sustainable Energy Africa	Mark Botha	No quantitative estimates are available on energy savings / GHG emission reduction from use of renewable energy
Glynn Morris	Agama Energy	Research is required to contextualise international estimates for SA conditions
National Cleaner Production Centre		Cleaner production currently focused on water and waste
Sugar Milling Research Institute	Gavin Smith & Steve Davis	No quantitative estimates are available on energy savings / GHG emission reduction from use of renewable energy
Pioneer Foods	Neil Wiggil & Peter Hardcastle	No quantitative estimates are available on energy savings / GHG emission reduction for grain milling

**Table : Expert consultation on mitigation options in South Africa Agro-processing sector**

*Source: Genesis Analytics, 2010*

Project developer or owner	Project description	Project type	Project lifespan (years)	Annual emission reductions (tCO <sub>2</sub> -e)
1) SA Brewery	Replacement of coal with natural gas & biogas	Fuel switching	7	107 000
2) SAPPI Kraft limited	Conversion from coal to bark fired	Fuel switching	7	70 000
3) Mondi Business Paper	Generation of electricity from biomass	Cogeneration	10	220 000
4) Omnia Fertiliser Limited	Reduce emissions from nitrous oxide from nitric acid production	Nitrous oxide reduction	21	576 000
5) Biotherm SPV 1	Generating electricity from anaerobic digestion of piggery manure	Renewable energy	10	27 000
6) Humphries Boerdery Ltd	Generating electricity from anaerobic digestion of piggery manure	Renewable energy	20	11 000
7) Tongaat Hullet Starch Property Limited	Fuel switch from coal to natural gas in product dryer	Fuel switch	14	8 360
8) MTO Forestry Pty Limited	Generate electricity from sawmill residues	Renewable energy	10	14 010
9) Exclusive Access Trading Limited	Production of biodiesel from waste vegetable oils	Biofuels	10	Not available
10) Mafikeng Biodiesel	Production of biodiesel from waste vegetable oils	Biofuels	30	Not available
11) Exclusive Access Trading Limited	Production of biodiesel from soya and palm oils	Biofuels	21	Not available
12) Siyanda Biodiesel	Production of biodiesel from soya	Biofuels	7	Not available
13) Tongaat-Cogeneration Company	Cogeneration	Cogeneration	21	Not available
14) Carbon & Environmental Options Limited	Generate electricity from biomass	Renewable energy	25	Not available
15) African Biofuels Company	Ethanol production from sugar cane	Biofuels	7	Not available
16) TSB	Use bagasse to generate electricity for export	Biomass	10	Not available

**Table : CDM project portfolio in South African agriculture and Agro-processing sector**

*Source: SA CDM Project Portfolio*

## 11.4. APPENDIX : IMPACT OF CLIMATE POLICIES – INTERNATIONAL PRECEDENTS

### 11.4.1. EUROPEAN COMMISSION APPROACH

The European Commission is currently analysing all energy-intensive sectors (defined as sectors where energy costs amount to 3% or more of production value) in the EU to determine if additional costs imposed by the EU ETS is placing them at risk of reduced competitiveness and carbon leakage (EC, 2008a). EC (2008a) mentions that the analysis of a sector or sub-sector should be done at a high level of disaggregation to take account of differences in carbon-intensity between different processes used within the sector being analysed.

The Commission's methodology started off from the premise that sectors can be categorised into one of four categories based on potential product price increases linked to the ETS (taking account of both direct costs linked to emissions and indirect costs linked to increases in electricity prices) and exposure to trade with countries outside the EU (EC, 2008a). The four categories are shown in Table .

	Low cost increase	High cost increase
Open to trade	<p><i>Category III:</i> Moderate-to-high risk of loss of competitiveness</p>	<p><i>Category IV:</i> High risk of loss of competitiveness</p>
Closed to trade	<p><i>Category I:</i> Low or no risk of loss of competitiveness (or carbon leakage)</p>	<p><i>Category II:</i> Low-to-moderate risk of loss of competitiveness</p>

**Table : Theoretical basis for European Commission's approach to assessing vulnerability**

*Source: Genesis Analytics based on EC (2008a)*

In December 2008, the European Commission and the European Parliament agreed to an official methodology to assess the risk of carbon leakage as part of the new amended EU ETS Directive (2003/87/EC) (European Parliament, 2008). The new methodology states that a sector (or sub-sector) is exposed to a significant risk of carbon leakage if:

- Its total increase in production cost (direct and indirect) as a percentage of gross value added is greater than 30%; or
- Its trade intensity (defined as ratio between the sum of its imports and exports to countries outside the EU divided by the total market in the EU [defined as the sectors annual turnover plus imports]) is greater than 30%, or
- Its total increase in production cost relative to gross value added is greater than 5% AND its trade intensity (as defined above) is greater than 10%.

The classification of sectors is done following a two-step process (European Parliament, 2008). Sectors that meet the quantitative criteria set out above will be deemed to be exposed to a significant risk of carbon leakage. This list can however be added to based on an additional

qualitative analysis which takes account of features of the markets in which sector operates that that may influence the ability of firms to pass on carbon costs, like the geographic scope of the market in question, the concentration of firms in the market, the influence of transport costs, the tightness (capacity utilisation) in the market etc. If these factors are deemed to significantly decrease the ability of firms in specific sectors to pass on carbon costs without losing significant market share, these sector can also be classified as „significantly exposed’ (Bergmann, 2008; European Parliament, 2008). The qualitative analysis also takes account of formal GHG reduction targets accepted by Parties of the UNFCCC and sectoral agreements, as well as profit margins which is believed to provide an indication of the attractiveness of long-term investment decisions in sectors (European Parliament, 2009). EC (2009:4), however, states that the qualitative assessment must influence the decisions to classify a sector as exposed to significant risk of carbon leakage only in “exceptional circumstances”. The reason for this is that it is important that the classification be seen as a “credible evidence-based exercise” (EC, 2009:4).

#### 11.4.2. AUSTRALIAN GOVERNMENT APPROACH

The Australian Government assesses the risk of sectors facing competitiveness concerns due to climate change policies by considering two measures, trade exposure and emission intensity (Australian Government, 2008b). The potential impacts of climate policy on individual sectors differ based on the interaction of these two measures, and are shown in Table .

	Low emissions	Emissions intensive
Trade exposed	May benefit from depreciation of exchange rates as terms of trade weakens in response to fall in emissions-intensive exports and rising world demand for low-emission goods.	Face reduced world demand, and without unified global action, unable to pass through increase in costs.
Non-traded	May experience relative price fall or benefit from an emission price due to the creation of new markets.	Able to pass through some of increased costs but faces reduced domestic demand from higher prices.

**Table : Theoretical basis for Australian government’s approach to assessing vulnerability**

*Source: Genesis Analytics adapted from Australian government (2008a)*

The Australian Government uses exposure to trade and the emissions-intensity of production to identify emissions-intensive trade-exposed (EITE) industries that are believed to be at risk of carbon leakage (Australian Government, 2008b). In addition, the Australian Government also identifies industries that are not trade exposed, but which are expected to be “strongly affected” by climate policies as a result of being significantly constrained in passing on carbon costs (Australian Government, 2008b:13-1)<sup>61</sup>. The Australian Government methodology classifies

<sup>61</sup> The Australian Government methodology classifies firms into these categories based on an evaluation of the “activities” that firms undertake. All firms in a sector would thus not necessarily belong to the same category. The reason for this is to ensure that assistance is targeted to the most exposed entities in the economy (Australian Government, 2008b).

firms into these categories based on the industry-wide emissions from a process or activity. All firms in a sector would thus not necessarily belong to the same category. The reason for this is to ensure that assistance is targeted to the most exposed entities in the economy. The process of defining activities is still ongoing.

### **Emission-intensive trade-exposed (EITE) industries**

The Australian government defines trade share as the value of annual imports and exports relative to domestic production (Australian Government, 2008b). A sector or activity will be defined as trade-exposed if the trade share is equal or greater than 10% in any of the 4 years preceding the implementation of carbon policies. If a sector or sub-sector's trade share is below 10%, entities may apply to the Australian government for a qualitative assessment (based on information provided by the industry in question, its customers and the Australian Government's own analysis) of the ability of firms to pass on costs due to potential international competition. The government may then, based on the qualitative analysis, define the activity as trade-exposed due to "a demonstrated lack of capacity to pass through costs due to the potential for international competition" (Australian Government, 2008b: 12-31).

The qualitative analysis may deem a sector to be trade-exposed based on, inter alia, one or more of the following conditions holding (Australian Government, 2008b:12-29):

- Evidence that a historical trade share of more than 10% (not present in the period evaluated in the quantitative analysis) may once again hold in future.
- A high correlation existing between the price received by domestic firms and a transparent international price for a good (taking cognisance of transport costs and any relevant tariffs or import-specific charges and taxes).
- International producers exist who trade in products that are perfect substitutes for the locally-produced products in terms of price, quality, range etc. The analysis needs to take into account relevant Australian or industry standards, and there needs to be a lack of barriers preventing increased imports of the product produced by the potential EITE industry in the medium term indicated by:
  - Effective local distribution networks being in place and the development of any specialised facilities needed to supply domestic customers being relatively low cost;
  - Transport costs accounting for a relatively low percentage of the value of the imported good;
  - No customs restrictions existing; and
  - Switching costs for customers wanting to move from domestic to imported goods being relatively low.

The default test for emissions-intensity specified by the Australian Government is the weighted-average (weighted by production) emissions per million Australian dollars of revenue (Australian Government, 2008b). Firms may however request that the assessment be based on the weighted average emissions per million Australian dollars of value-added, rather than revenue. In instances that firms request the use of a value-added metric, government will need to determine which input costs are to be adjusted to enable the calculation of value added in consultation with industry. Emissions include all direct emissions from the activity as well as all indirect emissions related to the use of electricity and natural gas feedstock.

The Australian Government (2008b; 2008c) mentions that using either value-added metric or a revenue metric provides very similar results in terms of ranking EITE activities. Given that there is no clearly defined estimate of value added for most activities in Australia, and that value added measures tend to vary greatly over time and between firms involved in the same activity as a result of firm-specific factors like profitability, the Australian Government believes that using a value-added metric would lead to significantly higher compliance costs, uncertainty and implementation risk for both government and firms. For firms involved in a certain activities in a small number of industries<sup>62</sup>, like petroleum refining, the paper and pulp industries, and the chemicals and plastics industries, the use of a value-added metric may make a significant difference to the estimation of their emissions intensity. It is for this reason that the Australian Government allows the option of firms requesting the use of a value-added metric.

*Activities with emissions intensities of more than 1000t CO<sub>2</sub>-e/million Australian dollars of revenue or 3000t CO<sub>2</sub>-e/million Australian dollar of value added are considered as emissions-intensive. Activities with emissions intensities of more than 2000t CO<sub>2</sub>-e/million Australian dollars of revenue or 6000t CO<sub>2</sub>-e/million Australian dollar of value added are considered as very emissions-intensive and qualify for greater support from the Australian government.*

The Australian Government noted that some industries that are not trade exposed may be particularly strongly affected by climate change measures because competitive pressures may prevent them from passing on the full cost impact of these measures to their customers (Australian Government, 2008b). In order to be classified as a „strongly affected’ industry, and potentially qualify for government support, industries must:

- Not be trade exposed;
- Be emissions-intensive (based on the criteria used to identify EITE industries);
- Include entities that are unable to pass on carbon costs as a result of being relatively emissions-intensive compared to their competitors, and as a result is expected to experience significant declines in asset values;
- Have significant sunk capital costs; and
- Not have significant economically viable abatement opportunities open to them (Australian Government, 2008b).

The Australian Government (2008b) evaluated a number of activities, and concluded that only coal-fired electricity generators had the relevant characteristics to be deemed „strongly affected’ in Australia. The Australian Government also mentioned that contractual impediments to carbon cost pass-through did not qualify a firm to be „strongly affected’.

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<sup>62</sup> The use of a revenue metric to define emissions intensity may lead to lower measured intensities for activities where input costs make up a larger proportion of the final product value, like industries further down the value chain (Australian Government, 2008c). Also, because value added points out the costs that are under direct control of firms, and is the most representative indicator of the “real economic value of an industrial activity”, it may be more highly correlated with the possibility of carbon leakage (Australian Government, 2008c).

## **11.5. APPENDIX : DATA SOURCES FOR POLICY IMPACT ANALYSIS**

A number of issues were encountered in the course of gathering data for this report. It is always difficult to match data from different sources as there is not a single method of classifying sectors internationally or in South Africa, and some of the case study sectors we found difficult to define even within the most commonly used classification systems (Agro-processing for example – see Sector Case Study for further details). The method that was used therefore was to match the case study sectors to the most appropriate Standard Industry Classification (SIC) codes, since this is the classification system used by Statistics South Africa where much of the data used was sourced. Where it was necessary to use data from sources using a different system of classifying sectors, every effort was made to ensure that the data matched as closely as possible to the correct sector definition. Inevitably, however, some problems were encountered, and these are described in more detail below.

### **Emissions data**

#### **Direct emissions**

The 2000 South African GHG inventory compiled by DEAT in 2009 is the most accurate and up-to date publicly available data on emissions in South Africa. This was therefore used as the basis for breaking down emissions data by sector. However, the inventory does not conform to any commonly used industry classification system, and provides only very aggregated data. From the GHG inventory we were able to gain emissions data for the electricity, chemicals and non-ferrous metals sectors. For the Agro-processing, liquid fuels, iron and steel and mining sectors, estimates of GHG emissions from energy use were used, as calculated by Blignaut et al. (2005) from the National Energy Balance for 1998. This source, however, only includes combustion emissions and therefore significantly underestimates emissions from sectors where process emissions make up a large proportion of total emissions. In the case of mining, the GHG inventory gives a value for the fugitive emissions from mining which was added to the figure given for combustion emissions from Blignaut et al. in order to get closer to the true value of emissions. In the liquid fuels and Agro-processing sector the estimate from Blignaut et al. was used, and in the iron and steel sector the Blignaut estimate plus an increase in emissions proportionate with the sector's increase in energy use since 1998 (see section of the relevant sector case study for details).

#### **Indirect emissions from electricity use**

In order to get an estimate of the indirect emissions from electricity use by each sector, the National Energy Balance for 2000 was used, as it provides electricity use in MWh by sector. These figures were then multiplied by an emissions factor to give the implied Scope 2 emissions of each sector. The emissions factor used was that reported by Eskom in their Carbon Disclosure Project submission in 2008 which suggests an emissions intensity of 1 kg CO<sub>2</sub>-e per kWh of electricity sold.

However, the Energy Balance definition of sectors did not conform to the SIC code definition, and this was a problems for two sectors. In the Energy Balance the chemicals sector includes petrochemicals, which, according to the SIC code definition, should sit in the liquid fuels sector. For the purposes of illustration, the number given for petroleum refineries was assigned to liquid fuels and the number for chemicals and petrochemicals to chemicals. Therefore the electricity usage of the chemical sector may be over-estimated to some extent and liquid fuels

vice versa. However, the chemicals number is so small relative to the sector's direct emissions, it does not make much difference to the overall picture.

### **Energy intensity**

Energy intensity is measured as the expenditure on energy per sector as a proportion of that sector's value added. This data was sourced from a paper by the World Bank – Devarajan et al. (2009) – which calculates energy intensity using a Social Accounting Matrix for South Africa in 2003.

Again there was a problem of sector definition, as the sectors in a number of cases were more disaggregated than our case study sectors, and without the underlying data it was not possible to aggregate them accurately. Therefore the data is displayed by sub-sector where necessary. In addition, the Agro-processing sector is defined here as food only, and not beverages, due to beverages not being reported as a separate sector.

### **Trade data**

The trade data used was reported by the dti by SIC code and in Rand values, making it easy to relate to our case study sectors and to the sub-sectors used in the energy intensity graph. The only data issue here is a slight anomaly in the non-ferrous metals sector which, according to the data reported by the dti, has export revenues higher than the total value of sales of domestic firms. The value of sales data comes from a different source (Statistics South Africa), but since both use the same classification system, it seems unlikely to be a definitional problem. The StatsSA data comes from the manufacturing survey which surveys around 50 000 firms once a month while the trade data is actual data recorded as goods enter and leave the country. This anomaly may thus be due to the combination of estimated and actual data, it may be due to an error in one of the databases, or it may simply reflect a timing difference between when exports sales are recorded and when the physical units are shipped.

Trade data was not provided by the dti for the electricity generation sector, so instead Statistics South Africa's publication "Electricity Generated and Available for Distribution" (published quarterly) was used.

To avoid trade patterns being skewed by the current global financial crisis, 2007 data trade data was used.

### **Value of sales data**

Finally, the data relating to value of sales was sourced from Statistics South Africa, who provided us with a spreadsheet of monthly sales data for the manufacturing sector by SIC code from 1998 to 2008. Statistics South Africa confirmed that the value of sales data include exports by domestic firms. In one case (the liquid fuels sector) the data given was not sufficient to disaggregate a specific sector, but the other sub-sectors grouped with the sector of interest were judged likely to have very small or zero-value sales, so the sales of the sector should not be over-estimated to a great extent.

For mining sales data Statistics South Africa's publication "Mining Production and Sales" (published monthly) was used, and for data on the electricity sector their publication "Electricity Generate and Available for Distribution" (published quarterly) was used.

## 11.6. APPENDIX : TRADE STRUCTURES AND THE IMPACT OF CLIMATE POLICIES

One of the most important elements of the qualitative analysis of the impact of climate policies is likely to be the structure of trade of the focus sectors. Sectors that predominantly export to carbon-constrained countries<sup>63</sup> are likely to see market access becoming an issue as a result of carbon leakage fears if credible climate policies are not introduced in South Africa. The impact of domestic climate policies on these sectors may even be a secondary concern compared to the competitiveness impact of climate policies implemented internationally. Depending on the measures implemented in their destination market, credible climate policies at home may actually increase the competitiveness of sectors that export predominantly to carbon-constrained countries by allowing them to compete on an even keel.

Sectors whose imports originate mostly from non-carbon constrained countries, however, may be at a competitive disadvantage as a result of additional carbon costs and may face the risk of carbon leakage themselves. Climate policies may thus have a significant impact on the competitiveness of these sectors.

Table illustrates the position of the focus sectors with regards to the proportion of exports that are destined for carbon constrained economies and the proportion of imports that originate in non-carbon constrained economies.

Exports to carbon-constrained economies		Imports from non-carbon-constrained economies	
Mining	62%	Liquid fuels	94%
Non-ferrous metals	56%	Mining	75%
Metals and engineering	54%	Non-ferrous metals	72%
Agro-processing	47%	Metals and engineering	57%
Chemicals	44%	Chemicals	55%
Liquid fuels	14%	Agro-processing	46%

**Table : Trade with carbon constrained and non-carbon constrained economies, 2007**

Source: dti 2009

<sup>63</sup> Carbon-constrained countries are the countries that currently have carbon policies in place, or who are either planning or officially considering to implement or join trading schemes or implement carbon taxes. Countries included are the EU, US, Australia, Japan, New Zealand, Canada, Switzerland, Norway, Liechtenstein and Iceland (Genesis Analytics updated from Reinaud, 2009). For a discussion of carbon leakage and measures to address carbon leakage, see Section .

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## GLOSSARY

<b>Biomass</b>	An energy resource derived from organic matter. These include wood, agricultural waste and other living-cell material that can be burned to produce heat energy. They also include algae, sewage and other organic substances that may be used to make energy through chemical processes.
<b>Carbon “leakages”</b>	The result of policies which only target GHG emissions abatement indirectly so that less than 100% of the potential abatement is captured.
<b>Deadweight loss</b>	The difference between the benefits gained as a result of policy and the benefits that would have been gained from a policy which achieved the most economically efficient solution.
<b>Externality</b>	The product of the actions of an individual or firm (or a group of individuals or firms) which have a “spillover” effect on other actors or society as a whole, which is not reflected in the cost of undertaking that activity and is not otherwise factored into their decision to consume or produce. This is caused by a failure or an inability of the market to accurately value the impact of the activities in question on society as a whole.
<b>Grandfathering</b>	The free allocation of tradable permits to polluting firms according to the historical distribution of emissions in some baseline period.
<b>Information asymmetry</b>	Where one economic agent has access to information that others do not. Leads to market failure.
<b>Market failure</b>	A market failure occurs when the market is not able to achieve the Pareto optimal solution. Can be caused by market power, asymmetric information, externalities or public goods.
<b>Opportunity cost</b>	The economic benefit forgone by the choice of one alternative over another.
<b>Pareto optimality</b>	An economic term for a situation which is perfectly efficient, i.e. no person in society can be made better off without making another person worse off.
<b>Polluter pays principle</b>	A concept in law which requires producers to pay to remedy any damage which they cause to the environment.
<b>Rent</b>	Economic rents are returns in excess of the opportunity cost of the resources devoted to the activity.
<b>Regressive</b>	Imposes the greatest cost (as a proportion of income) on the poorest in society.
<b>Windfall profits</b>	An unexpected profit arising from a circumstance not controlled by a firm or an individual.