CEMENT PRODUCTION AND GREENHOUSE GAS EMISSION: IMPLICATIONS FOR MITIGATING CLIMATE CHANGE

BY

LERATO MUDEME

SUPERVISOR

PROF: VOGEL, C

An MSc Research report presented in partial fulfilment in the School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa

DECLARATION

I declare that this research report is my own, unaided work. It is submitted in partial fulfilment of the requirements of the degree of Master of Science by coursework at the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

……………………….. ……………day of ……………….2008

(Signature of candidate)

ABSTRACT

In this research, the greenhouse gas emission reduction strategies of a cement producing company, Pretoria Portland Cement (PPC) in South Africa are examined. The implications of the various greenhouse gas emission reduction strategies for climate change mitigation are also analysed. Climate change has become an issue of global prominence and is possibly the greatest environmental challenge facing the world today. The study shows that PPC has greenhouse gas emission reduction strategies and this has positive implications for climate change mitigation. These strategies include the Secondary Materials Co-Processing Programme, retrofitting of some of its old plants to reduce air pollution etc. The results of the study also indicate that the company has taken a proactive approach to greenhouse gas emissions.

Greenhouse gas emission reduction presents certain challenges and the company has identified the use of huge financial resources and lack of clear guidance and regulations with regards to greenhouse gas emissions as some of the major challenges. However, the relevant government department, the Department of Environmental Affairs and Tourism (DEAT), which is the lead agency for climate change response in South Africa has stated that a number of projects targeted at achieving sustainable development and climate change mitigation (directly or indirectly) have been developed and some implemented by the various government departments which include the Department of Minerals and Energy (DME). However, the DEAT also stated that there are numerous barriers to climate change mitigation. These challenges include lack of skilled personnel, financial constraints and pressing social and economic challenges which are prioritised over environmental issues and lack of co-operation between industry and government with regards to environmental protection. The DEAT stated that efforts are being made to intensify co-operation between government and industry with regards to climate change mitigation and the achievement of sustainable development.

DEDICATION

This dissertation is dedicated to my beloved husband, Nqobile Khumalo, whose overwhelming support and patience encouraged me to complete this study.

ACKNOWLEDGEMENT

I wish to acknowledge Professor Coleen Vogel for her excellent supervision and guidance. I would also like to thank my husband, parents and family for their immense support, motivation and assistance during this research.

I also want to thank the various Pretoria Portland Cement (PPC) staff that assisted me during the research, government institutions, namely the Department of Environmental Affairs and Tourism (DEAT) and the Department of Minerals and Energy (DME).

I am also grateful to the Lecturers of the School of Geography, Archaeology and Environmental Studies at the University of Witwatersrand, South Africa for their contribution to this research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

APPA- Air Pollution Prevention Act of 1965
AQA- National Environmental Management: Air Quality Act of 2004
DEAT- Department of Environmental Affairs and Tourism
DME- Department of Minerals and Energy
IPCC- Intergovernmental Panel on Climate Change
IPPC- Integrated Pollution Prevention and Control
NEMA- National Environmental Management Act of 1998
PPC- Pretoria Portland Cement Company (Pty) Ltd
UNFCCC- United nations Framework Convention on Climate Change
US-EPA –United States Environmental Protection Agency

1. CLIMATE CHANGE

1.1 Introduction

Given the fact that climate change is a global threat, various institutions, governments and organisations are involved in climate change mitigation efforts which include various global treaties such as the United Nations Framework Convention on Climate Change (UNFCCC). Various bodies such as the Intergovernmental Panel on Climate Change (IPCC), an international body of climate change scientists which assesses the scientific, technical and socio-economic information relevant to the understanding of human-induced climate change and its mitigation have also played a major role in the climate change arena. This chapter examines climate change as a global environmental problem and outlines some of the impacts and mitigation measures associated with climate change.

1.2 Climate change

Climate change refers to any significant change in measures of climate such as temperature, precipitation or wind lasting for an extended period, typically decades or longer (http://www.epa.gov/climatechange, 2007). It is possibly the greatest environmental challenge facing the world today and is more about the serious disruptions of the entire world's weather and climate patterns, including impacts on rainfall, extreme weather events and sea level rise, rather than just moderate temperature increases (Hunter, 2002). The term climate change is often used interchangeably with the term global warming, which is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, which can contribute to changes in global climate patterns. According to the National Academy of Sciences, however "the phrase 'climate change' is growing in preferred use to 'global warming' because it helps convey that there are [other] changes in addition to rising temperatures" (http://www.epa.gov/climatechange, 2007).

1.3 Causes of Climate Change

Climate change may result from:

- natural factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun;
- natural processes within the climate system (e.g. changes in ocean circulation);
- human activities that contribute to climate change which include in particular the burning of fossil fuels and agriculture and land-use changes like deforestation. These activities lead to the emission of carbon dioxide (CO_2), the main gas responsible for climate change, as well as of other 'greenhouse' gases. To significantly reduce climate change, global greenhouse gas emissions must be proactively managed (http://ec.europa.eu/environment, 2007).

Industrialisation, urbanisation, the increase of motor transport, apart from social and economic benefits, have resulted in the increase of greenhouse gas emissions, which intensify the natural greenhouse effect. Greenhouse gases are gases that absorb the infrared radiation emitted by the earth, thus preventing the escape of terrestrial radiation into space (http://www.epa.gov/climatechange, 2007). The anthropogenic effects on the physical and chemical properties of the atmosphere therefore have the potential to directly influence the climatic system. The three most important greenhouse gases are carbon dioxide, methane and nitrous oxide. Global greenhouse gas emissions have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (Barker *et al*, 2007) (Figure 1-1).

Greenhouse gases are produced from a variety of industrial activities. The main sources, other than power generation, are those energy intensive industries that chemically or physically transform materials from one state to another. Energy intensive industries such as oil refining, chemicals and metal production and cement production are the main sources of greenhouse gas emissions after power generation. Most of these industries, especially the cement industry, are heavily dependent on fossil fuels (McCaffrey, 2003).

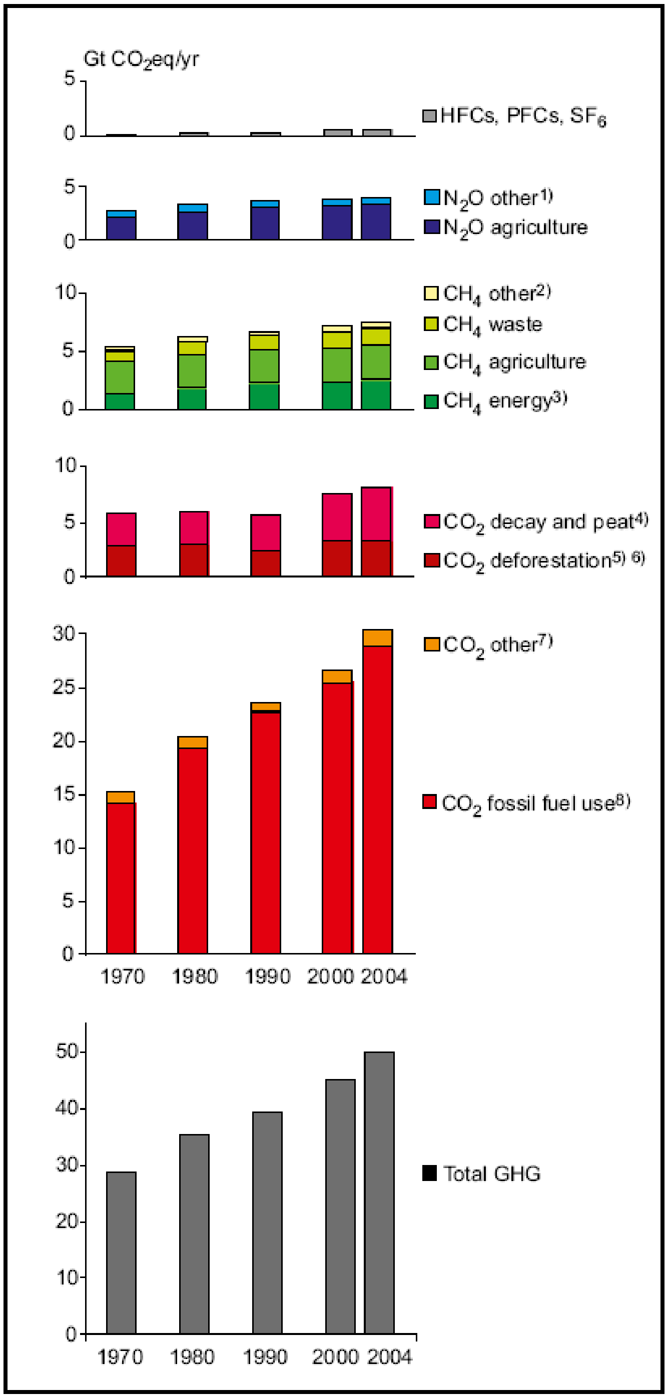


Figure 1-1: Global anthropogenic greenhouse gas emissions (1970-2004) (as cited in the IPCC Fourth Assessment Report, 2007, pg 104).

Notes to Figure1-1 (as cited in the IPCC Fourth Assessment Report, 2007, pg 104).

1. *Other N_2O includes industrial processes, deforestation/ savannah burning, waste water and waste incineration.*
2. *Other is CH_4 from industrial processes and savannah burning.*
3. *CO_2 emissions from decay (decomposition) of above ground biomass that remains after logging and deforestation and CO_2 from peat fires and decay of drained peat soils.*
4. *As well as traditional biomass use at 10% of total, assuming 90% is from sustainable biomass production. Corrected for 10% carbon of biomass that is assumed to remain as charcoal after combustion.*
5. *For large-scale forest and scrubland biomass burning averaged data for 1997-2002 based on Global Fires Emissions Data based on satellite data.*
6. *Cement production and natural gas flaring.*
7. *Fossil fuel use includes emissions from feedstocks.*

The IPCC (2007) in its Fourth Assessment report (a report designed to provide authoritative timely information on all aspects of technologies and socio-economic policies, including cost-effective measures to control greenhouse gas emissions) has also stated that the largest growth in greenhouse gas emissions between 1970 and 2004 has come from the energy supply sector, with an increase of 145% (Figure 1-2).

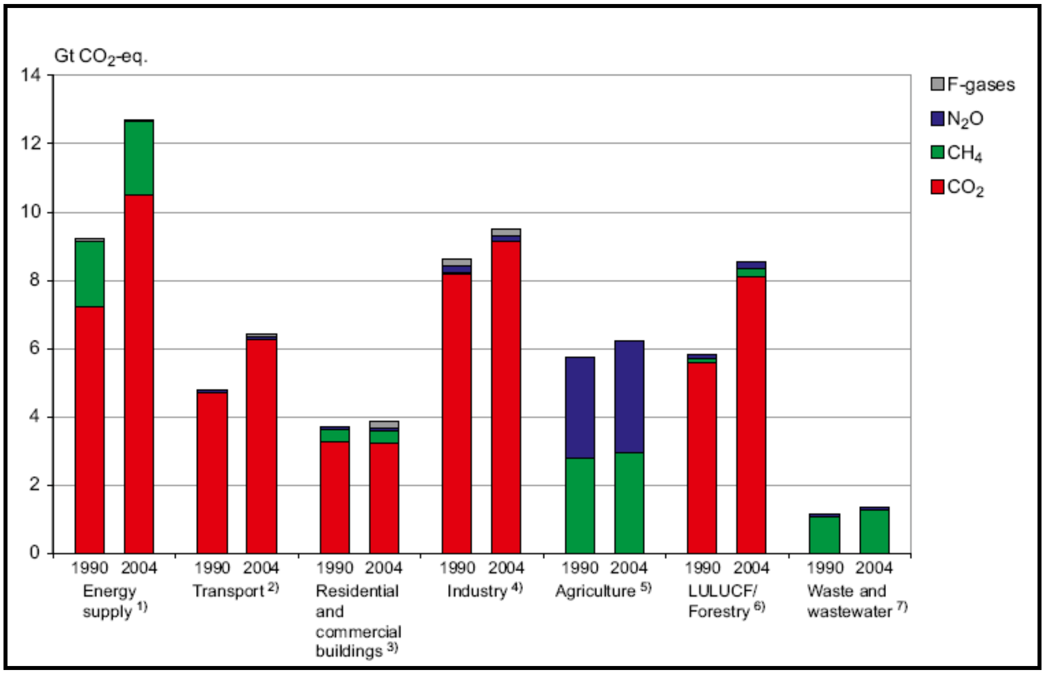


Figure 1-2: Greenhouse gas emissions by sector in 1990 and 2004 (as cited in the IPCC Fourth Assessment Report, 2007, pg 105).

Notes to Figure 1-2 (as cited in the IPCC Fourth Assessment Report, 2007, pg 105).

1. *Excluding refineries, coke ovens etc which are included in industry.*
2. *Including international transport (bunkers), excluding fisheries. Excluding off-road agricultural and forestry vehicles and machinery.*
3. *Including traditional biomass use.*
4. *Including refineries, coke ovens etc*
5. *Including agricultural waste burning and savannah burning (non-CO_2). CO_2 emissions and /or removals from agricultural soils are not estimated.*
6. *Data include CO_2 emissions from deforestation, decomposition of above-ground mass, peat fires and decay of drained peat soils.*
7. *Includes landfill CH_4 and N_2O and CO_2 from waste incineration (fossil carbon only).*

The atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased over the last 10 000 years (Figure 1-3) and climate models utilised by the climate change scientists have been instrumental in the prediction of global and continental temperatures due to anthropogenic forcings (Figure 1-4) (Barker *et al.*, 2007).

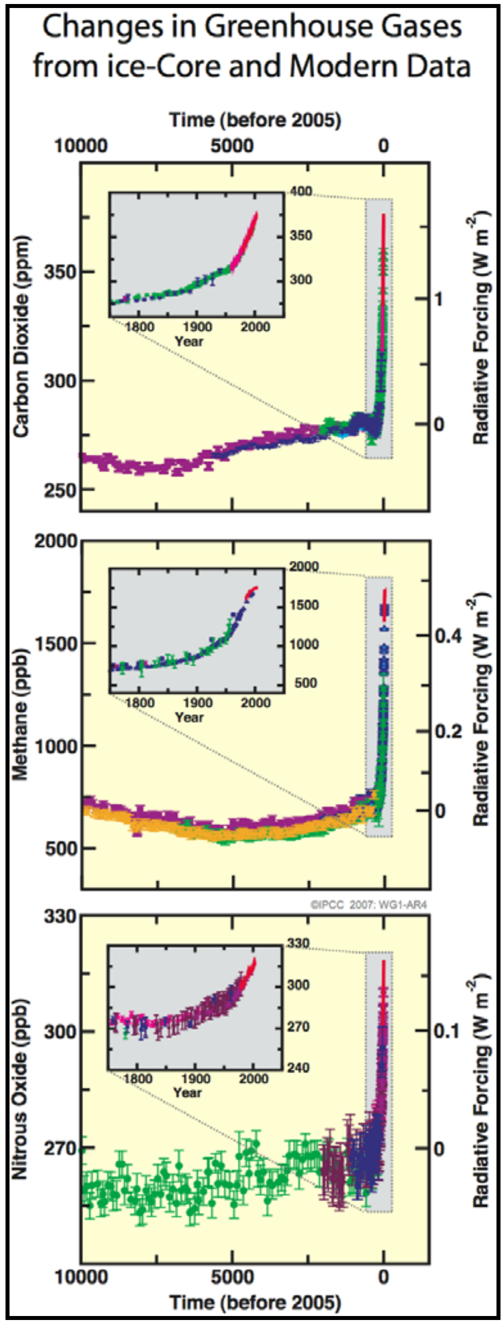


Figure 1-3: Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10 000 years (large panels) and 1750 (inset panels) (as cited in the IPCC Fourth Assessment Report, 2007, pg 108).

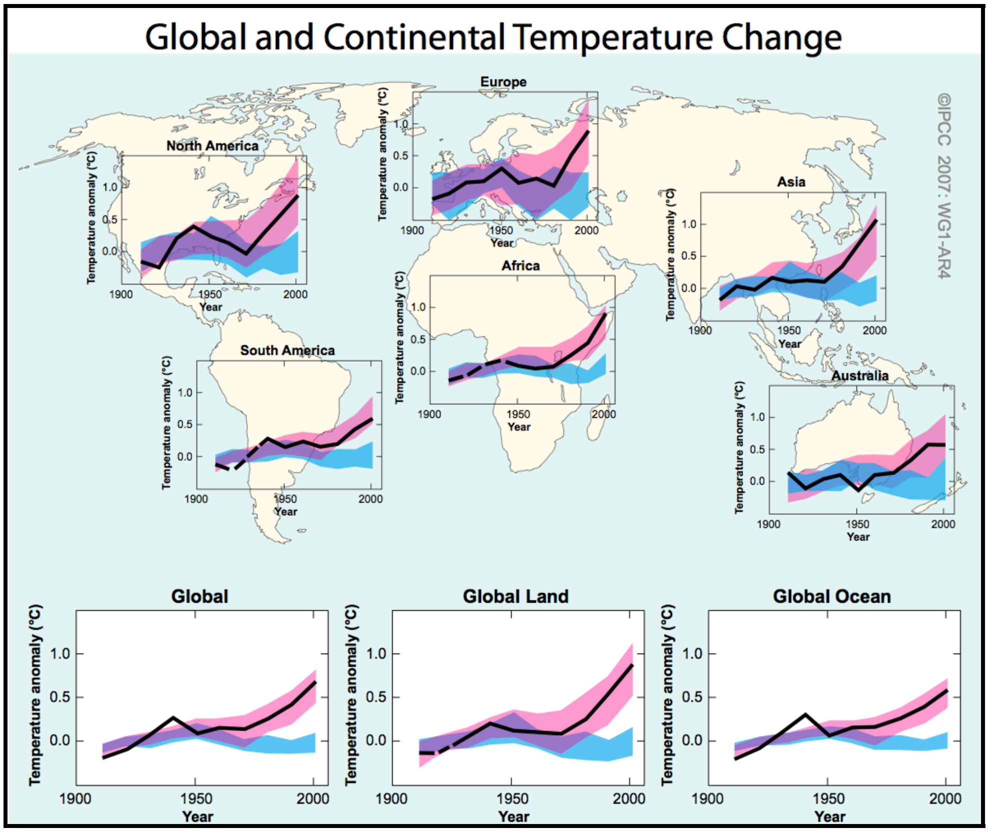


Figure 1-4: Comparison of the observed continental and global scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. The decadal averages of observations are shown for the period 1906-2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901-1950. Lines are dashed where spatial average is less than 50%. Blue-shaded bands show the 5-95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5-95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings **(**as cited in the **IPCC Fourth Assessment Report, 2007, pg 110).**

1.4 Impacts of Climate Change

The potential economic, social and political impacts of climate change include public health impacts, especially in developing countries and poorer communities, particularly on women, children and the vulnerable, as they lack the resources for coping or adapting to shocks. Existing studies also show that agriculture and food security might decrease, especially in the tropics and the subtropics leading to starvation (Devereux and Edwards, 2004). The United Nations Millenium Development Goals are focused on social security, food security and environmental sustainability among other issues and this has raised fears that climate change may have far reaching implications on sustainable development especially in poor countries (http://www.un.org, 2006).

The Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC, 2007) also states that some extreme events are projected to increase in frequency and/or severity during the 21st century due to changes in the mean and/or variability of climate, so it can be expected that the severity of their impacts will also increase in concert with global warming. Conversely, the frequency and magnitude of extreme low temperature events, such as cold spells, is projected to decrease in the future, with both positive and negative impacts. The impacts of future changes in climate extremes are expected to fall disproportionately on the poor, who are also the most vulnerable to the effects of climate change (IPCC, 2007). The IPCC's Third Assessment Report describes vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007). The Third Assessment report also states that Africa is highly vulnerable to the effects of climate variability and therefore there is a need for further intensive research on climate change and climate change adaptation.

The main roles of the IPCC are to provide regular assessments of the state of knowledge on climate change, preparation of Special Reports and Technical Papers on topics where independent scientific information and advice is deemed necessary and support to the UN Framework Convention on Climate Change (UNFCCC) through its work on methodologies for National Greenhouse Gas Inventories (Barker *et al*., 2007). The First IPCC Assessment Report was completed in 1990 and this Report played an important role in the establishment of the Intergovernmental Negotiating Committee for a UN Framework Convention on Climate Change by the UN General Assembly. The UN Framework Convention on Climate Change

(UNFCCC) was adopted in 1992 and entered into force in 1994. It provides the overall policy framework for addressing the climate change issue (www.wikipedia.org, 2007).

The IPCC has continued to provide scientific, technical and socio-economic advice to the world community, and in particular to the Parties to the UNFCCC through its periodic assessment reports and special reports. Its Second Assessment Report, Climate Change 1995, provided key input to the negotiations, which led to the adoption of the Kyoto Protocol to the UNFCCC in 1997 (http: unfccc.int/source/docs).

The projected likely or very likely changes in extreme events and associated effects between now and 2100 were documented by the IPCC (IPCC, 2007) (Table 1-1).

Despite the immense work done by the IPCC, as already stated, there are still some challenges associated with the science of climate change. Critics have also dismissed climate change results in the IPCC documents as unreliable. Critics have also mentioned the fact that the IPCC reports make predictions based on simple models that fail to take into account current or historical phenomena, are not calibrated to observe climate phenomena, fail to emulate fundamental climate processes and project an appearance of certainty that is not supported by the evidence in underlying technical reports or statements regarding the similar exercises made in mainstream science journals (Coon and Backgrounder, 2001). However, the IPCC has stated that global climate models have improved over time although they still have limitations that affect the simulation of extreme events and has expressed confidence in many qualitative aspects of the model results (IPCC, 2007). The IPCC's findings have also been largely affirmed by the scientific community and by most governments thereby signifying the role it is playing in the climate change arena (Barker *et al*., 2007).

Table 1-1: Projected changes in extreme events and associated effects (as cited in the IPCC Fourth Assessment Report, 2007, pg 21).

Projected Change	Projected Effects
Higher maximum temperatures; more hot days and heat waves over nearly all land areas	• Increase in heat-related deaths particularly among older adults and urban poor • Increased heat stress in livestock and wildlife • Shifts in tourism • Increased risk of damage to some crops • Increased cooling demand
Higher minimum temperatures; fewer cold days, frost days, and cold waves over nearly all land areas	• Decrease in cold-related deaths • Decreased risk of damage to some crops and increased risk to others • Increased range of some pests and diseases • Reduced heating demand
More intense precipitation events over many areas	• Increased flood, landslide, avalanche, and mudslide damage • Increased soil erosion • Increased flood runoff could recharge some floodplains
Increased summer drying over mid-continental areas and associated risk of drought	• Decreased water resource quantity and quality • Increased risk of forest fire
Increase in tropical cyclone (e.g. tropical storms and hurricanes) rainfall and peak winds over some areas	• Increased risks to human life, risk of infectious disease epidemics and other risks • Increased coastal erosion and damage to coastal buildings and infrastructure • Increased damage to coastal ecosystems such as coral reefs.

1.4.1 *Uncertainties Associated with Climate Change Science*

The US-EPA has stated that as with any field of scientific study, there are uncertainties associated with the science of climate change and this does not imply in any way that scientists do not have confidence in many aspects of climate science. Some aspects of the science are known with virtual certainty because they are based on well-known physical laws and documented trends. Current understanding of many other aspects of climate change ranges from ‘likely’ to ‘uncertain’. However, scientists know with virtual certainty that:

- Human activities are changing the composition of Earth's atmosphere. Increasing levels of greenhouse gases like carbon dioxide (CO_2) in the atmosphere since pre-industrial times are well-documented and understood (US-EPA, 2007).
- The atmospheric buildup of CO_2 and other greenhouse gases is largely the result of human activities such as the burning of fossil fuels.
- A warming trend of about 0.7 to 1.5°C occurred during the 20th century. Warming occurred in both the Northern and Southern Hemispheres, and over the oceans (US-EPA, 2007).
- The major greenhouse gases emitted by human activities remain in the atmosphere for periods ranging from decades to centuries. It is therefore virtually certain that atmospheric concentrations of greenhouse gases will continue to rise over the next few decades (US-EPA, 2007).
- Increasing greenhouse gas concentrations tend to warm the planet.

There are important scientific questions that remain unanswered about how much warming will occur, how fast it will occur, and how the warming will affect the rest of the climate system including precipitation patterns and storms (US-EPA, 2007). Answering these questions will require advances in scientific knowledge in a number of areas:

- Improving understanding of natural climatic variations, changes in the sun's energy, land-use changes, the warming or cooling effects of pollutant aerosols, and the impacts of changing humidity and cloud cover.

- Determining the relative contribution to climate change of human activities and natural causes.
- Projecting future greenhouse emissions and how the climate system will respond within a narrow range.
- Improving understanding of the potential for rapid or abrupt climate change which refers to sudden (on the order of a decade), large changes in some major component of the climate system, with rapid, widespread effects (US-EPA, 2007).

Addressing these and other areas of scientific uncertainty is a major priority of the US Climate Change Science Program (CCSP). The CCSP is developing twenty-one Synthesis and Assessment products to advance scientific understanding of these recognition of common but differentiated responsibilities and respective capabilities as well as the precautionary principle (IPCC, 2007).

1.5 International Responses to Greenhouse Gas Emissions and Climate Change

1.5.1 *The United Nations Framework Convention on Climate Change (UNFCCC)*

The establishment of the IPCC was followed by the formation of the United Nations Framework Convention on Climate Change (UNFCCC), a treaty that signified how seriously the issue of climate change was considered by governments. The UNFCCC was adopted in May 1992 in New York and was opened for signature at the 'Rio Earth Summit' in Rio de Janeiro a month later. The treaty entered into force in March 1994 (http://unfccc.int/essential_background/convention/items/2627.php, 2007).

Signatories to the UNFCCC are split into three groups:

- Annex I countries (industrialised countries)
- Annex II countries (developed countries which pay for costs of developing countries)
- Developing countries

Annex I countries have been urged to reduce their emissions (particularly carbon dioxide) to target levels below their 1990 emission levels and if they cannot do so, they must buy emission credits or invest in conservation. Annex II countries that have to provide financial resources for the developing countries are a sub-group of the Annex I countries consisting of the Organisation for Economic Co-operation and Development (OECD) members, without those that were in transition economy in 1992 (http://en.wikipedia.org/wiki/United Nations Framework on Climate Change, 2007).

Developing countries have no immediate restrictions under the UNFCC and this serves two purposes:

- Avoids restrictions on growth because pollution is strongly linked to industrial growth, and developing economies can potentially grow very fast.
- They get money and technologies from the developed countries in Annex II (Braconnot *et al*., 2007).

The ultimate objective for the Parties is the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent anthropogenic interference with the climate system. Such levels should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner (Article 2) (Braconnot *et al*., 2007).

Article 2 of the UNFCCC specifies the ultimate objective of the Convention and states that:
'The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' (Rogner *et al.*, 2007). Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner'(Rogner *et al*., 2007).

Decisions made in relation to Article2 will determine the level of climate change that is set as the goal for policy and have fundamental implications for emission reduction pathway, the feasibility, timing and scale of adaptation required and the magnitude of unavoidable losses (Braconnot *et al*., 2007). Issues related to the mitigation, adaptation and sustainable development aspects of the implementation of Article 2 thus include, among others, the linkages between sustainable development and the adverse effects of climate change, the need for equity and co-operation and the recognition of common but differentiated responsibilities and respective capabilities as well as the precautionary principle (IPCC, 2007).

1.5.2 *Criticisms against the United Nations Framework Convention on Climate Change*

As already stated, one of the main objectives of the UNFCCC, according to Article 2, is to enable economic development to proceed in a sustainable manner. Critics have argued that the criterion that relates to enabling economic development to proceed in a sustainable manner is a double-edged sword (Braconnot *et al*., 2007). Projected anthropogenic climate change appears likely to adversely affect sustainable development, with adverse effects tending to increase with higher levels of greenhouse gas concentrations (IPCC, 2007). Conversely, costly mitigation measures could have adverse effects on economic development (Wakumonya and Spalding-Fecher, 1999). This dilemma facing policymakers results in (a varying degree) tension that is manifested in the debate over the scale of interventions and the balance adopted between climate policy (mitigation and adaptation) and economic development (Braconnot *et al*., 2007).

It has also been argued that the split between Annex I and developing countries is unfair and that both developed and developing countries need to reduce their emissions. Some countries, such as the United States claim that their costs of fulfilling the Convention's requirements will stress their economies (http://en.wikipedia.org/wiki/United Nations Framework on Climate Change, 2007).

The uncertainty in climate change knowledge (assessing future greenhouse gas emissions, severity of climate change impacts and regional changes, estimating mitigation costs etc) has also been identified by critics as a barrier to the implementation of Article 2 (Wakumonya and Spalding-Fecher, 1999).

Despite the criticisms levelled against the UNFCCC, many people agree that this treaty has been a major step towards the mitigation of climate change and has opened many avenues for dealing with climate change. For example, negotiations to strengthen the UNFCCC led to the adoption by the Third Conference of Parties of the 1997 Kyoto Protocol.

1.5.3 *The Kyoto Protocol*

The Kyoto Protocol is an international treaty designed to limit greenhouse gas emissions and also reaffirms sections of the UNFCCC (http://www.greenhouse.gov, 2007). The Kyoto Protocol came into force in February 2005 and strengthens the international response to climate change. Countries which ratify this Protocol commit to reduce their greenhouse gas emissions. The Protocol establishes individual, legally binding targets for Annex 1 countries (mostly developed countries) and exempts developing countries from its binding emission targets (Wakumonya and Spalding-Fecher, 1999). It establishes three market-based mechanisms aimed at giving countries flexibility in meeting their own emission targets. A Clean Development Mechanism (CDM) will enable developed countries to finance emissions reduction projects in developing countries and receive emission credits for doing so (http://www.greenhouse.gov, 2007).

1.5.3.1 Criticisms against the Kyoto Protocol

Clean Development Mechanisms (CDM). Many governments and businesses are already expressing disappointment with the CDM and have declared it “cumbersome and unrewarding” It has also been stated that the CDM is failing in its mandate to promote sustainable development, especially by not financing projects that assist in the long-term transition of developing country energy sectors towards renewable energy technologies (http://environment.about.com, 2007).

The CDM is a market and not a development fund nor a renewables promotion mechanism. Its aim is to provide tradable emission reduction credits at the lowest cost in a limited timeframe (up to 2012) (http://www.greenhouse.gov, 2007). Various modifications, which include the restriction of project eligibility through to making the CDM, a sectoral-based mechanism instead of a project-based market mechanism, have been proposed (Schmidt, 2000).

Exempts developing nations. Criticisms levelled against the Kyoto Protocol include the fact that it does not include greenhouse gas emission limits for developing countries such as China, which is one of the major emitters of greenhouse gases (McRae, 2005).

It has also been argued that greenhouse gases' levels are increasing and that failure to include developing countries in the reduction goals will negate any reductions that industrialised countries could achieve (McRae, 2005). This has led to speculation that North South debates may hamper efforts of making the Kyoto Protocol an effective treaty that will address the problem of climate change. It has also been speculated that global emissions would increase as energy intensive production will transfer from developed countries to developing countries where energy use is less efficient and less costly (http://climatechange.sea.ca, 2006).

It has also been stated that carbon emissions have a social character that differs widely. For example, people around the world view America's carbon as 'luxury emissions' whereas those in the developing countries are primarily 'survival emissions' to meet basic human needs for food and shelter. By and large, the developing countries lack the financial, technological and institutional abilities to fight climate change (McRae, 2005). Poverty, air pollution, access to clean water, HIV/AIDS and other infectious diseases are major problems afflicting the world's poor countries and constitute more immediate priorities than fighting global problems created by industrialized countries through the course of their development (Schmidt, 2000).

Unrealistic targets. The Protocol requires industrialized countries to reduce their emission levels to below their 1990 levels. It has been stated that many countries will not be able to meet their emission targets, and even if they did, this would not reduce worldwide emissions since other studies show that emissions by developing countries will exceed those of industrialized countries (http://www.global issues.org, 2007).

Failure to distinguish between human and non-human caused factors. Projections are based on scenarios that predict population change, fuel use, technology development, international trade and the rate of development. By lumping together predictions based on human and non-human factors, the Protocol fails to provide the kind of verifiable information that would enable policy makers to make intelligent decisions on how to reduce human contributions to climate change and how to prepare for changes that are due to forces outside of human control (McRae, 2005).

Globalisation. One of the obligations of the countries that have ratified the Kyoto Protocol is that they must protect forests and other 'sinks' for the purposes of reducing greenhouse gases in the atmosphere. This is going to be a difficult task since the impacts of globalisation have triggered a form of institutional interplay between global markets and local political and economic systems that has exarcebated the forces leading to the destruction of forest ecosystems in some areas (Jodha, 1996). For example, the rise of global markets for wood products has generally increased the pressure to favour consumptive uses in the management of place based forest ecosystems (Young, 2002). Economically, developing countries have experienced powerful incentives to treat forests and other natural resources as commodities to be used in fuelling policies calling for export-led growth, and increasingly, in servicing national debts, which have burgeoned in the pursuit of national development (Jodha, 1996). It is therefore important to note that even in cases where efforts are being made to establish regimes that will encourage sustainable forestry, globalisation and the forces of institutional interplay generally favour consumptive use of place-based natural resources (Young, 2002).

There is no question that developing nations and industries will eventually need to reduce their emissions, although it would be impossible for them to take on reduction targets within the same time frame as developed countries. Both developed and developing countries should however, make efforts to mitigate climate change for the achievement of sustainable development.

1.5.4 *G8 Countries and Climate Change Mitigation*

The G8 (Group of 8) is a political forum and annual meeting attended by the leaders of eight of the most economically powerful countries (United States of America (USA), Canada, Britain, Germany, Japan, Italy, France and Russia). The G8 countries in the 2007 G8 Summit at Heiligendamm stated that they recognise the important opportunities offered by effective action addressing climate change, in particular for innovation, technological development as well as poverty reduction. (http.www.weforum.org, 2007).

The G8 countries have also stated that they are committed to taking actions that will tackle climate change in order to stabilise greenhouse gas concentrations at levels that would prevent interference with the climate system. These actions will involve setting a global goal for emissions reductions and this would include major emitters. The G8 countries have also agreed to take into consideration the decision made by the European Union, Canada and Japan to at least half the global greenhouse emissions by 2050 (http.www.weforum.org, 2007).

One of the agreements reached by the G8 countries during the summit was that in the addressing of the urgent climate change challenge, it is important that vital major economies that use most of the energy and generate the majority of greenhouse gas emissions agree on a detailed contribution for a new global framework by the end of 2008 which would contribute to a global agreement under the UNFCC by 2009. The

G8 countries have also stated the importance of engaging major energy consuming and greenhouse gas emitting developing countries like Brazil, India, Mexico and South Africa (http.www.weforum.org, 2007).

1.5.5 *Climate change mitigation policies, measures and instruments*

The IPCC in its Fourth Assessment Report has stated that a wide variety of policies and instruments are available to governments to create the incentives for mitigation action. The applicability of these policies and instruments, however, depends on national circumstances and the understanding of their interactions (Mezt *et al*., 2007).

Some of the policies and instruments that can be used by governments for climate change mitigation include:

- Integrating climate policies in broader development policies as this would make implementation and overcoming barriers easier.
- Setting of standards and making regulations with regards to greenhouse gas emissions. Regulations and standards are generally preferred as they generally provide some certainty about emission levels (IPCC, 2007).
- Voluntary agreements between industry and governments have been found to raise awareness among stakeholders and have played a role in the changing of many national policies. Voluntary agreements are initiatives that aim to improve environmental performance beyond existing legal requirements (http://www.sustainability.dpc.wa.gov, 2006). Although it has been stated that the majority of the agreements in the past have not led to a significant reduction of greenhouse gas emissions, recent agreements in a few countries, especially European countries and Australia, have accelerated the application of best available technology and led to measurable emissions reductions (IPCC, 2007).
- Information instruments, which include awareness campaigns have been found to positively affect environmental quality by promoting informed choices and contributing to behavioural change (IPCC, 2007).

Some corporations, local and regional authorities, Non-governmental Organisations (NGOs) like Greenpeace and civil groups are also adopting a wide variety of voluntary actions which may limit greenhouse gas emissions, stimulate innovative policies and encourage the deployment of new technologies. The actions of these various organisations, civil groups and various authorities generally have a limited impact on greenhouse gas reduction at national or regional levels (IPCC, 2007).

1.5.6 *Sustainable Development and Climate Change Mitigation*

Sustainable development can be defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). Sustainable development contains two key concepts and these are: the concept of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and the future needs (United Nations, 1987).

Sustainable development has environmental, economic and social dimensions. Properly designed climate change response can be part and parcel of sustainable development and the two can be mutually reinforcing (Cohen *et al*, 1998). Mitigation, by limiting climate change, can conserve or enhance natural capital (ecosystems, the environment as sources and sinks for economic activities) and prevent or avoid damage to human systems and, thereby, contribute to the overall productivity of capital needed for socio-economic development, including mitigative and adaptive capacity. In turn, sustainable development paths can reduce vulnerability to climate change and reduce greenhouse gas emissions (IPCC, 2007).

The notion is that policies that pursue sustainable development and climate change mitigation can be mutually reinforcing and this leads to a strong focus on integrating sustainable development goals and consequences into the climate change mitigation policy framework, and on assessing the scope of such ancillary benefits. For instance, reductions, in greenhouse emissions might lead to an improvement in public health due to reductions in air pollution and benefit ecosystems –both of which are elements of sustainable development (Beg *et al*., 2002).

1.5.6.1 Sustainable Development Benefits of Mitigation Options

The sustainable development benefits of mitigation options vary over sectors and regions. Generally, mitigation options that improve productivity of resource use, whether it is energy, water, or land, yield positive benefits across all three dimensions of sustainable development (Beg *et al*., 2002). In the agricultural sector, for instance, improved management practices for rice cultivation and grazing land, and use of bioenergy and efficient cooking stoves enhance productivity, and promote social harmony and gender equality. Other categories of mitigation options have a more uncertain impact and depend on the wider socio-economic context within which the option is being implemented (Sathaye, *et al., 2007).*

Some mitigation activities, particularly in the land use sector, have GHG benefits that may be of limited duration. A finite amount of land area is available for forestation, for instance, which limits the amount of carbon that a region can sequester. And, certain practices are carried out in rotation over years and/ or across landscapes, which too limit the equilibrium amount of carbon that can be sequestered. Thus, the incremental sustainable development gains would reach an equilibrium condition after some decades, unless the land yields biofuel that is used as a substitute for fossil fuels (Sathaye, *et al., 2007).* Governments and various organisations, however, can mainstream climate change into development choices in order to achieve sustainable development (Table 1-2).

Table 1-2: Mainstreaming Climate Change into Development Choice (Sathaye *et al*, 2007 pg 724).

Selected sectors	Non-climate policy instruments and actions that are candidates for mainstreaming	Primary decision-makers and actors	Global greenhouse gas emissions by sector that could be addressed by non-climate policies (% of global GHG emissions)[a,d]		Comments
Macro-economy	Implement non-climate taxes/subsidies and/or other fiscal and regulatory policies that promote sustainable development	State (governments at all levels)	100	Total global GHG emissions	Combination of economic, regulatory, and infrastructure non-climate policies could be used to address total global emissions
Forestry	Adoption of forest conservation and sustainable management practices	State (governments at all levels) and civil society (NGOs)	7	GHG emissions from deforestation	Legislation/regulations to halt deforestation, improve forest management, and provide alternative livelihoods can reduce GHG emissions and provide other environmental benefits
Electricity	Adoption of cost-effective renewables, demand-side management programmes, and transmission and distribution loss reduction	State (regulatory commissions), market (utility companies) and, civil society (NGOs, consumer groups)	20[b]	Electricity sector CO_2 emissions (excluding auto producers)	Rising share of GHG-intensive electricity generation is a global concern that can be addressed through non-climate policies
Petroleum imports	Diversifying imported and domestic fuel mix and reducing economy's energy intensity to improve energy security	State and market (fossil fuel industry)	20[b]	CO_2 emissions associated with global crude oil and product imports	Diversification of energy sources to address oil security concerns could be achieved such that GHG emissions are not increased
Rural energy in developing countries	Policies to promote rural LPG, kerosene and electricity for cooking	State and market (utilities and petroleum companies), civil society (NGOs)	<2[c]	GHG emissions from biomass fuel use, not including aerosols	Biomass used for rural cooking causes health impacts due to indoor air pollution, and releases aerosols that add to global warming. Displacing all biomass used for rural cooking in developing countries with LPG would emit 0.70 $GtCO_2$-eq., a relatively modest amount compared to 2004 total global GHG emissions
Insurance for building and transport sectors	Differentiated premiums, liability insurance exclusions, improved terms for green products	State and market (insurance companies)	20	Transport and building sector GHG emissions	Escalating damages due to climate change are a source of concern to insurance industry. Insurance industry could address these through the types of policies noted here
International finance	Country and sector strategies and project lending that reduces emissions	State (international Financial Institutions) and market (commercial banks)	25[b]	CO_2 emissions from developing countries (non-Annex 1)	IFIs can adopt practices so that loans for GHG-intensive projects in developing countries that lock-in future emissions are avoided

Notes:
a. Data from Chapter 1 unless noted otherwise.
b. CO_2 emissions from fossil fuel combustion only; source: IEA, 2006.
c. CO_2 emissions only. Authors estimate, see text.
d. Emissions indicate the relative importance of sectors in 2004. Sectoral emissions are not mutually exclusive and may overlap.

Despite the fact that sustainable development is an important concept which takes into consideration environmental, social and economic aspects, criticisms have been levelled against it.

1.5.7 *Criticisms against Sustainable Development*

Various criticisms have been levelled against the concept of sustainable development. Some critics have pointed out that the concept of sustainable development can be used to support ‘greenwashing’or hypocrisy (Athanasiou, 1996). Some of the responses to such practices have been the development of greatly improved monitoring and analytical techniques and standards in order to verify claims about sustainable practices (Hardi and Zdan, 1997).

The most serious concern about sustainable development is that it is inherently delusory. Some critics have argued that because biophysical limits limit the amount of future development that is sustainable, the term ‘sustainable development’ is itself an oxymoron (Dovers and Handmer, 1993). Others have also pointed out that the concept of sustainable development is anthropocentric (considering humans to be the centre of the universe), thereby avoiding a reformulation of values that may be required to pursue true sustainability (Suzuki and McConell, 1997)

Despite these criticisms, the principles of sustainable development have been incorporated in various national and international instruments (Boyle and Freestone, 1999).

1.6 Summary

Climate change and its mitigation have become issues of global urgency. Continued efforts towards climate change mitigation are still required from governments, various organisations, industry and society at large. Given the fact that industry also needs to play an active role in climate change mitigation through greenhouse gas emission reductions and other strategies, the next chapter focuses on the cement industry which is a relatively major emitter of greenhouse gases, particularly carbon dioxide.

2. CEMENT PRODUCTION AND CLIMATE CHANGE

2.1 Introduction

Industrial activities have been identified as major emitters of greenhouse gases, which in turn exarcebate the problem of climate change. In South Africa, the energy and cement sectors have been identified as major sources of carbon dioxide. These sectors produced 94 million tons of carbon in 1994, nearly ten times the African and twice the world average of carbon (Chandler *et al*., 2002). The fact that the cement sector has been identified as a major source of carbon dioxide emissions in the country is a cause of concern given the threat of climate change and its impacts and the fact that South Africa has been classified to be in a climatically sensitive region.

This chapter therefore examines the cement industry as an emitter of greenhouse gases, which are the gases that lead to climate change. The chapter also describes the process of cement production in general and cement production in various developing countries which include India, China and South Africa. The greenhouse gas reduction strategies employed by the cement production sectors in these countries and the cement industry in general are also examined, including barriers to sustainable cement production. Greenhouse gas reduction strategies related to other greenhouse gas producing sectors of these countries' economies are also discussed.

2.2 Cement production

Cement production is an energy intensive process in which a combination of raw materials is chemically altered through intense heat to form a compound with binding properties. The main raw materials include limestone, chalk and clay which are mined or quarried, usually at a site close to the cement mill (World Bank, 1998). These materials are then ground to a fine powder in the proper portions needed for the cement. These can be ground as a dry mixture or combined with water to form a slurry. The addition of water at this stage has important implications for the production process and for energy demands during production, which is often categorised as dry process and wet process (Figure 2-1). Additionally, equipment can be added to remove some water from the slurry after grinding, the process is then called semi-wet or semi-dry (PPC, 2006).

This mixture of raw materials enters the clinker production (or pyro-processing) stage. During this stage, the mixture is passed through a kiln or pre-heater system and exposed to increasingly intense heat, up to 1400°C (Figure 2-2). This process drives off all moisture, dissociates carbon dioxide from calcium carbonate and transforms the raw materials into new compounds. The output from this process, called clinker, must be cooled rapidly to prevent further chemical changes. Finally, the clinker is blended with certain additives and ground into a fine powder to make cement. Following this cement grinding step, the cement is bagged and transported for sale (Hendricks *et al.*, 2002).

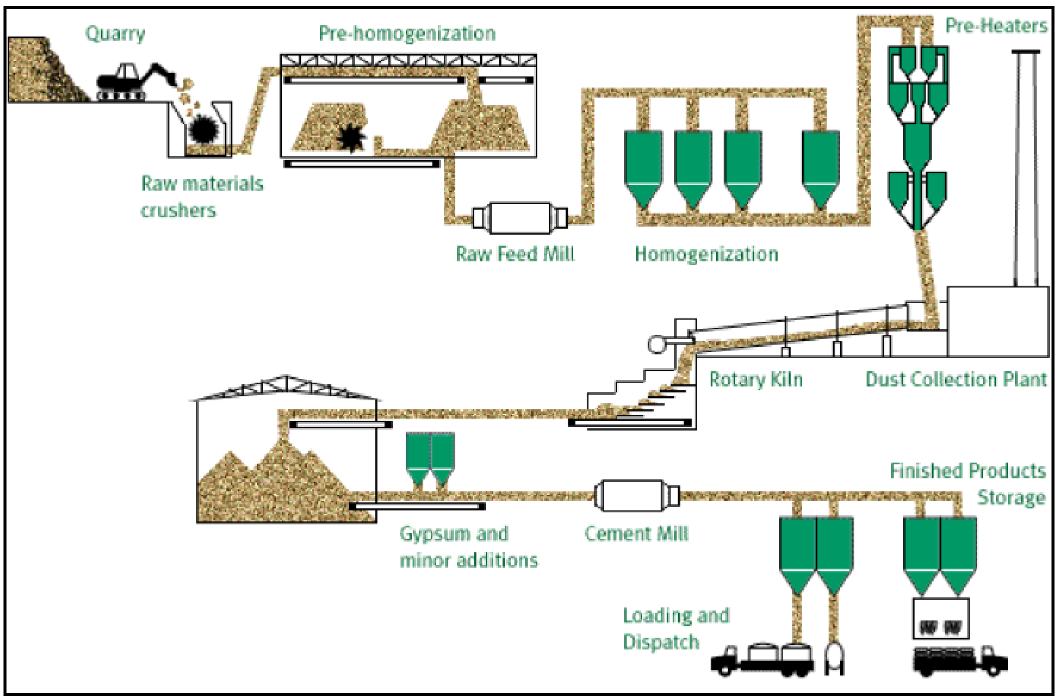


Figure 2-1: Cement Production Process (as cited in the PPC Background Document for the Proposed Secondary Materials Co-Processing Programme, 2006, pg 4).

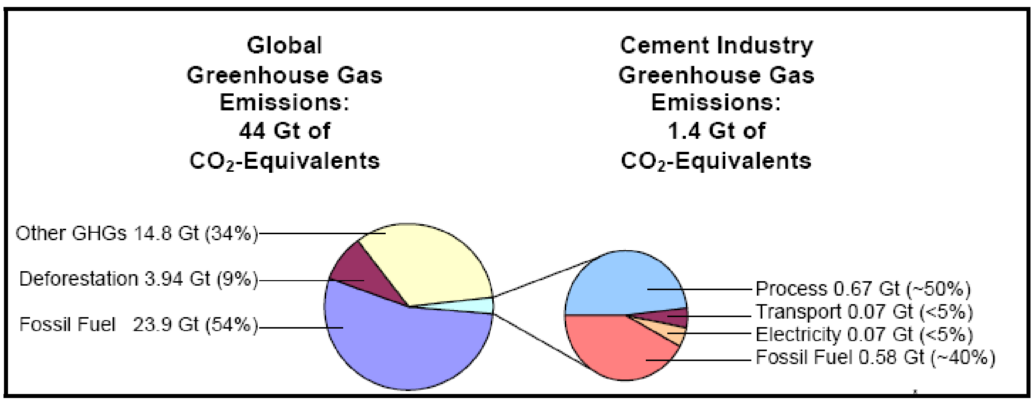
In cement production, carbon dioxide emissions result both from energy use and from the decomposition of calcium carbonate during clinker production. Clinker production is the most energy intensive stage of the process and accounts for up to 90% of the total energy use (Chandler *et al*., 2002). The grinding of the raw materials and the cement mixing process are both energy intensive steps and account for much of the remaining energy use in cement production. Particulate matter, nitrogen oxides, sulphur dioxide and carbon monoxide are some of the primary emissions in the production of cement. Emissions may also include residual materials from the fuel and raw materials or products of incomplete combustion that are considered to be hazardous (US-EPA, 2007).

Figure 2-2: Long dry kiln (as cited in the PPC Background document for the Proposed Secondary Materials Co-Processing Programme, 2006, pg 5).

Cement production therefore leads to greenhouse gas emissions. Studies have further shown that one tonne of carbon dioxide gas is released into the atmosphere for every tonne of cement which is made anywhere in the world (World Bank, 1998). Unless something drastic and different is done, the world's atmosphere will go on being destroyed by activities which lead to the production of greenhouse gases and the depletion of natural carbon sinks further intensifying the problem of climate change (World Bank 1998).

The cement industry is responsible for approximately 3.5% of the global anthropogenic greenhouse gas emissions (Figure 2-3). It is important to note that extensive research has shown that the cement industry does not generate large amounts of other greenhouse gases compared to carbon dioxide. Cement-related greenhouse gas emissions emanate from fossil fuel combustion at cement manufacturing operations (about 40% of the industry's emissions), transport of raw materials (about 5%) and the combustion of fossil fuel required to produce electricity consumed by cement manufacturing operations (5%). The remaining cement-related emissions (about 50%) originate from the process that converts limestone (CaCO3) to calcium oxide (CaO) the primary precursor to cement (Hendricks *et al*., 2002).

Cement is considered one of the most important building materials around the world and is mostly used for the production of concrete. Cement consumption and production is closely related to construction activity, and therefore to the general economic activity. Due to the importance of cement as a construction material and the geographical abundance of the main raw materials, cement is produced in virtually all countries (Hendricks *et al*., 2002).



* Battelle estimate based upon data from numerous sources, including the following major sources: Nakicenovic, N. and R. Swart;[1] IEA 1999[2]; IPCC 2001[7]; CEMBUREAU 1998;[4] CEMBUREAU 1996;[3] and CEMBUREAU 1999[5].

Figure 2-3: Greenhouse Gas Emissions from the Cement Industry for the year 2002 (as cited in the WBCSD Report, 2002, pg 1).

2.3 South African Cement Industry

The South African cement industry is characterised by cement plants that vary in age from recently commissioned plants (5 years ago) to plants built in the early 1930s, all of which incorporate old and new technologies (DME, 2003). All South African cement plants produce Portland cement and blended cement products such as CME l, and more recently CEM ll and CEM lll products, which are the most common manufactured products in South Africa. Portland cement is a fine, typically grey powder comprised of several compounds which include various silicates (Building Research Establishment, 2005).

Different types of Portland cements can be produced depending on the application, as well as the chemical and physical properties desired. The capital investment per worker in the cement industry is among the highest in all industries. All local cement producers have to comply with the European Norm Standards for cementitious products. A number of other European standards for different cement and binder types are currently at various stages of preparation by the responsible technical committees (Building Research Establishment, 2005).

In South Africa, four companies, PPC, Holcim, Lafarge SA (formerly Blue Circle) and Natal Portland Cement (NPC), dominate the cement industry (Figure 2-4).

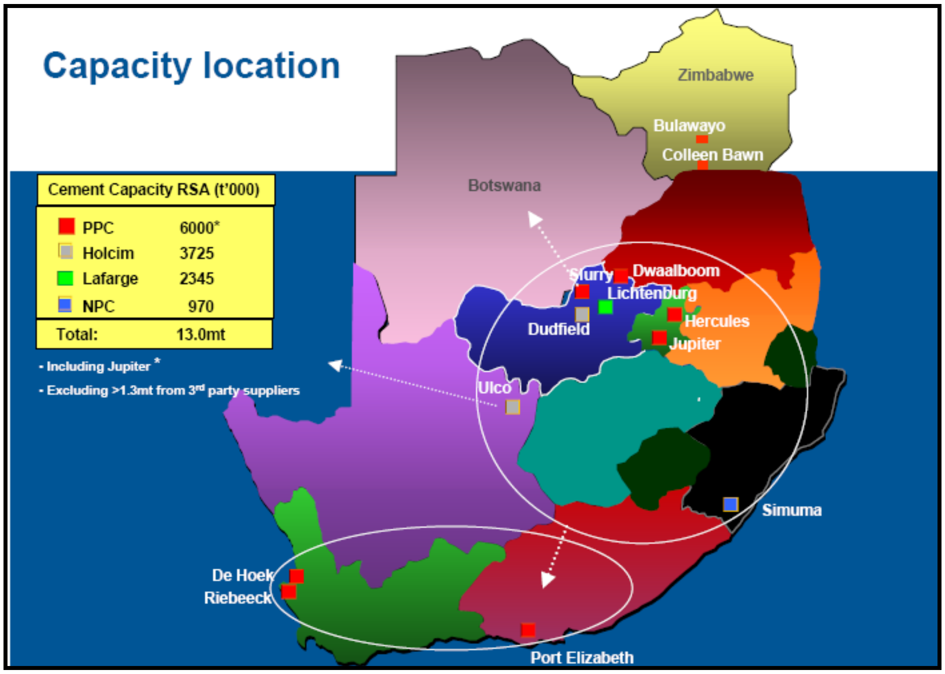


Figure 2-4: Locations of various cement manufacturing plants in South Africa (as cited in the PPC Dwaalboom Expansion Project "Batsweledi": Analysts and Media Presentation, 2005, pg 3).

It has been stated that the demand for cement in South Africa continues to outstrip supply because of private developers and public works programmes, including the construction of new stadiums for the 2010 World Cup. Also, regional demand for cement grew by 8.3% and customer requirements have been met from local production and supplemented by Zimbabwe' PPC operation (Mail and Guardian, 2007).

Local sales are defined as sales within South Africa's provinces, regional sales include sales to Namibia, Botswana, Lesotho and Swaziland, whilst exports pertain to sales beyond these SADC countries, that is to West Africa, Indian Ocean Islands and other neighbouring African countries. In 2002, total cement sales (by mass, excluding exports) increased by 5% to 9.6Mt- the highest volume sold in 5 years (DME, 2002). Six of the nine provinces showed positive growth in 2002, with cementitious demand being the highest in the North West province (Figure 2-5). South African Cement exports for the years 1993 to 2002 show that annual sales were highest for the year 1999 and lowest in the year 1994 (DME, 2002) (Figure 2-6).

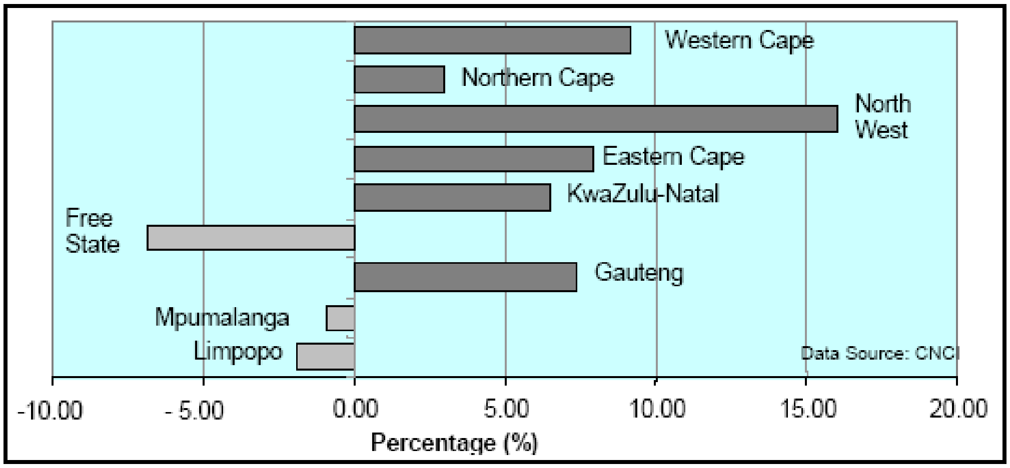


Figure 2-5: Cementitious Demand by Province (DME, 2002, pg 8).

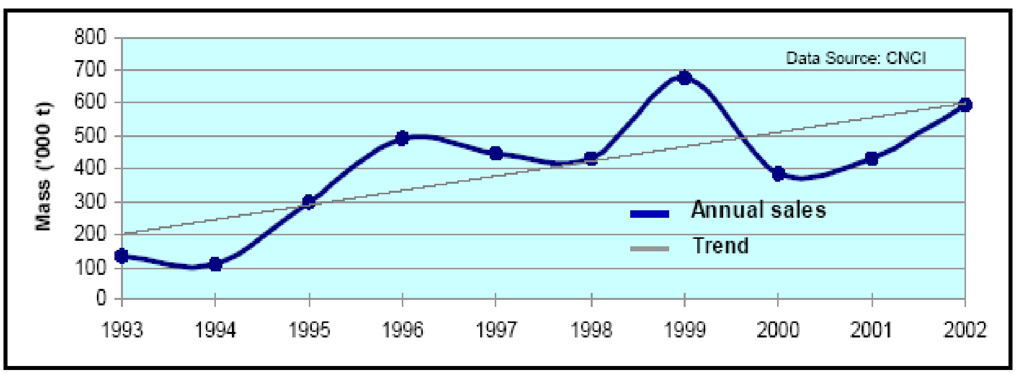


Figure 2-6: South African Cement Exports by Mass (1993-2002) (DME, 2002, pg 10).

Cement production is one of the industrial processes that have contributed significantly to carbon dioxide emissions in South Africa (DEAT, 1999). In 1994, cement production contributed 14% of the total carbon dioxide emissions from the industrial sector. Studies indicate that carbon dioxide emissions from cement production in South Africa have increased over the last decade at a rate of 2% per year (DEAT, 1999). This can be attributed to the high demand for cement in South Africa and regionally (Figure 2-7).

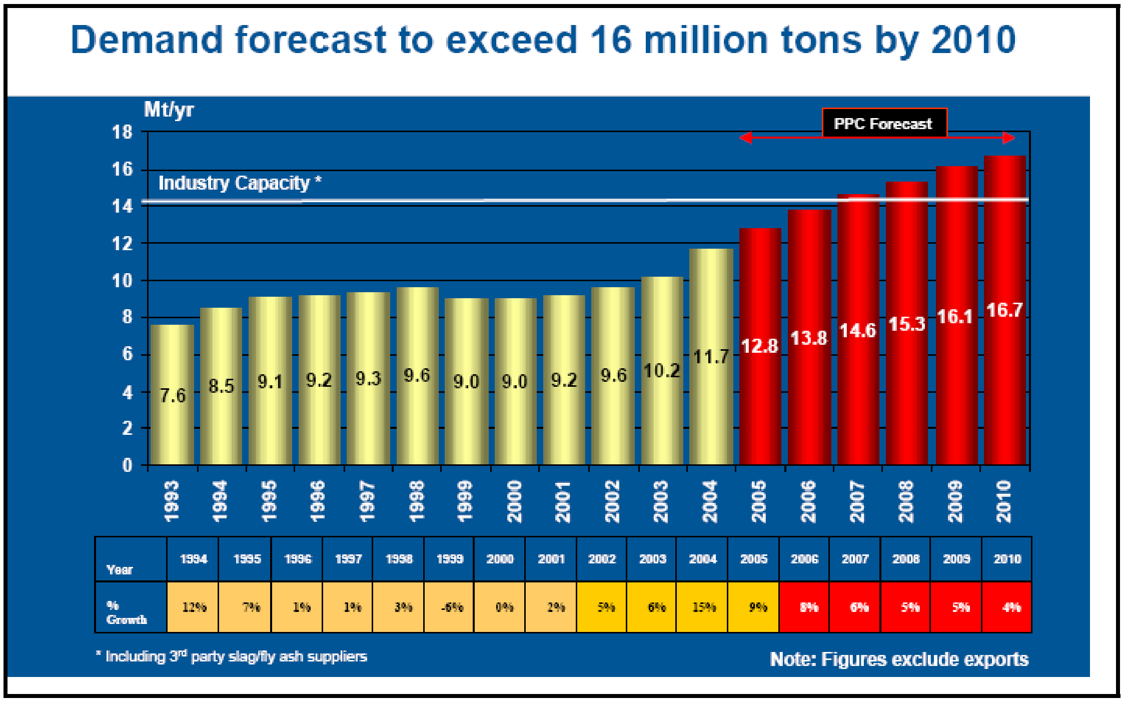


Figure 2-7: Monitored trends and projected trends for cement demand in South Africa (as cited in the PPC Dwaalboom Expansion Project "Batsweledi": Analysts and Media Presentation, 2005, pg 4).

South Africa's contribution to global greenhouse gas emissions has been estimated to be 1.2% and the country has been ranked as the eighteenth highest contributor to global greenhouse gas emissions (Parker and Blodgett, 2005). The energy and cement sectors in 1999 produced 94 million tons of carbon, or 2.3 tons per capita-nearly ten times the African and twice the world average. While total emissions increased substantially from 1990 to 2000, per capita emissions remained roughly constant. Compared to other major developing countries, South Africa's emissions intensity, that is the emissions per unit of economic output, is relatively high. Coal use during electricity production is the main reason for this emission profile (Howells, 2002).

General climate change mitigation measures by the South African government include taking steps to phase out subsidies to its unusual, carbon-intensive coal liquefaction industry and to open the country to natural gas imports (Sustainable Energy Society of Southern Africa, (http://www.sessa.org.za, 2007). As in many other developing countries, the absence of rigorous and publicly available studies of future energy use and greenhouse gas emissions remains an obstacle to future emissions mitigation (Chandler *et al*, 2002).

The South African government also has a National Climate Change Response Strategy which proposes a number of priority actions relating to pollution and waste management, energy, agriculture and water. The country is rated as one of the world's top 20 polluters (http:en.wikipedia.org, 2007) and therefore there is need for urgent action by government and industry in addressing climate change and other environmental problems. The Department of Minerals and Energy (DME) is currently involved in a number of programmes to reduce emissions intensity. The DME has also developed a white paper on renewable energy and clean energy development. This sets a target of 10000GWh renewable energy contribution to final energy consumption by 2012. Training and capacity building is also being conducted by the Household Energy Action Training (HEAT) programme (DME, 2003). Through the Climate Change Response Strategy, government also plans to increase awareness and capacity, particularly in those departments that are not directly involved with climate change and other environmental issues (DEAT, 2004). Financial constraints have however, been cited as a barrier to the implementation of the National Climate Change Response Strategy.

In addressing the problem of climate change, it is also important to study what problems are faced by the cement industries of other developing countries and industry in general and what strategies have been used or are currently in use for greenhouse gas reduction and ultimately climate change mitigation. Greenhouse gas reduction strategies from the other developing countries like China and India can prove useful and applicable to a country like South Africa which is also a developing country. For example, the country can adopt policies which promote sustainable development and climate change mitigation which have been implemented in India and China, taking into consideration the suitability and applicability of these in the South African context.

2.4 Chinese Cement Industry

The Chinese cement industry is the largest of that sector in the world and this growth has been driven mostly by strong demand for construction and new housing in many urban centres (Figure 2-8). The projected production of cement in China (Figure 2-9) shows that cement production is set to increase steadily (Soule *et al*., 2002).

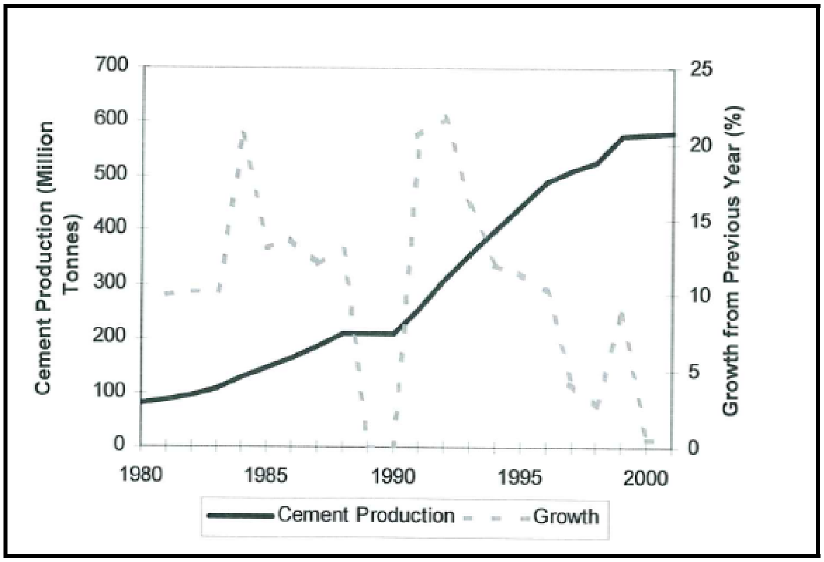


Figure 2-8: Cement production in China from 1980 to 2000 (Soule *et al*, 2002, pg 8).

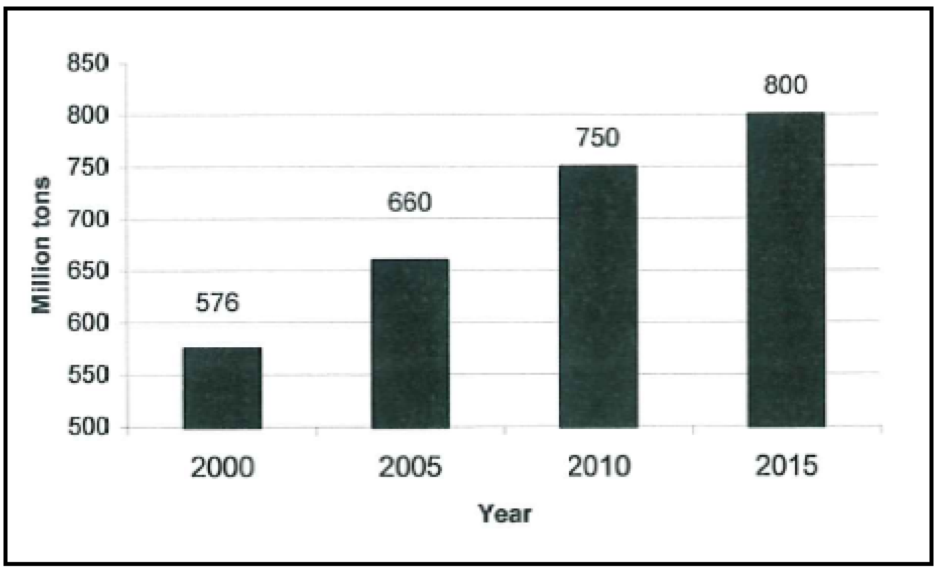


Figure 2-9: Projected Chinese Cement Production, 2000-2015 (Soule *et al*, 2002, pg 9).

China has been the world's leading cement producer since 1985 (WBCSD, 2002). The United States Survey estimated that China produced 576 million tonnes in 2000, about 36% of the world's total (Hengchen, 2004).

The estimated number of Chinese cement plants ranges from 8000 to 9300, although the actual number is uncertain due to the fragmented nature of the industry, the small size of most of the plants and the fact that some of the plants exist illegally, and data reliability issues.

About 50% of these facilities are rural township enterprises with average annual output of less than 30 000 tonnes (Soule *et al*., 2002). Most of the facilities, approximately 85% are small, vertical shaft kiln-type facilities which operate at village and township levels. There are few modern rotary kilns (with energy and less pollution and material consumption) which are similar to those used in the EU and USA (Hengchen, 2004).

Only about 570 of the 8500 cement producers had production capacities exceeding 275 000 tonnes per year in 1995, and only ten plants produce more than 1 million tonnes annually. However, China plans to increase the average production capacity at facilities throughout the industry through plant upgrades and closures. The country plans to increase average plant production to 300 000-400 000 tonnes by 2010 and up to 500 000 tonnes by 2015 (WBCSD, 2002).

2.4.1 *Chinese Cement Sector's Impact on the Environment*

China has significant environmental problems. Ambient air levels of total suspended particulates (TSP) and sulphur dioxide (SO_2) in Chinese cities are among the highest in the world and this has in turn led to significant respiratory illnesses. China's contribution to global carbon dioxide emissions has been estimated to be 14%. Cement plants in China are responsible for over 40% of the total industrial particulate (dust) emissions and for about 6-8% of the country's carbon dioxide emissions (Hengchen, 2004). These emissions are produced due to fuel combustion and the release of carbon dioxide from limestone at high temperature. Carbon dioxide emissions from small Chinese plants are two or more times higher than those of plants in industrialised countries mainly due to the inefficient utilisation of resources in these plants. This has resulted from the obsolete industrial structure, including products, technical level, facility size and the unacceptable configuration of the industry (Soule *et al*, 2002).

Particulate and sulphur dioxide emissions from China's cement sector for 1991 to 1999 increased at a steady rate (Table 2-1). According to the data in 2000, China produced 600 million tonnes of cement and discharged 10-12 million tonnes of powdered dust, 400 million tonnes of carbon dioxide, 1 million tonnes of nitrogen dioxide and over 0.5 million tonnes of sulphur dioxide. These figures are a clear indication that the technology used in cement plants in China is outdated compared to world cement production technology (Table 2-2) (Soule *et al*, 2002).

Table 2-1: Particulate and Sulphur Dioxide Emissions from China's Cement Sector (Soule *et al*., 2002, pg 26).

	Particulate Emissions from Industry (Million Tonnes)	Cement Industry Particulate Emissions (% of Total Industry)	SO_2 Emissions from Industry (Million Tonnes)	Cement Industry SO_2 Emissions (% of Total Industry)
1991	14.2	22	11.0	5.0
1992	14.5	17	13.2	3.2
1993	15.0	25	12.9	5.2
1994	13.9	27	13.4	5.5
1995	14.8	29	14.1	5.5
1996	12.4	29	13.1	5.2
1997	15.8	42	14.7	5.4
1998	25.0	44	15.9	5.5
1999	21.3	--	14.6	--

Table 2-2: Technical level of cement industry between China and the world (Hengchen, 2004, pg 5).

	World Levels	Chinese Level
Ratio of the production capacity of dry-kiln type	98.3% in Japan and 96.5% in Italy	About 20%
Average size of plants	0.60-1.0 million tonnes, 2.56 tonnes in Japan	Less than 0.15 M tons
All labour productivity	3000 tonnes/person yr in France; 15000 tonnes in Japan	Less than 500 tonnes/person
Heat consumption for clinkers	2900Kj/kg in Japan.	5121Kj /kg (average for rotary kilns)
Total power consumption	92kWh/ton	114 kWh/ton
Rate of cement in bulk	80-90% or above	20%-30%

The country's booming industry and its corresponding burst in energy consumption, rapid urbanisation and the fact that it generates most of its energy by burning coal, are largely responsible for its rapidly climbing greenhouse gas emissions (http://www.scidev.net, 2007).

According to researchers at the US-based Pew Centre on Global Climate Change, China is likely to be the number one emitter in twenty years (Baumert and Peshing, 2004).

2.4.2 *Environmental Protection in China*

China has developed a range of environmental laws to address the problem of air pollution. These laws also indirectly address the issue of climate change mitigation. Many of these are modelled after the United States of America or European Legislation. Since 1989, emission limits for cement production have been set at 150 milligrams of particulates per cubic metre of exhaust gas. This emission limit was reduced to 100 milligrams of particulates per cubic metre of exhaust gas in April 2000 (Bhandari, 2006).

A stringent emission limit for particulates, however, exists in Europe for cement plants and this is 70 milligrams of particulates per cubic metre of exhaust gas and this is going to be lowered to 50 milligrams per cubic metre of exhaust gas. South Africa currently does not have emission limits that apply to cement plants in the country and it would be ideal to have emission limits for particulates and other pollutants that all cement plants in the country will have to adhere to (Hengchen, 2004). This is because emission limits will encourage cement producing companies to reduce emissions from their operations to acceptable levels that will ensure environmental and human health protection.

Despite the existence of environmental laws in China, the main problem has been the ineffectiveness of government departments in the enforcement of legislation, which in some cases is not uniform. Provincial level environmental protection agencies are responsible for enforcing emission limits and can direct capital toward polluters to upgrade their equipment. Production and profit however, often supersede enforcement (WBCSD, 2002). Environmental regulations tend to be strictly enforced when foreign companies are involved. The other major problem in China is that information is not widely and uniformly available. It is important to note that these problems are not only unique to China, but are also characteristic of other developing countries including South Africa which also has numerous environmental legislation but faces the problem of lack of effective law enforcement (Ruth *et al.,* 2002).

Despite some setbacks, the Chinese government has, however, taken steps towards promotion of strategic reorganisation of many state-owned enterprises, introduction of structural mechanisms which will aid in the elimination of outdated technology and reduction of severe pollution problems. For instance, the government has proposed a strategy of closing older plants and building new ones and encourage the Chinese cement producers to use technologically advanced rotary kilns instead of old vertical kilns. Vertical shaft kilns account for more than 400 million tonnes of cement production. The government is also encouraging public participation in all new cement projects (Schumacher and Sathaye, 1999).

Studies have also indicated that the country has dramatically reduced its emissions growth rate, now just half its economic growth rate, through slower population growth, energy efficiency improvements, fuel switching from coal to natural gas, and continued policies for economic reform, efficiency, and environmental protection could reduce emissions growth by an additional 500 million tons a year in 2020 (China Statistical Bureau, 2005).

2.5 India's Cement Industry

Having examined China's cement industry, attention now turns to India, which is also a developing country with a growing cement production sector. In 2000, India's contribution to global greenhouse gas emissions was estimated to be 5.5% and the country has been ranked as the fourth highest global emitter of greenhouse gas emissions (Parker and Blodgett, 2005). India is the fourth largest cement producing country in the world, after China, Japan and the US, with approximately 115 large cement plants within 57 cement companies. About 94% of the thermal energy requirement in the Indian cement manufacturing sector is met by coal while the rest is met by fuel oil. So far, no real substitute for coal exists (Bureau of Energy Efficiency, 2005). To make matters worse, over the years, there has been a steady decline in the quality of coal with an increase in the ash content. This has resulted in lower calorific values of coal and increased coal consumption to provide the energy needed for clinker production (Schumacher and Sathaye, 1999).

Despite all these problems facing the Indian cement sector, there have been on-going changes in this sector. These changes include modernisation and expansion programmes that are currently underway in the Indian cement industry. Through the adoption of modern technology and equipment, input substitution, output modification, institutional changes and other process specific measures, India is trying to increase output at the same time as to improve efficiency, conserve energy and control pollution (Bhandari, 2006).

Process conversion has proven to be an effective way of conserving energy in this sector's history. Over the last 30 years, the more energy- intensive wet process of cement production has been virtually phased out. Other process specific measures that have increasingly found application in the Indian cement industry include multi-stage suspension pre- heaters, pre-calciners, cyclone designs of kilns and improved burners and most of these measures are related to the energy-intensive pyro-processing step in cement production (Cohen *et al*., 1998). The Indian cement industry has also ventured into the installation of captive power generating units that are based on co-generation and /or waste heat recovery and lead to substantial energy and cost saving. Co-generation of power using waste heat is a viable option for energy conservation worldwide. However, unlike in other countries, Indian cement manufactures have not exploited co-generation much (Schumacher and Sathaye, 1999).

India's growth in energy-related carbon dioxide emissions was reduced over the last decade through economic restructuring, enforcement of existing clean air laws by the nation's highest court, and renewable energy programs (Chandler *et al.*, 2002). Generally, in it's efforts to reduce greenhouse gas emissions, the Indian government is already participating in global efforts through a number of programmes. For example, India's National Auto-fuel Policy mandates cleaner fuels for vehicles (Bhandari, 2006). The Energy Conservation Act, passed in 2001, outlines initiatives to improve energy efficiency. Similarly, the Electricity Act of 2003 encourages the use of renewable energy. Recent trends in importing natural gas and encouraging the adoption of clean coal technologies show India is making real efforts (Bhandari, 2006).

2.5.1 *Sustainable Development Barriers in the Indian Cement Sector*

There are barriers to improvements of the Indian cement industry and these include the fact that in a capital scarce country like India, capital-intensive industries like the cement industry generally focus on reducing capital costs rather than being concerned about energy inputs that hold low shares in overall input costs and environmental problems (Schumacher and Sathaye, 1999). Lack of finance and incentives and investment programs have also impeded the implementation of measures targeted at improving the Indian cement industry. Process conversions might also not be possible due to constraints in plant layout or other technical reasons (Schumacher and Sathaye, 1999).

The study of the Indian and Chinese cement industries brings attention to the different methods used in cement production and the challenges (different or common) faced by the cement producing industry in each of these developing countries. The challenges faced by each country's cement producing sector are important as they have implications for sustainable development and climate change mitigation, especially given the fact that there is growing literature on the two-way nature of the relationship between climate change and sustainable development (Cohen *et al.*, 1998). Other developing countries' cement sectors, including South Africa, can also learn and adopt policies that have been successfully used by India and China for the reduction of greenhouse gas emissions and achievement of sustainable development.

2.5.2 Conclusions on developing countries and greenhouse gas emissions reduction

Generally, four broad conclusions concerning the developing countries (China, India and South Africa) are:

- These developing countries are undertaking actions to reduce their greenhouse gas emissions.
- Most of the greenhouse gas reduction efforts are not driven by climate policy but by the quest for development and poverty alleviation, local environmental management, and energy security (Chandler *et al.*, 2002).
- Developing nations offer large opportunities for further emissions mitigation, but competing demands for resources may hamper progress (Cohen *et al.*, 1998).
- Developing countries can use policies to leverage human capacity, investment, and technology to capture large-scale mitigation opportunities, while simultaneously augmenting their development goals (Sathaye *et al.*, 2002).

Other common barriers to climate mitigation include the lack of good data, which has also been cited as one of the barriers to efforts of identifying and realising mitigation potential. The lack of personnel to analyse energy and emission futures, identify mitigation opportunities, execute economic reforms, and cultivate investment opportunities- represents another significant barrier (Ruth, *et al.*, 2002). In most countries, public control of large portions of energy resources works against emissions mitigation by preventing the emergence of more efficient private actors. Finally, a range of concerns- from the absence of transparency and rule of law to the extra risk associated with nontraditional energy investment- impedes investment and technology transfer that would contribute to emission mitigation (Chandler *et al.*, 2002).

The experiences of South Africa, India and China have implications for future policy at multiple levels- for national efforts within developing countries, for the evolving international climate framework, and for other bilateral or multilateral efforts aimed at encouraging emission reduction in developing countries. One broad lesson, given the diversity of drivers and co-benefits, is the need at both the national and international levels for flexible policy approaches promoting and crediting a broad range of emission reduction and sequestration activities (Sathaye *et al.*, 2002). Other policy priorities include: continuing to promote market reforms, such as more realistic energy pricing, that can accelerate economic growth while reducing emissions growth; working within developing countries and through bilateral and multilateral efforts to improve investment environments and create stronger incentives for climate-friendly investments; targeting capacity-building assistance to most effectively capitalize on natural synergies between climate mitigation and other development priorities; and supporting policies that address both climate and local environmental needs, such as improving air quality and reducing deforestation (Ruth, *et al.*, 2002).

However, in trying to mitigate climate change, it is important to note that an intensification of efforts to reduce emissions in both developed and developing countries will be required in the near future to avert the worst consequences of global climate change. These efforts must include stronger national policies as well as an evolving international regime that ensures adequate efforts by all major emitting countries. By highlighting the current and potential contribution of developing countries to emission mitigation, prospects for stronger international cooperation toward the shared goal of climate protection are enhanced (Sathaye, 2002).

2.6 Cement Industry and Climate Change Mitigation

Greenhouse gas emissions reduction, especially of carbon dioxide emissions, is a serious challenge to the cement industry. However, the industry has come up with various strategies for the reduction of greenhouse gas emissions. Some of the possible strategies to achieve reductions offer business opportunities.

2.6.1 *Reducing of Process Emissions in Cement Production*

Some of the conventional carbon dioxide reduction approaches include reducing process emissions and this relies upon reducing the amount of clinker in cement. Substituting pozzolanic materials, such as blast furnace slug, fly-ash and natural pozzolans substantially reduces process related carbon dioxide emissions and this represents one of the best, technically proven approaches for reducing process emissions (Anderson, 2007). A pozzolanic material is defined as a siliceous or siliceous and aluminous material which, in itself, possesses little or no cementitious value but which will, in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties (Gibbons, 1997). Fly-ash from coal combustion is available in larger quantities compared to the other materials. However, there are challenges associated with the use of blended cements and these include securing a reliable and sufficient supply of substitute materials and finding substitute materials at convenient locations, (Humpreys and Mahasenan, 2002).

Enhanced grinding methods have also been encouraged as a method of reducing carbon dioxide emissions. This is because enhanced grinding methods increase the reactive surface area of the clinker, resulting in decreased need for limestone-based clinker, which generates carbon dioxide. The Energetically Modified Cement (EMC) Technology is one specific grinding method which has been found to enhance the performance of cement containing 50% fly-ash or silica sand and 50% ordinary Portland Cement (Anderson, 2007).

According to the World Business Council for Sustainable Development reports, widespread use of this technology could lead to increases in the use of non-limestone based cement and hence reduce the carbon dioxide emissions per unit of cement consumed (WBCSD, 2002).

2.6.2 *Retrofitting of existing plants*

Retrofitting existing plants or phasing out energy-intensive manufacturing plants has been identified as one strategy for increasing the efficiency at which they operate. Retrofitting refers to the addition of new technology or features to older systems. The challenge is to accomplish the retrofits or closures cost effectively and at an appropriate time (http://www.iigcc.org, 2007).

2.6.3 *Switching of Fuels*

Switching from high-carbon to low-carbon content fuels is an additional approach for reducing on-site fuel-related emissions. For example, cement plants can switch from using coal (high carbon content fuel) as a source of fuel to natural gas (low carbon content fuel). It is estimated that fuel switching could result in global average emission reductions of 3% with some regions having the technical potential to cut emissions as much as 7% (Humpreys and Mahasenan, 2002). Other approaches that could lead to the reduction of fuel-related carbon dioxide emissions include the use of “alternative fuels”. The term “alternative fuels” is widely used to encompass other fuels. Examples of alternative fuels include waste tyres, biomass, used solvents, sewage sludge, municipal solid waste and petroleum coke (WBCSD, 2002).

2.6.4 *Reducing Electricity Generation and Transport Emissions*

Electricity generation and transport emissions globally contribute to greenhouse gas emissions, especially carbon dioxide and these also account for less than 10% of the total cement-related emissions. Transport emissions can be reduced through the use of biomass based-fuel such as bio-diesel for transport. Emissions associated with electricity generation can be reduced by switching to renewable or nuclear electricity sources which generate low or no carbon dioxide (WBCSD, 2002).

It is also important to note that a combination of these conventional carbon greenhouse gas reduction actions will be required to sufficiently reduce greenhouse gas emissions (Humpreys and Mahasenan, 2002) (Figure 2-10).

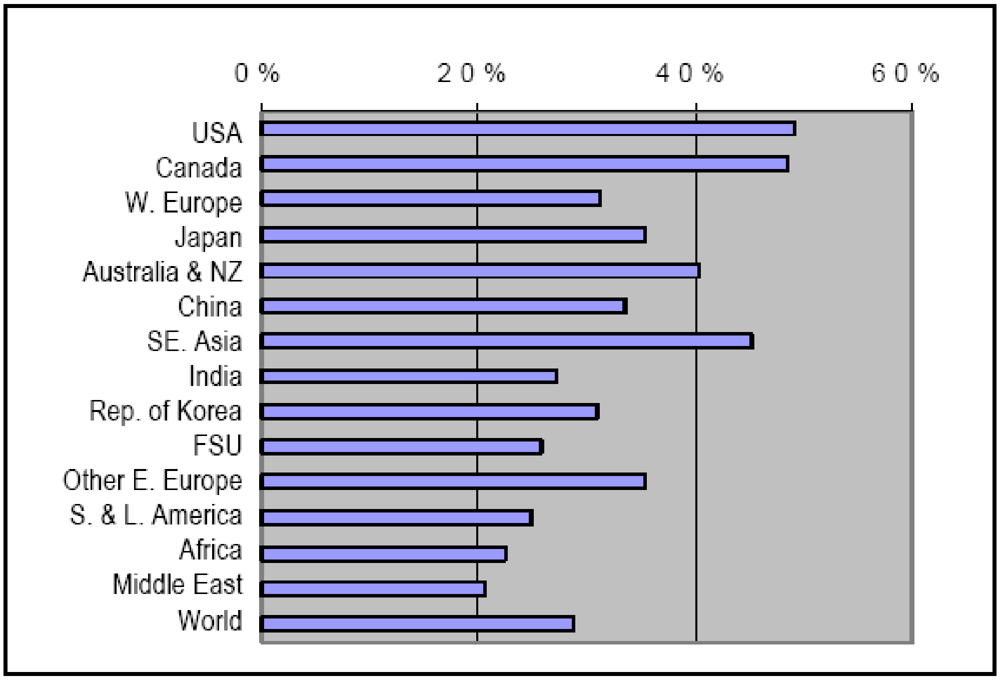


Figure 2-10: Carbon dioxide emissions reduction potential using a combination of conventional reduction approaches (Humphreys and Mahasenan, 2002, pg 25).

2.7 Advanced Greenhouse Gas Reduction Strategies

In addition to the conventional greenhouse gas reduction strategies, use can be made by the cement industry of advanced greenhouse gas reduction strategies. Among these advanced strategies is the use of hybrid energy-cement plants.

2.7.1 *Hybrid Energy-cement Plants*

Advanced reduction strategies for greenhouse gas emissions include the hybrid energy cement plants. These plants are integrated facilities that produce both electricity and cement and then through the integration process, efficiencies are achieved that result in substantially less carbon dioxide and other pollutants being emitted in the integrated facility than would otherwise be produced in two standalone facilities. For example, in China and the United States technology called the Global New Energy Process is currently in use and it involves a proprietary admixture (AMC) that is mixed with the coal-fired plant’s fuel supply (WBCSD, 2002) (Figure 2-11). The coal and the admixture burn and react together inside the power plants’s existing boilers. All the fly ash and bottom ash is converted into cement clinker. A life-cycle assessment performed by First Environment suggests that the clinker will be produced without adding to the carbon dioxide output of the power plant and therefore the process yields little or no carbon dioxide clinker (Humpreys and Mahasenan, 2002).

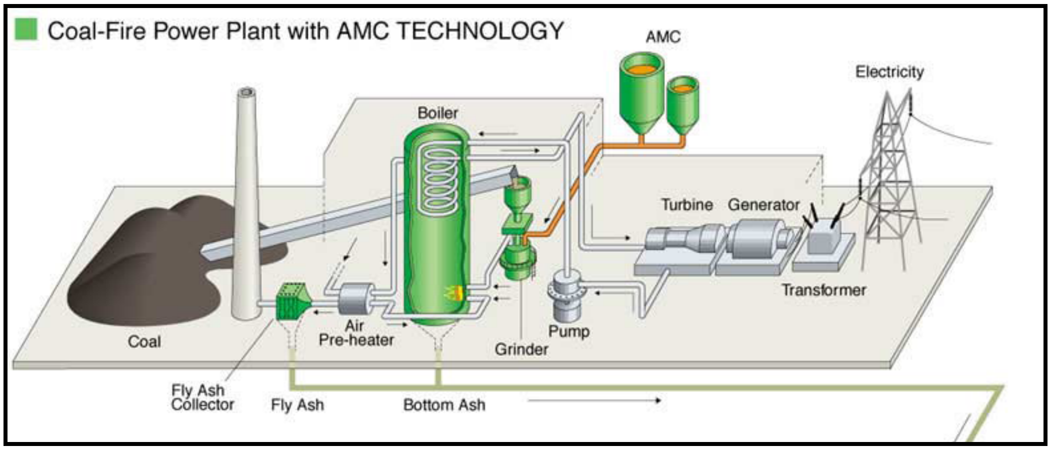


Figure 2-11: Global New Energy Cement/ Power Plant (as cited in the WBCSD Report, 2002, pg 27).

2.8 Status of the Cement Industry on the Issue of Climate Change Mitigation

It is important to note that the challenge for greenhouse gas emissions reduction and ultimately climate change mitigation is a great challenge for the cement industry. The industry as a whole has not significantly reduced its emissions over the decade. There are numerous opportunities for this industry to reduce its emissions. The climate change challenge could lead to new manufacturing processes, products and new business lines and creative and proactive cement companies have the potential to emerge as leaders in greenhouse gas mitigation and remain profitable at the same time (Table 2-3).

Table 2-3: Summary of the Status of the Cement Industry on Climate Change Mitigation (as cited in the WBCSD Report, 2002, pg vi).

Strengths: ▪ Some companies have reduced their average CO_2 released per tonne of cement. ▪ 10 major cement companies have developed a standardised CO_2 inventory.	**Opportunities** ▪ Emission reduction credits ▪ Energy efficiency improvement ▪ Use of alternative low carbon fuels ▪ Use of alternative raw materials
Weaknesses: ▪ Heavy dependence on fossil fuels ▪ Reliance on limestone based cement ▪ Limited attention to the significant CO_2 reductions required ▪ Lack of a clear long-term agenda for climate change mitigation	**Threats** ▪ Possibility of imposed technological controls. ▪ Large financial burdens ▪ Loss of market share to competing materials that are less greenhouse gas intensive. ▪ Early retirement of plants and equipment.

A study conducted by the World Business Council for Sustainable Development (WBCSD) for the cement industry has also shown that certain actions would facilitate the sustainability of the cement industry and climate change mitigation (Table 2-4). Some of these actions include the establishment of mechanisms to document corporate-level CO_2 emission levels and reductions and the setting of greenhouse gas reduction targets for various timeframes and encouraging development of innovations that would dramatically decrease industry –wide emission levels.

Table 2-4 : Potential actions for climate change mitigation (as cited in the WBCSD Report, 2002, pg vii).

Potential Actions	Responsibility	Timeframe
1. Establishment of carbon dioxide emissions baseline and mechanisms which enable cost effective emission reduction.	Cement companies working collaboratively. Independent Review by Government and non-governmental organizations (NGOs)	Short -term
2. Setting of challenging emission reduction targets and stating them publicly. Industry- wide and company specific targets may be set.	Cement companies	Short –term and medium term
3. Co-operation with stakeholders to develop government policies, product standards, and market practices that remove barriers to the sale of innovative but safe cement products with lower embodied CO_2 emissions and the use of appropriate waste fuels that reduce lifecycle of CO_2 emissions.	Cement companies Cement Associations Government Regulatory Agencies Non-Governmental Organisations	Short –term and medium term
4. Exploration of prospects of reducing CO_2 emission reduction costs through emissions trading or offset schemes.	Cement companies Government Regulatory Agencies and Academia. Other industries	Short -term

The identification of emission sources and the estimation of greenhouse gas emissions by cement companies have been identified as major steps towards greenhouse gas emissions reduction and ultimately, climate change mitigation. Environment Canada (2004) published a guidance manual for the accurate estimation of greenhouse gas emissions from fuel combustion and process related sources during cement production. This can be useful to cement companies as it will assist them to accurately measure their greenhouse gas emissions and ultimately, to accurately determine the effectiveness of their greenhouse gas emission reduction strategies (Humpreys and Mahasenan, 2002). A facility involved in cement production may have various stationary and mobile fuel combustion processes, for example the combustion of kiln fuels. Mobile fuel combustion sources that may occur on-site include various transportation related activities that are integral to the production process. This may include the on-site transport of raw materials or intermediate products from one process to another at the facility, using different modes of transport. Process related emissions during cement production occur primarily from the production of clinker (Environment Canada, 2004).

The Environment Canada Guidance Manual for Estimating Greenhouse Gas Emissions also states the importance of the identification of emission sources as a first step towards the accurate estimation of greenhouse gases. It is also useful to categorise the emissions sources during the identification of the greenhouse sources as this would assist in the clarification of the estimation process and ensuring that no greenhouse gas emission-generating activities are omitted (The steps that can be utilized for the identification of emission sources are shown below).

Identification of Emission Sources (Environment Canada, 2004)

a. Determine the potential sources of GHG emissions from stationary and mobile fuel combustion and specific production processes or facility systems by analyzing your facility's operations in detail, and identify the specific area(s), process(es) and/or equipment used where GHG emissions are occurring (Figure 2-12 and 2-13).
b. Construct an engineering flow diagram(s) for your facility, which details the various processes of interest that are occurring within the facility. Limit the diagram(s) to those processes involving fuel combustion and specific production processes or systems that result in GHG emissions covered here.
c. Document typical engineering specifications for the identified process(es), such as reaction temperatures, flow rates, etc. Include these in the flow diagram.
d. Identify the fuel and combustion technology types used in each stationary and mobile combustion source.
e. Identify the relevant stoichiometric chemical reactions related to the sources of GHG emissions at the facility.
f. List any side reactions that may decrease or reduce emissions and catalytic processes or other methods (e.g. recycling of by-product CO_2, pollution control devices) that may be used to control emissions generated by the fuel combustion or process activities.
g. Document each emission source under the chosen categories.

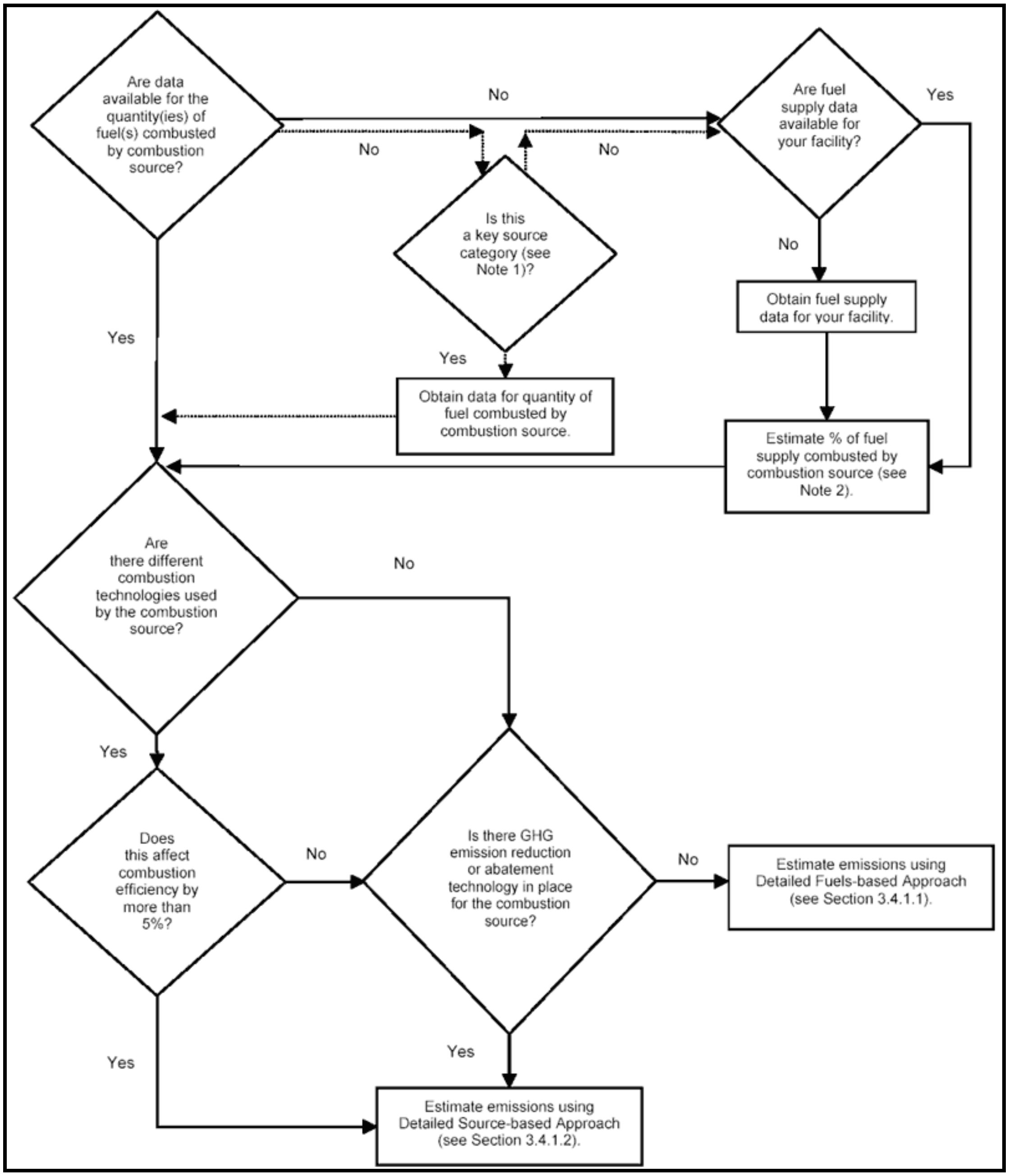


Figure 2-12: Decision Tree for Selecting the Method for Estimating CO_2 emissions from Stationary Fuel Combustion (Environment Canada, 2004, pg 14).

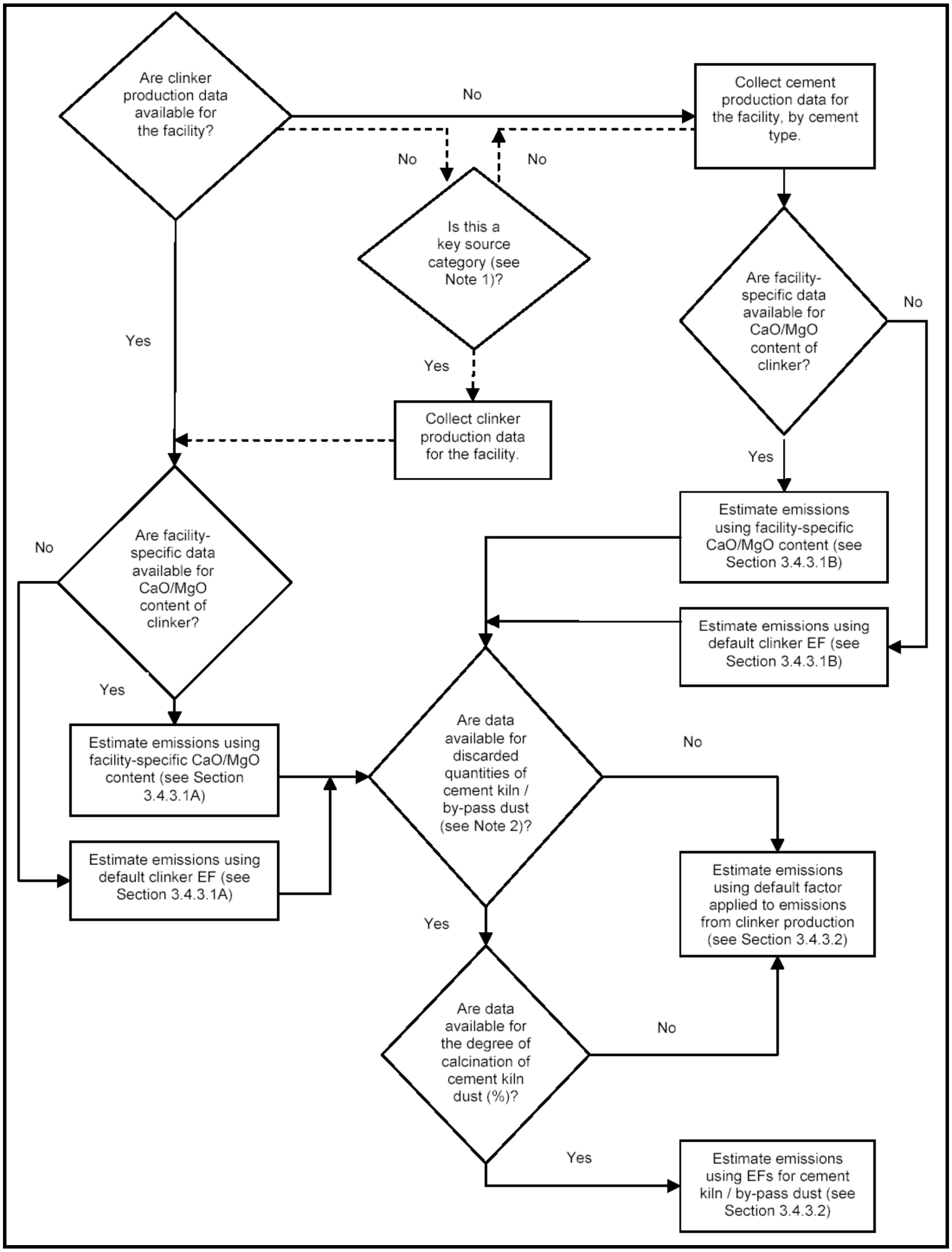


Figure 2-13: Decision Tree for Selecting the Method for Estimating CO_2 emissions from Clinker Production (Environment Canada, 2004, pg 16).

2.9 Other Emissions from Cement Production

In order for sustainable development to be achieved in the cement industry, all sources of emissions like fugitive dust have to be taken into consideration. Fugitive dust emissions from cement production have always been of major concern to the cement producers and regulators (Chandler *et al*., 2002). There are three main point sources of dust emissions from cement plants and these are kiln systems, clinker coolers and cement mills. Fugitive dust releases from handling and storage of materials, and the crushing and grinding of raw materials and fuel (coal) can be significant (IPPC, 2001). Environment Australia (1998) published a dust control checklist that companies can use during their dust control campaigns efforts (Table A, Appendix A).

It is also recommended that cement companies continue to carry out dispersion modelling to determine the potential impacts their activities or projects (including greenhouse gas emission reduction projects) will have on the environment and the surrounding communities. A model is a simplified picture of reality. Models are widely used to make predictions and /or to solve problems, and are often used to identify the best solutions for the management of specific environmental problems (Figure 2-14) (US-EPA), 2001).

Dispersion models according to the US-EPA can also be used for:

- assessing compliance of emissions with air quality guidelines, criteria and standards.
- planning new facilities
- determining appropriate stack heights
- managing existing emissions
- designing ambient air monitoring networks
- identifying the main contributors to existing air pollution problems
- evaluating policy and mitigation strategies (for example the effect of emission standards)
- forecasting pollution episodes
- assessing the risks of and planning for the management of rare events such as accidental hazardous substance releases
- estimating the influence of geophysical factors on dispersion (for example terrain elevation, presence of water bodies and landuse).

- saving cost and time over monitoring as modelling costs are normally a fraction of monitoring costs and a simulation of annual or multi-year periods may only take a few weeks to assess.

However, it is important to note that even the most sophisticated atmospheric dispersion model cannot predict the precise location, magnitude and timing of ground level concentrations with 100% accuracy. However, according to the National Institute of Water and Atmospheric Research (New Zealand), most of the models used nowadays (US-EPA models) have been through a thorough model evaluation process and the modelling results are reasonably accurate, provided an appropriate model and input data are used. The most significant factors that determine the quality and accuracy of the results are:

- the suitability of the model for the task
- the availability of accurate source information
- the availability of accurate meteorological data

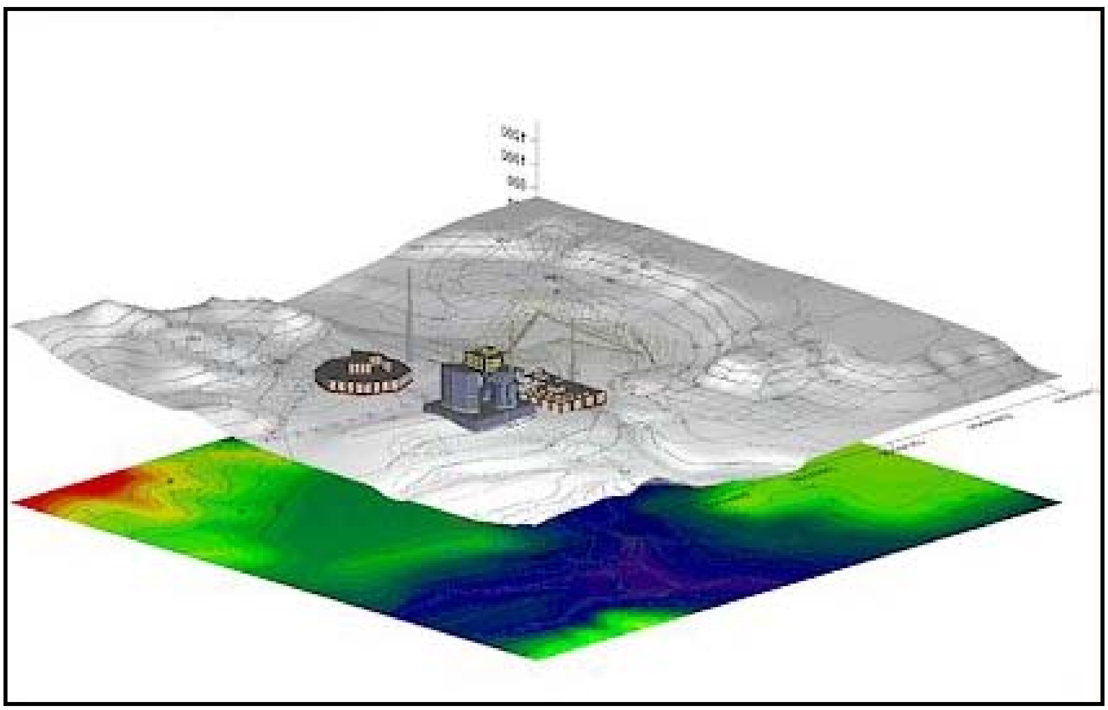


Figure 2-14: Example to illustrate the importance of dispersion modelling in assessing compliance of emissions with air quality guidelines for pollutants (Lakes Environmental (http://www.weblakes.com, 2007).

2.10 Summary

Cement production contributes to greenhouse gas emissions and climate change. This poses challenges to the industry as a whole, especially in developing countries like South Africa, India and China, which are currently experiencing an increase in cement production due to economic growth. Globally, the cement industry has made efforts towards greenhouse gas emissions reduction and ultimately, climate change mitigation through various methods which include technological changes. For climate change mitigation to be a success, combined efforts are required from government, various organisations and industries (including cement companies). The identification of emission sources and the estimation of greenhouse gas emissions by cement companies have also been identified as major steps towards greenhouse gas emissions reduction and ultimately, climate change mitigation. In order for sustainable development to be achieved by the cement industry, cement companies have also been encouraged to take a holistic approach towards emissions reduction by taking all sources of emissions, including fugitive dust, into consideration. Fugitive dust emissions from cement production have always been of major concern to the cement producers and regulators.

Many developing countries have undertaken efforts that have led to the significant reduction of greenhouse gas emissions although in most cases climate mitigation is not the goal, but rather an extension of efforts driven by economic, security and local environmental concerns.
The fact that many developing countries have undertaken efforts to reduce their greenhouse gas emissions, without any obligations requiring them to do so under the Kyoto Protocol, is important given the fact that greenhouse gas emissions from developing countries will likely surpass those from developed countries, highlighting the need for developing country efforts to reduce the risk of climate change. Developing countries also face barriers to climate change mitigation and sustainable development and these include lack of skilled personnel to analyse energy and emission futures, and identification of mitigation opportunities. Despite the fact that many governments play an important role in climate change mitigation, industry also plays a key role. The next chapter provides background detail on Pretoria Portland Cement Company Limited, a major cement producing company in South Africa and the focus of this study. The aim, study objectives and methodology are also outlined in the chapter.

3. BACKGROUND TO THE STUDY AND METHODS

3.1 Introduction

This chapter focuses on Pretoria Portland Cement Company Limited (PPC), a large cement-producing company which is the focus of this research study. Background information on the company's operations is provided. The chapter also describes the aims, rationale and objectives of the study.

3.1.1 *Why Pretoria Portland Cement Company Limited (PPC) was chosen for the study*

As already stated in the previous chapters, cement production leads to the production of greenhouse gases, which in turn contribute to climate change. In most developing countries, cement production is booming. In South Africa, this is due to the fact that cement producers are investing heavily in extra capacity to meet a burgeoning demand- and that means the country is creating new infrastructure (houses, factories, shopping centres, airports and stadiums in preparation for the 2010 World Cup etc). Experts have predicted that the demand for cement is likely to continue rising given the government's intention to raise its spending levels on infrastructure and job creation. Cement companies in the country have acknowledged that government's intention to substantially increase infrastructural investment has positive implications for them (Mining and Manufacturing Systems, 2007).

Although it cannot be denied that the economic boom in South Africa is good for the country and the cement industry, it cannot be ignored that this increase in cement production has also led to an increase in greenhouse gas emissions and concerns about the cement industry's contribution to climate change. This study therefore focuses on whether PPC has greenhouse gas emission reduction strategies and what the implications of these are for climate change mitigation.

PPC was chosen for the study after background research had been carried out on all the major cement producers in the country. These major cement producers included PPC, Holcim, La Farge and Natal Portland Cement. The research indicated that PPC Cement is the only South African owned producer and is the leading supplier of cement in Southern Africa and is the market leader in South Africa, with a product range that encompasses all applications (Mining and Manufacturing Systems, 2007).

3.2 Pretoria Portland Cement Company (PPC)

PPC is a Group whose principal activity is manufacturing cementitious products, lime, and limestone. PPC Cement is the largest cement supplier with at least 35% of the market share in South Africa and the Group operates through nine manufacturing facilities in South Africa, Zimbabwe and Botswana having a capacity to produce 6.9 million tons of cementitious products per annum (Mining and Manufacturing Systems, 2007). PPC currently has seven operating cement manufacturing cement plants in South Africa. These plants are PPC Dwaalboom, PPC Slurry, PPC Hercules, PPC Jupiter, PPC Port Elizabeth, PPC Riebeeck, PPC Dehoek (PPC, 2006) (Figure 3-1).

The Group's distribution network supplies branded cement to the building and construction industry, concrete product manufacturers and retail outlets such as builders merchants, hardware stores and DIY centres. Product brands are Surebuild in South Africa and Unicem in Zimbabwe. In addition to serving the southern African domestic markets, cement is exported to other African countries and the Indian Ocean Islands. Related products sold include aggregate from the quarries at Mooiplass and Laezonia and in Botswana. The Group also supplies metallurgical grade lime, burnt dolomite, limestone and related products. It has operational plants located in the Northern Cape Province of South Africa (PPC, 2006).

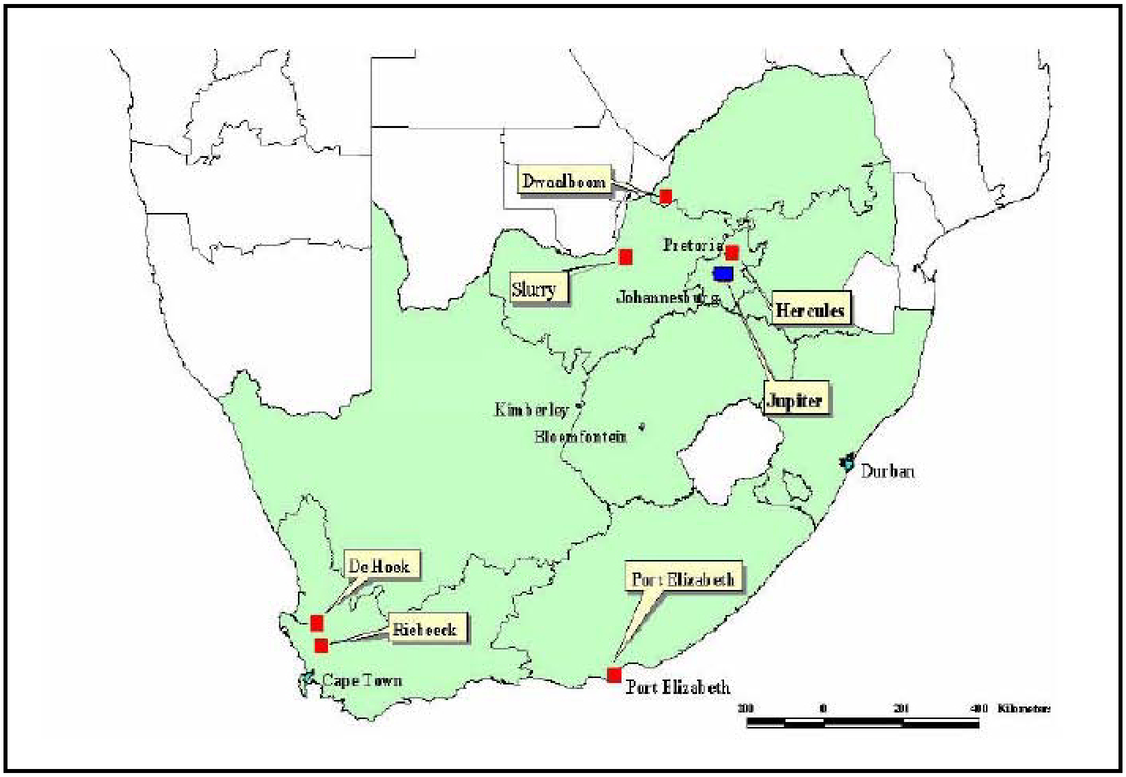


Figure 3-1: Location of PPC Cement Plants in South Africa (as cited in the PPC Secondary Materials Background Information Document, 2006, pg 7).

The PPC Hercules plant (Figure 3-2) supplies Surebuild Cement, Ordinary Portland Cement (OPC) and Rapid Hardening Cement (RHC) and the limestone for this plant is mined at the Beestekraal Quarry. The PPC De Hoek plant (Figure 3-3) is located Western Cape Province near Piketberg and currently supplies Surebuild Cement and Rapid Hardening Cement. The Riebeeck manufacturing plant (Figure 3-4) is located in the Western Cape Province near Riebeeck West. It began operations in 1960 and produces OPC and RHC cement. PPC Dwaalboom (Figure 3-5) located in the Limpopo Province was commissioned in 1985 and was mothballed due to a market downturn. The cement factory was re-commissioned in 1996 and production commenced in the same year. This plant produces Surebuild Cement.and OPC. The raw materials are mined at the Dwaalboom quarry adjacent to the manufacturing plant (PPC, 2006).

Figure 3-2: PPC Hercules plant (as cited in the PPC Secondary Materials Background Information Document, 2006, pg 8).

Figure 3-3: PPC De Hoek Plant (as cited in PPC Secondary Materials Background Information Document, 2006, pg 9).

Figure 3-4: PPC Riebeeck Plant (as cited in the PPC Secondary Materials Background Information Document, 2006, pg 9).

Figure 3-5: PPC Dwaalboom Plant (as cited in the PPC Secondary Materials Background Information Document, 2006, pg 10).

3.3 Rationale of the Study

It is evident from the theoretical background that cement production leads to the production of greenhouse gases, which in turn exacerbate the problem of climate change. Climate change is indeed a serious global environmental problem which needs to be addressed as a matter of urgency. One method of addressing this problem has been through the reduction of greenhouse gas emissions. Greenhouse gas emission reduction, as discussed in Chapter 1, requires international, national and local efforts for the effective mitigation of climate change. The identification of various greenhouse gas emission reduction strategies employed by various sectors of society will enhance knowledge on the extent of efforts carried out to reduce these emissions and what implications these efforts have or will have on the mitigation of climate change. Greenhouse gas reduction strategies that have been proven to be effective in one region, company and communities can also be utilised in other parts of the world for the mitigation of climate change. The use of these strategies in various parts of the world, however, should take into consideration local conditions, economic status, technological status and technical knowledge among other factors.

Cement production and consumption is closely related to construction activity and therefore to the general economic activity. South Africa is a developing country with a fast growing economy and the country is experiencing an increase in construction activity in response to this economic growth. This in turn means that the cement producing sector has to respond to the growing demand for cement. As already mentioned, carbon dioxide is the primary greenhouse gas emitted by the cement industry in significant amounts and this in turn further intensifies the problem of global climate change. In the face of the climate change challenge, creative and proactive cement companies with greenhouse gas reduction strategies, have the potential to emerge as leaders in greenhouse gas management across all industries and remain profitable. The study therefore focuses on Pretoria Portland Cement (PPC), a large cement-producing company in South Africa.

3.4 Aim of the study

With this as background, the aim of the study is to find out if PPC has greenhouse gas emission reduction strategies and what implications these strategies have for climate change mitigation. Further sub-themes include examining the challenges and opportunities presented to the company during its greenhouse gas emission reduction efforts.

3.4.1 *Study objectives*

- To investigate and examine the company's greenhouse gas reduction strategies.
- To identify the constraints and challenges faced by the company in its greenhouse gas emission reduction efforts.
- To determine if there are any opportunities to be gained by the company due to its greenhouse gas emission reduction efforts.
- To establish how the company's greenhouse gas reduction strategies are aligned to those of the Department of Environmental Affairs and Tourism (DEAT) and Department of Minerals and Energy (DME).

The research also serves as an indicator of some of the emerging factors internal to the company and will also determine whether the company is reactive or proactive in its greenhouse gas reduction policies with respect to the following indicators:

a) To what degree is the company accepting that greenhouse gas emissions need to be reduced in order to mitigate the human- induced global climate problem.

b) What are some of the long-term consequences, both negative and positive, of the company's choice of reducing greenhouse gas emissions for its business operations and climate change.

3.4.2 *Selection of Interviewees from PPC and DEAT and Data Collection*

Research is usually conducted for the purpose of systematically collecting and analysing data from which general conclusions may be drawn that may aid in solving problems in the future. The chief role of human participants in research is to serve as sources of needed data. It is, however, important that the appropriate research participants are included in the study in order to get reliable responses, especially for the purposes of scientific research (Resnik, 2007).

Background research was therefore carried out to identify the key people at PPC and the DEAT who are relevant to the research and are experts in the respective fields relevant to the study.

3.4.3 *Selection of PPC Interviewees*

Environmental Managers, General Managers and the Group Sustainability Manager from PPC were selected to participate in the study as they have the knowledge and the expertise relevant to the research. They also control the very processes of industrial production, environmental management and technological aspects of the company and make key decisions on environmental investments, on production techniques and waste disposal (Lozt, 1999). They also know their workplaces better and are the most likely source of innovation, if they are sufficiently interested in the environmental impacts of the company's activities (Burgess, 2001).

3.4.4 *Selection of DEAT Interviewees*

The Department of Environmental Affairs and Tourism has various branches which include Environmental Quality and Protection, Marine and Coastal Management, Tourism, Biodiversity and Conservation etc. It is important that relevant participants with knowledge on the fields covered in the study are selected (Resnik, 2007). Five interviewees from the Air Quality Management and Climate Change branch of the DEAT were therefore selected, taking into consideration their knowledge on climate change.

3.4.5 *Ethics in Research*

Ethics are norms for conduct that distinguish between acceptable and unacceptable behaviour (Resnik, 2007). There are several reasons why it is important to adhere to ethical norms in research:

- Some norms promote the aims of research, such as knowledge, truth and avoidance of error (http://socialresearchmethods.net, 2007).
- Since research often involves a great deal of co-operation and coordination among many different people in different disciplines and institutions, many of these ethical standards promote the values that are essential to collaborative work, such as trust accountability, mutual respect and fairness (Resnik, 2007).

- Many of the ethical norms help to ensure that researchers can be held accountable to the public.
- Ethical norms in research also help to build public support for research (Resnik, 2007).
- Many of the norms of research promote a variety of other important moral and social values such as social responsibility, human rights, compliance with the law etc (http://socialresearchmethods.net, 2007).

Ethics play a fundamental role, especially in research involving the participation of human beings. This is because research involving the participation of human beings implicates a variety of ethical concerns pertaining to values such as dignity, confidentiality, informed consent, participant safety and voluntary participation (Kapp, 2006).

3.4.6 *Ethics and the study*

Due to the importance of ethics in research, various steps were taken to protect the rights of the research participants. The prospective research participants were fully informed about the research, its objectives and procedures to be followed during the research through the use of a participant information sheet. Questionnaires of the study were also sent to the participants so that they could familiarise themselves with the research questions. All this was done to ensure informed consent and voluntary participation. The principle of voluntary participation requires that people not be coerced into participating in research (Kapp, 2006).

Ethical standards also require researchers not to put participants in a situation where they might be at risk of harm as a result of their participation. Harm can be defined as both physical and psychological. In order to help protect the privacy of the prospective research participants, confidentiality was guaranteed (http://socialresearchmethods.net, 2007). This was done by providing the prospective research participants with letters assuring them that identifying information will not be made available to anyone who is not directly involved in the study. Prospective research participants who agreed to take part in the study signed consent forms for participation in the study. Suitable dates and times for the research interviews were arranged with each participant. This study was approved by the University of Witwatersrand Ethics Committee for Human Subjects and the relevant protocol issued (Protocol Form in Appendix A).

3.4.7 *Survey Methods*

Various methods can be used for data collection and these include survey methods. The survey is a non-experimental, descriptive research method. Surveys can be useful when a researcher wants to collect data on phenomena that cannot be directly observed (such as opinions and views on climate change). In a survey, researchers directly question only a small proportion of the population (http://gslis.utexas.edu, 2007). In this study, the survey research method was used to collect data in connection with climate change and its mitigation from PPC, DME and DEAT interviewees.

3.4.7.1 Types of surveys

Surveys can be divided into two broad categories: the questionnaire and the interview. During surveys, data are usually collected through the use of questionnaires, although sometimes researchers directly interview subjects. Surveys can use qualitative (eg ask open- ended questions) or quantitative (eg use forced-choice questions) measures (Burgess, 2001).

3.4.7.1.1 Interviews

Interviews are a far more personal form of research than questionnaires. In the personal interview, the interviewer works directly with the respondent and the interviewer has the opportunity to probe or ask follow up questions. During this research, personal interviews were conducted and there were opportunities to ask respondents follow up questions, opinions and clarification on certain issues. Interviews are generally easier for the respondent, especially if what is sought are opinions or impressions (Burgess, 2001). One of the disadvantages of interviews is that they can be time-consuming and they are resource intensive. Interviews can also be done telephonically and this enables the researcher to gather information rapidly and like personal interviews, allow the researcher personal contact with the respondent. The disadvantages of telephonic interviews include the fact that some people do not have telephones and telephone interviews have to be relatively short or people will feel imposed upon (Kapp, 2006).

3.4.7.1.2 Questionnaires

A questionnaire is a formal, written, set of closed-ended and open-ended questions that are asked of every respondent in the study. The questions may be self-administered, or interviewer-administered (www.analytitech.com, 2007). Types of questionnaires include the structured interview questionnaire (the researcher asks questions orally from the questionnaire and writes down responses from the interviewee) and the self-administered questionnaires (the respondent completes the questionnaire) (Burgess, 2001). Questionnaires are a relatively inexpensive method of carrying out research and the same questionnaire can be sent to a wide number of people (http://socialresearchmethods.net, 2007). The disadvantages of using self-administered questionnaires include the fact that sometimes respondents might find it hard to complete the questionnaires and give up. These questionnaires must be therefore be designed for easy interpretation and understanding by the respondents (Burgess, 2001).

3.4.8 *Data collection during the study*

The methodology used in data collection included the interviewing of the research participants from PPC and the DEAT. Interviews were conducted separately and once for each of the interviewees through the use of structured questionnaires (see structured questionnaires in Appendix A). The responses and illustrations from the interviewees were noted.

3.4.9 *Problems encountered during the study*

The major problem encountered during the study was the issue of trade secrets. A trade secret is a confidential practice, method, process, design, or other information used by a company to compete with other businesses (Wikipedia, 2006). It is also referred to in some jurisdictions as confidential information. The company typically invests time and work into generating information regarding refinements of process and operation. If competitors had access to the same knowledge, the company's ability to survive or maintain its market dominance would be impaired. Where trade secrets are recognised, the creator of property regarded as a "trade secret" is *entitled* to regard such "special knowledge" as intellectual property" (Wikipedia, 2006).

It was therefore difficult to get technical information with regards to the future greenhouse gas emission reduction strategies of the company due to the fear that this information will be available to competitors who will then use it. The above mentioned factor has undoubtedly introduced limitations to the study results.

3.5 Summary

PPC is a large South African cement producing company with various operations in the country and in the Southern African region. The fact that the company has large scale operations has implications for greenhouse gas emissions and climate change. The next chapter focuses on the study results, that is PPC and government departments' greenhouse gas emission reduction strategies and how the company and the government departments work together in the mitigation of climate change.

4. PRESENTATION OF RESULTS

4.1 Introduction

Greenhouses gas emission reduction strategies have been identified as one of the methods for mitigating climate change. Some industries have already implemented these emission reduction strategies in an effort to reduce their emissions thereby indirectly mitigating climate change. It has been stated that the implementation of these strategies could have positive implications for the mitigation of climate change and could encourage other industries to take greenhouse emissions reduction seriously.

4.2 Strategies for Reducing Greenhouse Gas Emissions

4.2.1 *Minimising Coal Use*

PPC has strategies in place for the reduction of greenhouse gas emissions. Cement production involves large-scale use of coal, which leads to the production of greenhouse gases. PPC has been searching for means of minimising their use of coal by investigating the use of secondary materials in the cement manufacturing process and this use of secondary materials in the kilns is accepted internationally.

The logic behind this project is that many wastes generated in South Africa contain significant energy. This property makes it possible for the waste to be utilised as a suitable substitute for coal and in the process, the energy value of the waste is recovered. PPC intends to substitute some coal and raw materials with secondary waste materials at its six sites (PPC Dwaalboom, De Hoek, Port Elizabeth, Hercules and PPC Slurry Personal communication, PPC Environmental Personnel, 2006).

4.2.2 *Use of Waste and Secondary Materials in Kilns*

PPC proposes using waste material such as scrap tyres (Figure 4-1), rubber waste, dewatered and treated pellets, hydrocarbon waste (such as oil, oil-contaminated soil and coal fines, plastic waste and biomass which includes paper waste, saw dust, wood chips and waste from bio-fuel production). The company has also stated that prior to accepting waste streams in their kilns, they will conduct further tests which include comprehensive sampling and analysis for each waste material considered and the results of these tests will be made available to government authorities on request (Personal communication, PPC Environmental Personnel, 2006).

Figure 4-1: Scrap tyres are part of the waste material to be used in PPC's kilns (as cited in www.google.co.za, 2007).

Spent-pot liner (SPL) (Figure 4-2), is used in some PPC kilns as a secondary material. SPL is the carbon liner of the steel cell where the electrical reaction of aluminium oxide occurs to produce the aluminium product in the aluminium industry. The carbon liner absorbs chemicals over time and eventually loses its usefulness. The pot liner typically lasts five to seven years and must be removed and replaced (Haskins, 2007). The disposal of spent pot liner has been one of the biggest challenges in the aluminium manufacturing industry and has been mostly done in landfills. The problem of disposal has however, been partly solved through the use of SPL in cement kilns. This is due to the fact that SPL has a high energy value that has made it a good choice as an alternative fuel (Haskins, 2007). The use of SPL as an alternative fuel has proved to be successful in tests done at the PPC Hercules plant and authorisation has already been given by the relevant authorities for the project to go ahead.

Figure 4-2: Spent Pot Liner is used in some of PPCs kilns as a secondary material (as cited in the PPC Secondary Materials Background Information Document, 2006, pg 12).

The company states that it has begun investigating the use of secondary materials by means of trials and surveys, in line with their ISO 14001 (environment), OSHAS 18001 (safety) and ISO 9001 (quality) management systems, they have developed the Secondary Materials Policy (Table 4-1), as a guideline to minimise possible health, safety and environmental impacts which may arise from the use of secondary materials.

Table 4-1: PPC's Secondary Materials Policy (as cited in PPC Secondary Materials Background Information Document, 2006, pg 10).

Principle I
When using Secondary Materials PPC will strive to ensure occupational health and safety.
Principle II
When using Secondary Materials PPC will strive to keep our environment safe.
Principle III
When using Secondary Materials PPC will refuse the listed "banned wastes" as per the ACMP Waste Charter dated 5 November 2004.
Principle IV
When using Secondary Materials PPC will guarantee the quality of their products.
Principle V
When using Secondary Materials PPC will act as a partner offering waste management solutions to society for problematic waste streams.
Principle VI
When using Secondary Materials PPC will comply with the relevant regulations and promote best practices.
Principle VII
When using Secondary Materials PPC will communicate transparently.

The company has also stated that one of the advantages of incinerating waste in cement kilns is their thermal stability as cement kilns are large manufacturing units with high heat capacities, constant temperatures, with brief temperature drops in this equipment not possible. During upset conditions (any sudden or unavoidable failure of air pollution equipment or process equipment or unintended failure of a process to operate in a normal or usual manner (http://www.cdphe.state.co.us, 2007), the feed of secondary materials to the kiln can be discontinued and the kiln will still retain its heat for a sufficient time to destroy any residue material. Also, no waste is generated during the cement manufacturing process. The ash generated from the burning of coal and/or secondary materials is incorporated into the clinker and then into the final cement product. When wastes are incinerated in a hazardous waste incinerator, ash is one of the end products and is classified as hazardous waste and must be disposed of in an appropriate manner. Normally, this is done by transporting the ash to a hazardous waste landfill site (PPC Secondary Materials Background Information Document, 2006).

4.2.3 *Clinker Extension*

The company has also embarked on the use of extenders in the clinker to reduce emissions from the clinker production process. Extension of the clinker involves the addition of material to the clinker to produce cement of the same quality with less burning and therefore production of less carbon dioxide. It is important to note that this strategy of extending clinker and the other strategies are minor compared to the secondary materials project which has been proven to be effective in reducing greenhouse gas emissions (Personal communication, PPC Environmental Personnel, 2006).

4.2.4 *Technological Changes*

Technological changes have been identified as one of the ways of reducing greenhouse gas emissions and other general emissions from the cement industry. The future strategies of PPC include proposed technological changes at some of its plants in an effort to reduce greenhouse gas emissions. For example, the company is planning to expand its cement manufacturing capacity at the PPC Riebeck Plant, which is situated in the Western Cape. The overall kiln process proposed by PPC consists of a rotary kiln with an in-line calciner and a 6 –stage preheater, grate cooler for cooling the clinker produced in the kiln and dust control equipment for cleaning the gas vented from the kiln and raw mill, cooler and coal mill (Marsh Environmental Services, 2007).

The company has stated that the proposed design of the Riebeeck Plant was based on international best practices and according to the company’s engineers, the principal improvements of this new plant in comparison with the existing operation are thermal energy efficiency resulting in more cost effective cement production, as well as improved environmental controls. A technical review of the proposed design of the new plant was carried out by Marsh Environmental Services (Marsh Environmental Services, 2007). The key finding of this technical review was that the proposed design incorporates many features of cutting edge cement technology and that the design will lead to greatly improved energy efficiency over the current kilns at Riebeeck. The energy efficiency of the 6-stage preheater is predicted to result in decreased coal usage per tonne of clinker produced (approximately 31%

less coal is used per tonne of clinker produced than the current kilns) (Marsh Environmental Services, 2007).

One of the most important reasons for the company's recommendation of the 6-stage preheater kiln technology and bag filtration for exhaust gas cleaning is the potential improved environmental performance of the proposed design. The company also stated that this is particularly important since coal used in the Riebeeck Plant is transported for great distances from Mpumalanga to the Western Cape. This reduction in the amount of coal used means reduced operating costs, as well as a corresponding reduction in carbon dioxide emissions attributable to coal combustion (more than 4 000 tonnes CO_2 year based on a saving of 1700 tonnes of coal per year (Personal communication, PPC Environmental Personnel, 2006).

PPC believes that the new design will also lead to greatly reduced emissions to the atmosphere and the proposed calciner design with its tertiary air inlet location will achieve a significant reduction in nitrogen oxide emission levels. As cement production also leads to high levels of fugitive dust emissions, the company proposes to overcome this problem in this proposed plant by using a bag filter instead of an electrostatic precipitator (ESP) as this would result in physically-guaranteed low dust emissions and would result in the achievement of international best practice with regards to dust emissions (Marsh Environmental Services, 2007).

To further achieve international best practices and improved environmental performance and sustainable development, the company also proposes to carry out dispersion modelling for the determination of ground level particulates and community health risk assessments (in fulfilment of the social aspects of sustainable development).

One of the main challenges of this proposed project has been the fact that there is an absence of any operating plants of this design within the PPC Group at present and the fact that cement plants are built very infrequently in this country means that most of them have relatively little or no technological improvements that could be used as a basis for comparison with the new plants. For example, the last new kiln line built by PPC was completed in 1985 (Personal communication, PPC Environmental Personnel, 2006).

The company has also made technological changes and new design aspects in their current Dwaalboom expansion to improve production and environmental performance. The Dwaalboom Plant, for example, is expected to be operational in 2008. Also, as part of the company's strategy of improving its cement production and sustainable development initiative, PPC's engineers, as part of their ongoing technology research, are keeping up with international developments in cement kiln technology through site visits to plants overseas as well as communicating and liaising with leading international suppliers of technology and equipment (PPC Dwaalboom Analysts and Media Presentation, 2005).

PPC has also made several technological improvements in its other plants, with environment improvement being a huge contributor to the final decisions. For example, in the PPC Jupiter plant, funds which were used for environmental improvement were in excess of R40 million (PPC, 2006). Part of this involved improvements to the air quality mitigation equipment such as general upgrade of the kiln electrostatic precipitator and additional dust controls on the conveyors and cement mills The future plans of the plant include operation in an environmentally acceptable manner to meet cement demand and improved relationships with the interested and affected parties for sustainable development achievement (Marsh Environmental Services, 2007).

4.2.5 *Potential Risks and Opportunities Posed by Climate Change*

The results further indicate that climate change may pose some potential risks and opportunities to the company. Some of the potential risks the company stated included the fact that huge financial resources will be used in the reduction of greenhouse gas emissions and ultimately the mitigation of climate change and it is not guaranteed that all the efforts directed at greenhouse gas reduction would prove to be fruitful. Although significant CO_2 emission reductions are a serious challenge to the company, some of the possible strategies to achieve reductions may offer business opportunities. Ideally, a CO_2 management strategy would share three advantages which include a meaningful contribution to solving a critical environmental challenge, minimising corporate financial liability and creating new business opportunities.

The company believes that it has opportunities for improving its environmental performance through Clean Development Mechanisms (CDM) projects. This is because CDM offers mechanisms for developed countries to meet their greenhouse emission reduction requirements by gaining offsets from projects they fund in developing countries. Cement production is energy-intensive and is well-suited for CDM projects that are targeted towards energy efficiency and the reduction of greenhouse gas emissions. This is more the case in South Africa where cement production accounts for a majority of industrial energy consumption (Personal communication, PPC Environmental Personnel, 2006).

The company has stated that the National Environmental Management: Air Quality Act of 2004 (AQA) presents a lot of opportunities as it encourages industries to make inventories of their emissions and to develop site specific mitigation strategies with the guidance of a National Framework Document which would be established by the Minister for the protection of human health and wellbeing and the environment and must include mechanisms, systems and procedures to attain compliance with ambient air quality standards and national norms and standards for the control of emissions from point and non-point sources and norms and standards for air quality monitoring among other things. The company already carries out emissions monitoring, including stack monitoring for its various point sources as a method of keeping record of their emissions and making the necessary decisions based on monitored results to improve their greenhouse reduction strategies and environmental performance. The company however, does not carry out ambient monitoring at its various sites. The company makes use of dispersion modelling in its various EIAs for the determination of pollutant concentrations due to its operational activities and proposed projects (such as the various expansion projects) and as a tool for environmental management.

The company is also of the view that the Air Quality Act of 2004 will be useful to the cement industry in the country as it defines what controlled fuels are and how best they can be managed. A controlled fuel is defined in the Act as a substance or a mixture of substances, which, when used as a fuel in a combustion process, results in atmospheric emissions which through ambient concentrations, bioaccumulation, deposition or in any other way, present are a threat to health or the environment (Republic of South Africa, 2004).

4.2.6 *Greenhouse Gas Emission Reduction Challenges*

The company has also stated that there are challenges associated with greenhouse gas emission reduction and climate change mitigation and these include huge financial burdens due to the various upgrades and retrofitting of its plants and the possibility of government imposing technological controls for cement companies in efforts of reducing air pollution (including greenhouse gases).

Some of the challenges and constraints experienced by the company during its greenhouse gas reduction efforts include people's perceptions around the issue of burning waste in cement kilns during cement production, the potential price increases, quality of the product, and the lack of clear environmental legislation to guide the use of hazardous material and toxic emissions from the use of hazardous waste. For example, there have been issues around high risk elements such as mercury, cadmium, chlorine and lead being contained in some of the hazardous waste stream. The company, however, plans to solve this problem by specifically measuring the amounts of these high risk elements prior to accepting a waste stream (Personal communication, PPC Environmental Personnel, 2006).

PPC is of the opinion that the authorising agent (DEAT) should come up with more policies and structures that will assist in its various projects targeted towards greenhouse gas emission reduction and ultimately climate change mitigation. For example, this lack of national legislation or guidelines governing the thermal treatment of waste in cement kilns could have serious implications for the Secondary Materials Co-Processing Project in that the company will not be in a clear position to determine the effectiveness of this project in reducing greenhouse gas emissions from its operations and to ensure that the government's requirements are met. At the moment the Secondary Materials Co-Processing Project has not been approved for trial burns in order to evaluate the effectiveness of the strategies in the reduction of greenhouse gases.

4.2.7 *Liaisons with other Cement Producers and Government Departments*

As part of its greenhouse gas reduction efforts, the company liaises with other major cement producers in the country like Holcim and PPC is also part of the Association of Cementitious Materials Producers and sustainable development is one of the major driving forces of the project (Personal communication, PPC Environmental Personnel, 2006).

In an effort to promote sustainable development, the company also liaises with the government Departments (DEAT and DME) in issues pertaining to sustainable development and the environment. The DEAT states that as part of its climate change response strategies, it has previously developed greenhouse gas emissions inventories for South African industries. It is also in the process of developing a new greenhouse gas inventory which will incorporate updated information regarding emissions from industries. The new emissions inventory is made necessary by the fact that a lot of changes have occurred in industry over the past years and these include new industries whose operations lead to the emission of greenhouse gas emissions but have not been included in the previous emissions inventory and industries that have increased production through expansion activities

4.3 DEAT and Climate Change Mitigation

The DEAT's efforts of greenhouse gas emission reductions also include liasing with various industries and encouraging a self-regulatory approach towards emissions reduction. The Department has also signed a memorandum of understanding with Business Unity South Africa (BUSA) in addressing the greenhouse gas emissions issue. The department has also stated that it has intentions of improving its relationship with the business sector as part of the requirements of the National Environmental Management Act (NEMA) of 1998.

Some of the challenges faced by the DEAT during its climate change mitigation measures include the lack of financial resources for its various emissions reduction projects intended at greenhouse gas emissions reduction and climate change mitigation. The lack of technical expertise has also been cited as a major crippling factor of cooperation between government and industry. The department has also stated that some of the industries are not willing to co-operate with government in the reduction of greenhouse gas emissions and climate change mitigation as they feel that working closely with the regulatory agency would compromise their position by making them government targets if there are any changes required from industry.

The DEAT however, acknowledges the fact that as a department, it still has a lot of work to do when it comes to working with the cement industry and other various industries in relation to greenhouse gas emission reduction strategies and climate change mitigation. The department is also of the view that self-regulatory approaches to environmental management are to be encouraged to a certain extent in South Africa. This is because the country is a developing country and is currently experiencing industrial growth. It is believed that self-regulatory approaches would lead to a reduction in the use of scarce government resources and personnel that have to be utilised in ensuring that industry complies with environmental legislation. The DEAT however, states that the directive-based approach will continue to be used in the country in order to ensure that everyone has the right to an environment that is not harmful to their health and well-being as required by the Constitution of South Africa.

In an attempt to improve air quality in the country, the DEAT has also stated that it has unveiled a number of projects aimed at air quality management (which includes greenhouse emissions reduction) and environmental management in general. These projects include the APPA Review Project and the Vaal Triangle Air Quality Management Plan.

4.4 DME and Climate Change Mitigation

The Department of Minerals and Energy (DME) is the Designated National Authority (DNA) for the Clean Development Mechanism in South Africa. The DME states that its main task is to assess the potential CDM projects to determine whether they will assist South Africa in achieving greenhouse gas emissions reduction and sustainable development goals. At present, the DME is focusing on the approval process for potential CDM projects. This Department also plays a supportive role to project developers and plays an important role in promoting South Africa as an attractive location for potential CDM investors.

The Department has however, not worked extensively with the cement industry in the country in greenhouse emissions reduction programmes. Instead, it has worked closely with the energy-producing sector, especially Eskom (the national electricity producer). This is mainly because of the huge amount of coal used by this sector during energy production and this contributes immensely to carbon dioxide emissions and other greenhouse gases.

The DME also stated that there is a potential of working closely with the cement industry in its CDM projects as this industry also consumes huge amounts of electricity (generated using coal) and its activities, including the combustion of limestone, lead to greenhouse gas emissions. There is also a potential of including cement companies in CDM projects which include switching from coal to gas and clean coal technologies.

Some of the DME's CDM projects aimed at greenhouse gas reduction include the Lawley Fuel Switch Project South Africa. This project entails the conversion from coal to natural gas of the thermal fuel used in clay brick baking kilns at Lawley Brick Factory, a brick factory wholly owned by Corobrik (Pty) Ltd, South Africa.

4.5 Summary

PPC Cement has greenhouse gas emission reduction strategies, which directly or indirectly contribute to climate change mitigation. This has positive implications for climate change mitigation, especially in developing countries like South Africa where the impacts of climate change are going to be phenomenal. The company however, faces a number of challenges during its greenhouse gas emission reduction efforts and these include the fact that huge financial resources are required for various projects aimed at greenhouse gas reduction and lack of national standards or guidelines and legislation governing the thermal treatment of waste in cement kilns could have serious implications for the Secondary Materials Co-Processing Project. The government departments have stated that climate change mitigation is a serious environmental problem that will require industries and government to work together. Government has already implemented projects like the Vaal Triangle Priority Area Air Quality Management Plan for the reduction of air pollution levels (including levels of greenhouse gases in the country). Government departments, however, acknowledge that industry and government efforts towards climate change mitigation need to be intensified and that co-operation between government and industry is one of the key strategies to mitigating climate change. The next chapter entails an analysis of the study results.

5. ANALYSIS OF RESULTS

5.1 Introduction

This chapter discusses the responses to the study questionnaires obtained from both PPC and the government departments. The implications for climate change and sustainable development of the various greenhouse gas emission reduction strategies by PPC and government are also discussed.

5.2 Pretoria Portland Cement Company

The main finding of the study is that PPC has strategies for the reduction of greenhouse gas emissions from its operations. The company's realisation that the various operations it carries out lead to greenhouse gas emissions, which are the main cause of climate change, has been one of the major reasons why it has involved itself in research on greenhouse gas emission reduction techniques.

The results also indicate that the company has been proactive in reducing greenhouse gas emissions from its various operations and has gone to great lengths of improving its environmental performance. This is in line with the requirements of sustainable development, which according to NEMA, requires among other things, the consideration of all relevant factors including the fact that pollution and degradation of the environment are avoided, or where they cannot be altogether avoided, are minimised and remedied. By taking steps to reduce greenhouse gas emissions and other criteria pollutants like nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) and fugitive dust emissions from its various operational activities, the company is fulfilling the principles of NEMA. These principles in Section 2 of NEMA are the Act's core and serve among other things as a general framework within which environmental management and implementation plans must be formulated.

The fact that the company is involved in research that focuses on the substitution of coal with other materials during operations is another indication of pro-activeness and a major step towards the achievement of sustainable development. The substitution of coal with other materials in cement kilns has been studied extensively during the Secondary Materials Co-Processing Project. This attempt at greenhouse gas reduction by the company also fulfils the requirements of the NEMA and the National Climate Change Response Strategy for South Africa, whose conception was guided by the Constitution of South Africa and the principles of the National Environmental Management Act of 1998.

The utilisation of wastes in the cement industry, principally as alternative fuels and also as supplementary raw materials, is compatible with the general principles of waste management at European Union and other international levels. This is because cement kilns offer a safe alternative to conventional waste disposal in dedicated waste incinerators or landfills, resulting in overall benefits by reducing environmental burden and the need for dedicated treatment capacity. Furthermore, the use of waste in European cement kilns saves fossil fuels equivalent to 2.5 million tonnes of coal per year (Mokrzycki and Bocheczyk, 2003).

The fact that PPC considers other impacts that the company's operational activities may have on other environmental spheres such as water and soil instead of air quality only, is an indication that the company is approaching environmental management in a holistic manner. This is in line with the principles of NEMA, which state that environmental management must be integrated and should acknowledge that all elements of the environment are linked and interrelated and must take into account the effects of decisions on all aspects of the environment and all people in the environment by pursuing the selection of the best practicable environment option (RSA, 1998).

The company has also taken the 'precautionary approach' to environmental management in its Secondary Materials Co-Processing Project in that it has stated that materials whose properties and hazardous status are not known, will not be used in its various cement kilns. The 'Precautionary Principle' is an in international principle which is applicable where there is scientific uncertainty as to the potential effects on the environment of an action (Tickner *et al.*, 2001). It engages preventative rather than curative measures on the basis that harm to the environment can be irreversible (for example, the loss of a species), and therefore it is preferable to avoid harm rather than to try and remedy it later (Tickner *et al.*, 2001). NEMA principles also state that a risk averse and cautious approach is applied in environmental issues and should take into account the limits of current knowledge about the consequences of decisions and actions (NEMA Section 2, 1998). The company is therefore approaching greenhouse gas emissions reduction in consideration of both international and local legislation principles.

The results of the study also indicate that the company is also making use of ‘self-regulatory instruments’ towards greenhouse gas emissions reduction and environmental management in general. Self-regulatory instruments refer to a system of self-discipline that is adopted by the business sector in order to maintain its acceptance in the market place and to improve its environmental performance (DEAT, 2004). The fact that the company has taken a self-regulatory approach towards greenhouse gas emissions reduction and environmental management could be an indication that the company appreciates the implications of climate change mitigation for the achievement of sustainable development.

The advantages of a self-regulatory approach towards environmental management compared to directive-based regulation include the fact that self-regulatory instruments overcome some of the problems of the command and control approach in which government enacts and enforces environmental legislation through its various departments like the DEAT. Some of the problems that have been eased and or overcome by self-regulatory approaches include the lack of technical expertise in government since industries make use of their own entrepreneurial dynamism and informational advantages. They also promote the active involvement of the business community in the policy-making process, thereby facilitating the more effective integration of national economic and environmental activities which in turn promotes the achievement of sustainable development (Hanks, 1998).

Instead of adopting a ‘command and control approach, self-regulatory instruments make use of industry’s knowledge and resources, thus reducing the expense of governments collecting information and developing this into regulations and monitoring the effects, often without the technical expertise. Being less dependent on the scarce government resources (financial resources and technical skills), such approaches are particularly useful in the context of developing countries where there are numerous pressing social concerns and significant government resource constraints. The fact that the company is already engaging in greenhouse gas reduction strategies without much government regulation and intervention is also an indication of proactiveness, which will be useful in the near future given the fact that the Air Quality Management Act of 2004 Act requires companies to have greenhouse gas emissions inventories compared to the Atmospheric Pollution Prevention Act which does not have this requirement.

Although self-regulatory instruments have their advantages, there are some commentators that have dismissed the environmentalist efforts of business and industry as predominantly ‘greenwash’ and accuse industry of failing to address issues that are central to achieving sustainable development. Comments have also been drawn to the fact that industry plays a paradoxical role in the debate on how to achieve sustainable development. This is because industry is one of the major productive and wealth- creating sectors of society and is also a major polluter and resource consumer, both directly through its production processes and indirectly through the products it sells. The challenge is therefore for industry to meet consumer demands in ways that do not exarcebate environmental degradation (Lozt, 1998).

Although it is widely recognised that directive-based regulation has resulted in some significant steps towards meeting public health (as required by the Constitution of South Africa) and environmental objectives and not disputing the fact that this type of regulatory instrument should remain as an essential part of most environmental policy options, there are however a number of important limitations with directive-based regulation, especially in developing countries like South Africa. One of the main criticisms of this approach towards environmental management is the fact that regulations are inherently inflexible, with responses often requiring greater costs for smaller returns, especially in cases where the regulations mandate specific types of solutions (such as end of pipe technologies) rather than offering options of innovative alternative approaches such as cleaner production (Hanks, 1998).

The other shortfall of the command and control approaches for environmental management, especially in developing countries, relates to the expectations and demands it places on government resources in terms of setting and enforcing standards. In setting the appropriate site specific standards for each industry in South Africa, there is a need for government personnel to have sufficient knowledge, technical expertise and financial resources. Most of this expertise and financial resources however, rests almost exclusively with industry. An additional criticism of the traditional command and control approach is that it is often media-specific and thus fails to adequately address the impacts of cross-media pollution, often requiring the introduction of superfluous treatment technologies with pollutants having to be managed in each of the various environmental media (Hanks, 1998).

In its responses to the study questions, the DEAT has acknowledged the fact that the lack of technical expertise and financial resources are among the limitations towards effective regulation of industry when it comes to environmental management. These problems have also been compounded by the fact that in South Africa, the outdated Atmospheric Pollution Prevention Act of 1965 (APPA), an Act with a number of shortfalls, has been previously used to control air pollution. For example, the principle of ‘best practicable means’ as stated in APPA has been traditionally applied, with implications of general primacy of technical and economic considerations over the environment. The Act also authorised the Chief Air Pollution Control Officer, in consultation with the polluting industry (with little or no public participation), to decide the standards for air pollution. All the provisions of APPA, except the section on Registration Certificate application for scheduled processes, have however been repealed by the National Environmental Management: Air Quality Act of 2004 (AQA). In September 2005, most sections of AQA were brought into effect, although some of the most important provisions such as the issuing of emissions licences to industries have not been brought into effect (Joubert, 2005). The Air Quality Act of 2004 encourages a holistic approach to air quality and environmental management in general, in contrast to the fragmented approach that was promoted by APPA.

The fact that PPC currently monitors levels of carbon dioxide and carbon monoxide and already has a greenhouse gas emissions inventory, although this was not legally required by the old legislation (APPA), is also an indication that the company is proactive in its greenhouse gas emission reduction strategies. The establishment of an emissions inventory requires the identification and quantification of all sources of emissions and it should provide a comprehensive, accurate and current account of all pollutants released to the atmosphere as possible in order to provide a basis for assessing impacts on the receiving environment and for air quality management planning (Environment Canada, 2004).

For many businesses, compiling a comprehensive greenhouses gas emissions inventory is the first key step in developing an effective greenhouse gas management and reduction strategy. A properly developed greenhouse gas emission inventory will improve the company's understanding of its greenhouse gas emissions profile and thereby its potential greenhouse gas liability (Raganathan and Bhatia, 2003). This is also important given the fact that a company's greenhouse emissions profile is increasingly becoming a management issue in light of increasing scrutiny by re-insurers, climate-related shareholder resolutions and the emergence of environmental regulations/ policies designed to reduce greenhouse gas emissions (Raganathan and Bhatia, 2003). Some investors may also view significant greenhouse gas emissions from a company's operations as potential liabilities that need to be managed and reduced.

The company has stated that it has future plans to carry out ambient air quality monitoring. Ambient air quality monitoring can be done for several useful reasons which include compliance monitoring, that is the evaluation of monitoring results with ambient air quality guidelines and standards and tracking of progress due to pollution control measures implemented by the company.

The Air Quality Act of 2004 has a provision that requires industries to perform greenhouse gas monitoring and emission reduction. PPC already monitors greenhouse gas emissions from its operations and has emission reduction measures in place and will therefore find compliance to the Act not as difficult as it will be for companies that currently do not have greenhouse emissions inventories and mitigation measures in place. This also implies that for regulatory purposes, government will have readily available information on the company's greenhouse gas emissions and mitigation measures.

Cleaner production technologies have also been mentioned by the company as one of the strategies for reducing greenhouse gas emissions from its plants. The adoption of cleaner production approaches is also an indication that the company is following a preventative approach aimed at increasing resource efficiency and reducing the generation of pollution and waste at source, rather than addressing and mitigating just the symptoms by only technically addressing an existing waste or pollution problem. Cleaner production has been shown internationally to be essential if companies are to remain competitive in external markets as well as domestic markets in the face of globalisation. The implementation of cleaner production will result in products and product processes being more cost effective and 'less harmful to the environment (Yap, 1996). The company's adoption of cleaner production strategies is also in line with the requirements of the National Climate Change Response Strategy for South Africa, which states that mitigation efforts should form an integral part of sustainable development, and in particular, cleaner production strategies (DEAT, 2004).

The involvement of an informed public and the participation of affected groups in project planning and implementation are critical to the success of environmental management in South Africa as elsewhere. Public participation refers to a continuous, two way communication process which involves promoting full public understanding of the process and mechanisms through which environmental problems and needs are investigated and solved by the responsible parties, keeping the public fully informed about the status and progress and of studies and implications of plan formulation (Fields, 2006). Public participation is also about actively soliciting from all concerned people their opinions and perceptions of objectives and their preferences regarding development of management strategies (Southern African Institute for Environmental Assessments, SAIEA) (http://www.saiea.com, 2007).

PPC has stated that public participation is an integral part of its current and future projects, including projects aimed at greenhouse gas reduction such as the Secondary Materials Co-Processing Project. Public participation is also stressed as one of the requirements of NEMA which emphasises the fact that the participation of all interested and affected parties in environmental issues must be promoted and all people must have the opportunity to develop understanding, skills and capacity necessary for achieving equitable and effective participation by vulnerable and disadvantaged persons must be ensured. The Air Quality Act of 2004 also emphasises public participation in environmental and other issues that could affect people’s health and well-being and this is in contrast to the Atmospheric Pollution Prevention Act, which did not emphasise public participation. The World Bank has also stated the importance of public participation in development projects as evaluation evidence has linked project success and sustainability with beneficiary participation. A review of Bank-financed projects carried out in the mid-1990s showed that failure to attend to social variables in project design and implementation often led to failure to attain project objectives (World Bank, 2002).

The fact that the company considers public participation as an integral part of its projects and greenhouse gas emission reduction projects is useful for climate change mitigation in that a well informed public is able to voice out its concerns about environmental degradation and will pressure industries to act in a manner that does not exacerbate environmental degradation.

Public participation also has its advantages including the fact that members of the public may provide useful information to decision makers and it also helps to increase public confidence in companies and decision making because the public can clearly see that all issues have been fully and carefully considered (http://www.saiea.com, 2007). The disadvantages of public participation include the potential for confusion of the issues since many new perspectives may be introduced. It is also possible for erroneous information that results from the lack of knowledge on the part of participants to be imparted to the rest of the participants. One of the main problems is that sometimes the public tends to lose interest during the long development period of the project (World Bank, 2002).

The World Bank has identified factors that make it difficult for most Africans to participate effectively in public decision making and this includes poverty. Poverty has been identified as a major barrier to public participation as most people concentrate their energies on day to day survival and do not give high priority to participating in decisions relating to a distant future (http://www.saiea.com, 2007). The fact that the majority of people in most African countries live in the rural areas also creates an additional obstacle to public participation because of the relatively high cost of reaching small scattered groups of communities and the high costs borne by those who participate. Illiteracy and the proliferation of local languages are further barriers to public participation (http://www.saiea.com, 2007).

The fact that the company is part of the Association of Cementitious Material Producers, which is a group of cement companies in South Africa, whose main goals include improving cement as a product, its uses and methods of production, is a further indication of the company’s commitment to the achievement of sustainable development. On behalf of its members, the Association also promotes the industry’s goals through market development, education research, technical services and government affairs. It has also taken a leadership role in educating its industry about climate change, environmental management and the importance of sustainable development.

The fact that such an association for the cement industry exists has positive implications for climate change mitigation. This is because the greenhouse gas emission reduction efforts of many cement companies in the country will lead to significant reduction of greenhouse gas emissions from the cement sector. This ultimately means that climate change will be indirectly mitigated and the existence of such an Association will also put pressure on other cement companies that are not part of it to join because of the fear of producing an inferior product and poor environmental performance compared to the other companies that are part of the Association. The fact that the company is part of the Association of Cementitious Material Producers means that it is adopting an action for climate change mitigation that is recommended by the World Business Council on Sustainable Development (Table 2-4) by co-operating with other stakeholders to remove barriers to the sale of innovative but safe cement products with lower embodied carbon dioxide emissions and the use of appropriate waste fuels that reduce the lifecycle of CO_2 emissions.

5.3 Government departments

The two government departments have stated that not much liaison with the cement companies or industry as a whole, with regards to greenhouse gas emission reduction and climate change mitigation, has taken place. This is a setback for climate change mitigation in the country as government and industry are supposed to work closely together in tackling environmental problems. The National Environmental Management Act of 1998 stresses the importance of Environmental Management Co-operation Agreements between the various spheres of government with any person or community for the purposes of promoting compliance with the Act. Environmental Management Co-operation Agreements may contain provisions for regular independent monitoring and inspections and verifiable indicators of compliance with any targets, norms and standards laid down in the agreements as well as those laid down by the law.

It is therefore important for government departments to work closely with companies or industries during emissions reduction efforts and environmental management in general.

As already stated in the previous section, self-regulatory mechanisms and the command control approach have their advantages and disadvantages. Appreciating some of the weaknesses with regard to self-regulatory initiatives, and acknowledging the important role of government in defining the preferred environmental objectives, the role of co-regulatory instruments may be seen as a constructive attempt at combining the best of both approaches to policy-making. Co-regulatory instruments cover a variety of initiatives where the interactive relationship between the regulator and the regulated is particularly close. The environmental objectives are set by the government or public authorities, while the methods of achieving those objectives are determined by the regulated industry (Hanks, 1998).

Unlike pure self-regulation, where there is no public intervention, industry may be seen to benefit in that government intervention is more likely to secure the collective action of the sectoral organisations. Co-regulation may in principle be seen as more conducive to sustainable development in that it ensures active collaboration and co-operation between government and industry, thus facilitating the effective integration of long-term economic, social and ecological priorities (Hanks, 1998).

If the business community is to achieve the necessary substantial improvements in resource efficiency, while simultaneously meeting increasing demands for employment and redistribution, then it is essential that there is a common understanding between government and industry as the preferred development path. This requires that there is agreement on the environmental priorities that need to be addressed, as well as a clear appreciation as to how these priorities balance with the requirements of industrial competitiveness and job creation (World Bank, 2002).

Despite the fact that at the present moment government and industry are not working very closely in the reduction of greenhouse gas emissions and climate change mitigation, the fact that the government has several projects aimed at improving air quality management (including greenhouse gas emissions reduction and management) and environmental management in general in the country is a major step in the right direction. As already stated in the previous section, these projects include the APPA Review Project and the Vaal Triangle Air Quality Management Plan (http://www.environment.gov.za, 2007). The main objective of the APPA Review project is to review and amend Registration Certificates for prioritised air polluters in such a way as to ensure the building of initial air quality management capacity in provinces and affected local authorities as well as ensuring measurable air quality improvements during, and immediately following, the period of transition between APPA and AQA (http://www.environment.gov.za, 2007). An increase in the capacity of provincial and local authorities will assist in ensuring that environmental management in the country is effective in the solving of environmental problems which include climate change mitigation (http://www.environment.gov.za, 2007).

The Vaal Triangle and surrounding areas have been declared a national air pollution hotspot or priority area in terms of Section 18 (1) of the Air Quality Act of 2004. This area is known as the Vaal Triangle Airshed Priority Area and is the first such identified area in South Arica. The DEAT has made special interventions to improve air quality in the Vaal Triangle Airshed Priority Area (Figure 5-1) and these interventions include the development of a Priority Area Air Quality Management Plan (AQMP) that will be developed in accordance with the provisions of AQA (http://www.environment.gov.za, 2007).

A priority area in terms of Section 18 (1) of the AQA is declared if the Minister of Environmental Affairs and Tourism believes the ambient air quality standards are being, or maybe, exceeded in the area, or any other situation exists which is causing, or may cause, a significant negative impact on air quality in the area and if the area requires specific air quality management action to rectify the situation (http://www.environment.gov.za, 2007). The Vaal Triangle was declared as a priority area because several studies conducted in the area have indicated that the air quality in the area is extremely poor and this has a direct negative impact on the health and well being of people living there. There are densely populated sections of the Vaal Triangle Priority area (Figure 5-2). The main aim of the developing the Vaal Triangle Airshed Priority Area Air Quality Management Plan is to do it in accordance to the requirements of the Air Quality Act and once implemented to effectively bring air quality in the area into sustainable compliance with national air quality standards within agreed timeframes (http://www.environment.gov.za, 2007).

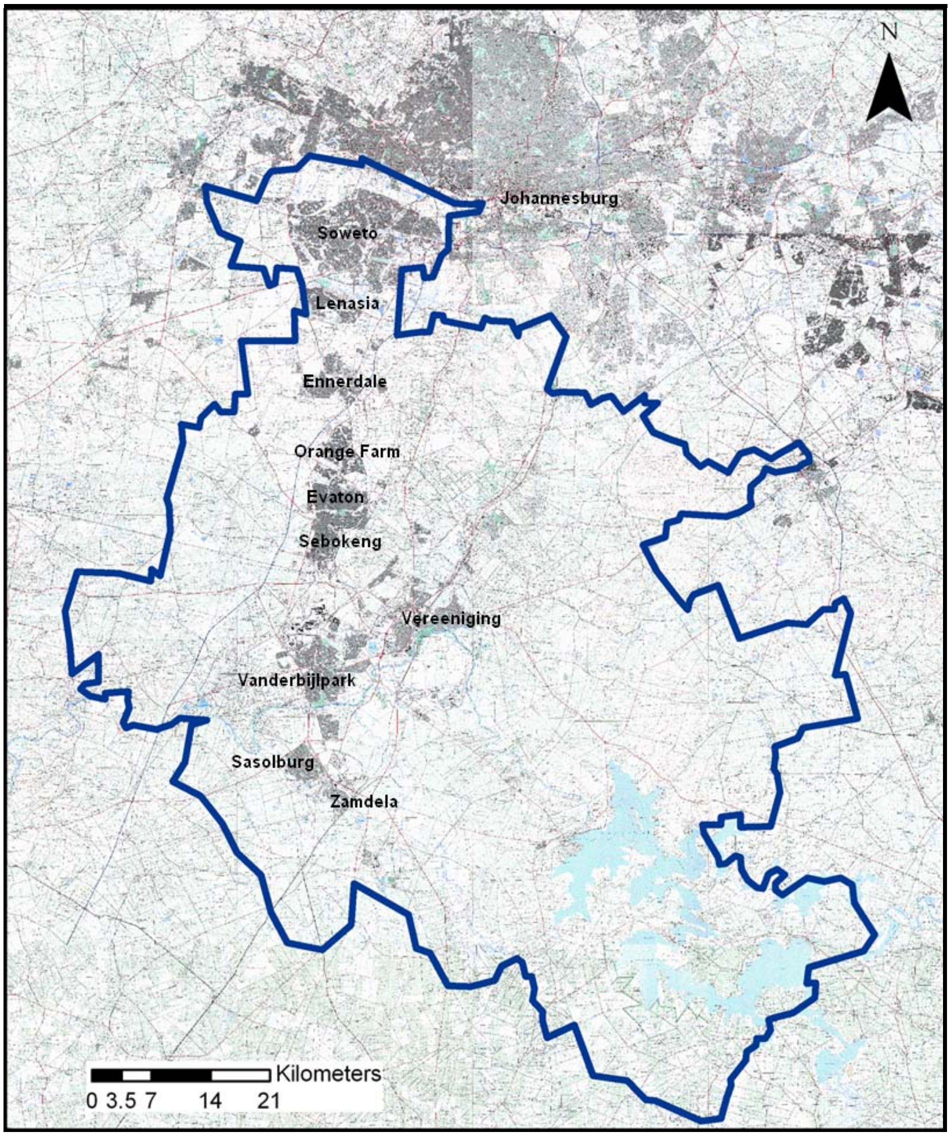


Figure 5-1: Vaal Triangle Airshed Priority Area (DEAT, 2007).

It is important to note that not only are these government projects aimed at improving air quality through emissions reduction measures for criteria pollutants such as particulate matter, (PM10), nitrogen dioxide and sulphur dioxide among other pollutants, but is also aimed at the reduction and management of greenhouse gas emissions and climate change mitigation. These types of environmental projects have the added advantage of the fact that they also assist in the achievement of the requirements of the Constitution of South Africa which emphasises the importance of the right of everyone to an environment that is not harmful to their health and well being. The projects also assist in the achievement of the United Nations Millennium Development Goals (MDGs), especially the environmental sustainability goal, whose main aim is to integrate the principles of sustainable development into country policies and programmes and to reverse loss of environmental resources among other objectives.

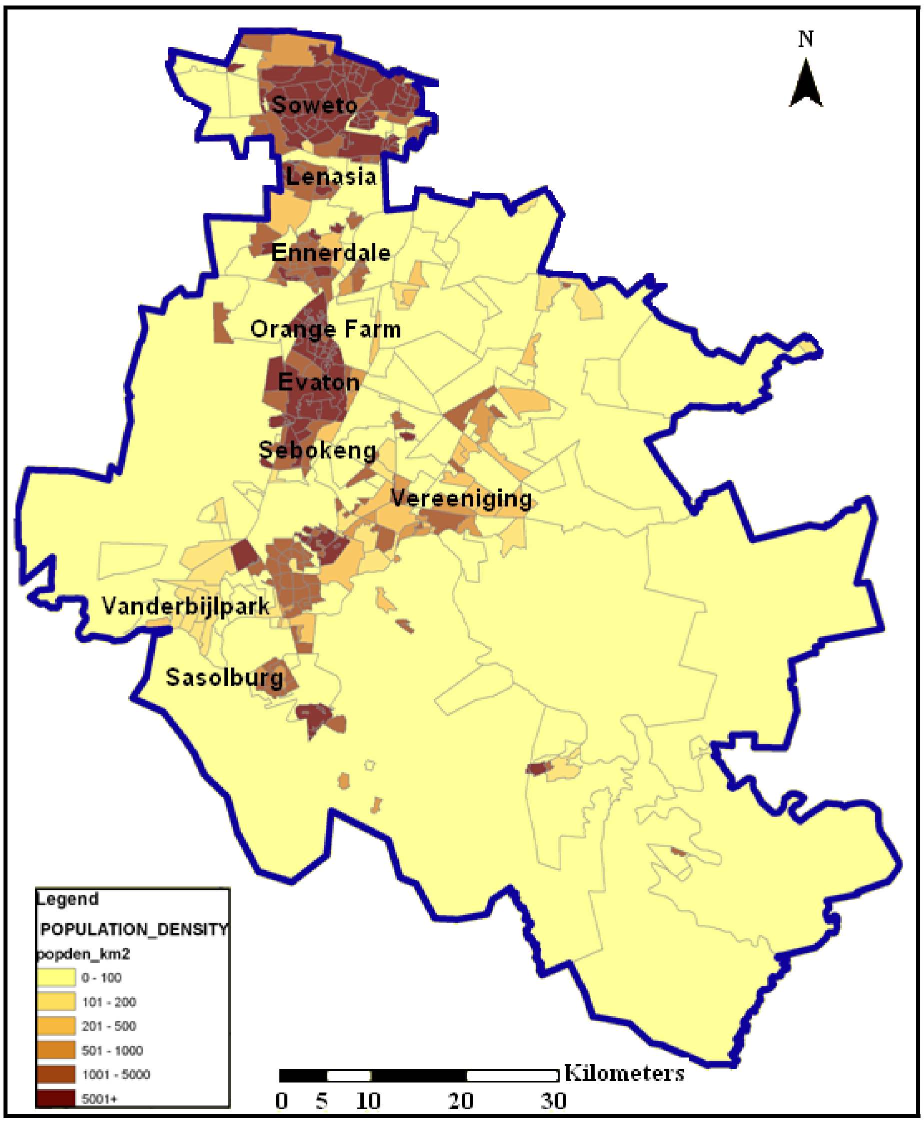


Figure 5-2: Population densities for the Vaal Triangle (Liebenberg-Enslin *et al.*, 2007).

There are high population densities in the various areas of the Vaal Triangle and therefore people need to be protected from pollution generated by the various industries located in the Vaal Triangle Airshed Priority Area (Figure 5-3).

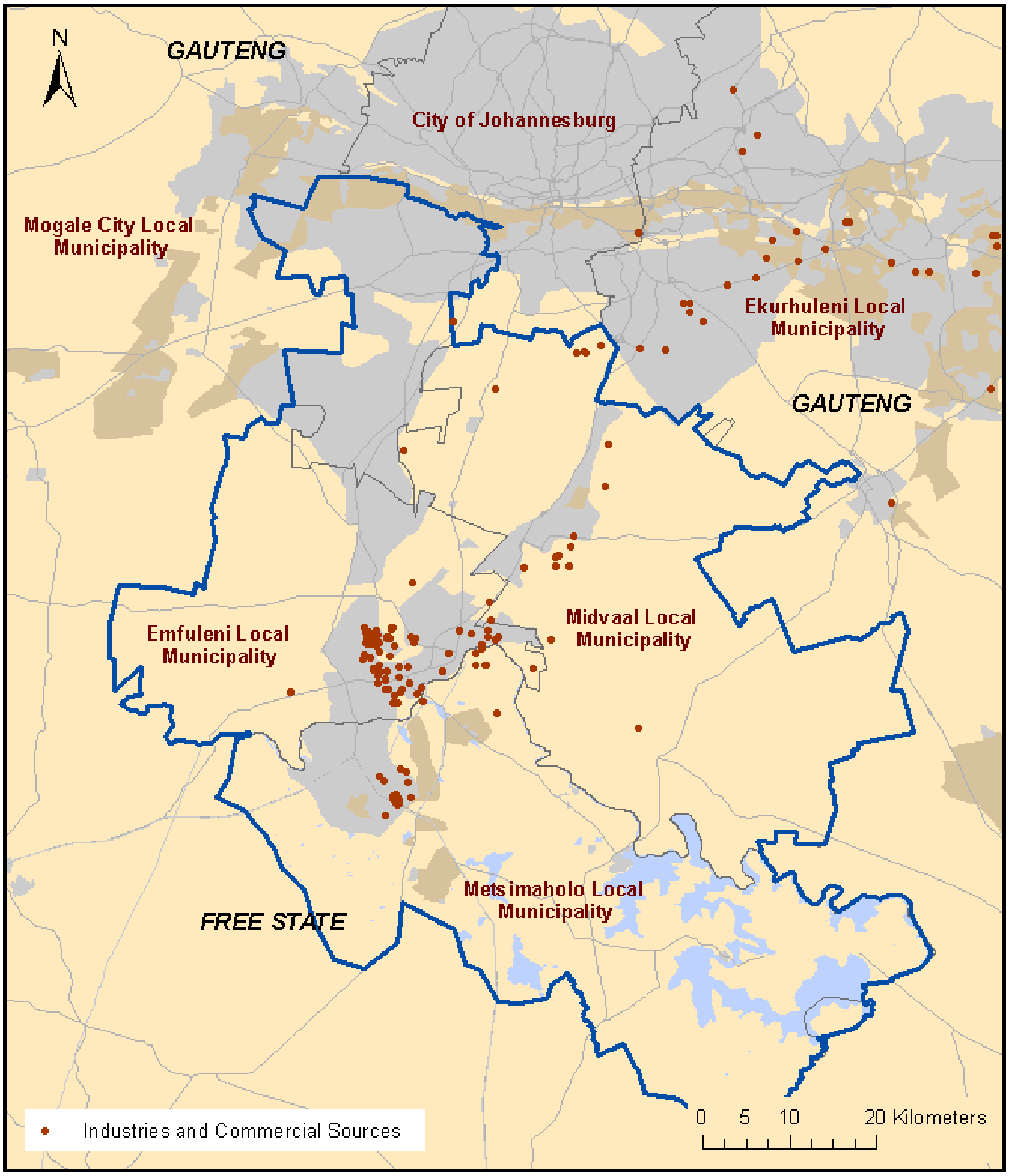


Figure 5-3: Industry locations in the Vaal Triangle (Liebenberg-Enslin *et al.*, 2007).

The government has also opened six air quality monitoring stations in the Vaal Triangle as part of it quest to ensure that people's health and well-being are not affected by air pollution (Figure 5-4). The stations will provide scientific air quality data to be used as a basis for air quality management decisions, especially given the fact that the Vaal triangle has been declared a priority area.

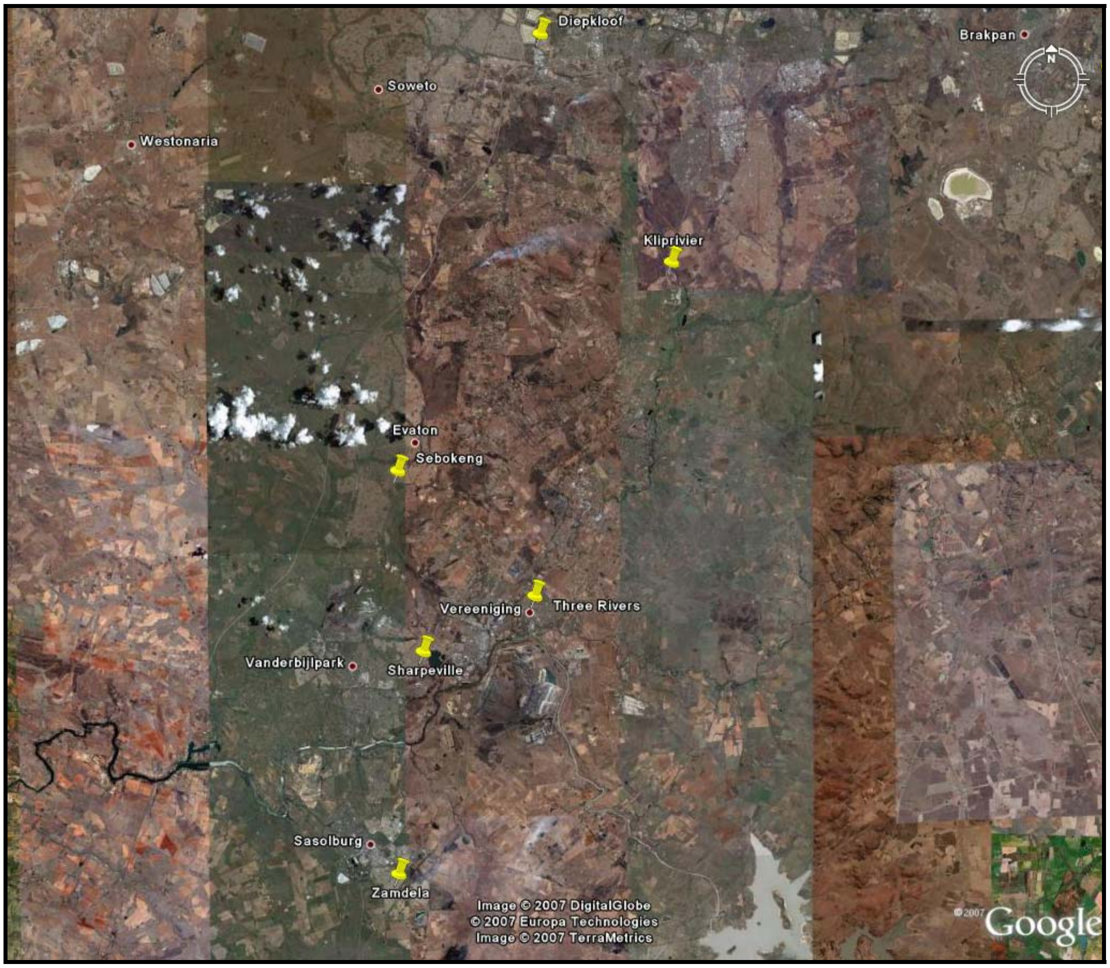


Figure 5-4: Positions of the government monitoring stations in the Vaal Triangle Priority Area (DEAT, 2006).

5.4 Summary

PPC has greenhouse emissions reduction strategies and the company has taken a proactive approach in the reduction of these gases as a result of its operational activities. These strategies could prove useful in the mitigation of climate change, especially if other cement companies (and industry in general) also intensify their greenhouse gas emission reduction efforts and strategies. Business as a major contributor to global greenhouse gas emissions will need to play a significant role in greenhouse gas emissions reduction. For climate change mitigation to be a success in the country, there is a need for government and industry to utilise the co-regulatory approach when tackling environmental issues. The advantage of this approach in environmental management compared to self-regulatory mechanisms and the command and control approach is that this approach combines the best of both approaches to policy-making. There are many strategies that could be used by both industry and government for the reduction of greenhouse gases and recommendations have been made with regards to these. The next chapter therefore includes the conclusions for the study and some recommendations to industry and government on how to further mitigate climate change.

6. CONCLUSIONS AND RECOMMENDATIONS

Climate change is one of the greatest environmental challenges facing the world due to the various threats it poses to the environment, people, sustainable development and efforts of achieving the United Nations Millenium Development Goals. This therefore means that any strategies and efforts directed towards climate change mitigation by governments, various organisations, industries and the public are important in light of this challenge. These strategies could collectively have positive implications for climate change mitigation and could also serve as a means of achieving sustainable development. It is even more important for industries (which are mostly the major polluters and emitters of greenhouse gases) to have greenhouse gas emission reduction strategies.

From the study, it can be concluded that Pretoria Portland Cement acknowledges that climate change is an existing global problem that requires international, national and local responses. The company therefore has greenhouse gas emission reduction strategies which might have positive implications for climate change mitigation. The fact that the company has greenhouse gas emission reduction strategies also has positive implications for sustainable development, which requires economic development to be conducted in such a manner that social and environmental factors are taken into consideration.

The company has also taken a proactive approach in greenhouse gas management and environmental management. This is in line with the requirements of the UNFCCC, Kyoto Protocol, NEMA and the Air Quality Act of 2004. A proactive approach towards environmental management in general is even more important in a developing country such as South Africa where there is a scarcity of government financial resources and skills for the enforcement of environmental law.

PPC stated that it wants to increase public participation in issues relating to the environment and progress on its activities and it can therefore be concluded that the company is taking its commitment to sustainability to a new level of transparency and accountability, which are core characteristics of good cooperate citizenship.

The company works closely with other cement producing companies on issues related to greenhouse gas management, product quality etc. Such associations might have positive implications for climate change mitigation and might lead to the cement companies involved becoming important players in the creation of policies benefitting the cement industry and other energy use initiatives as well. These associations among cement producing companies have also been internationally recommended by the World Business Council on Sustainable Development, especially for the purposes of promoting cement production practices that result in low greenhouse gas emissions.

The reduction of greenhouse gases and eventually the mitigation of climate change requires that government (the regulator) and industries (the regulated) work and liaise together. From the study, it can be concluded that a lot of effort needs to be directed towards industrial and government co-operation on climate change mitigation and other environmental issues. This co-operation can have positive implications for climate change mitigation and environmental management in general.

However, the government departments have cited lack of financial resources and technical knowledge as some of the crippling factors towards effective environmental management and co-operation with industry and have indicated that efforts to work closely with industries are being intensified.

Climate change therefore needs to be addressed at grass root level, especially by local industries and government. Addressing this problem should also involve the public, who should be informed about the negative consequences of climate change on their livelihoods, adaptation methods and how best to mitigate climate change.

Internationally, industry and governments have responded to emerging environmental issues and lack of sustainability through diverse ways which include the development of environmental management systems and standards such as ISO 14000, auditing procedures and the development of eco-efficient options for production. Environmental education and training is increasingly seen as an important process in responding to environmental issues such as climate change and other environmental risks. According to UNESCO's definition (1987), environmental education is a permanent process in which individuals gain awareness of their environment and acquire the knowledge, values and skills, experiences and also the ability to enable them to act- individually and collectively-to solve present and future environmental problems (http://portal.unesco.org, 2007). Education has also been described as the world's greatest resource in bringing about a preparedness for changes in social systems towards sustainable living and environmental educators are increasingly recognising the need to link environmental education to the social, economic and political nature of environmental problems in ways which move beyond narrow orientations of awareness raising and information communication which are technisist and managerial-hierarchical in their orientation (Lozt, 1998).

To further intensify its greenhouse gas emission reduction strategies and climate change mitigation efforts, it is recommended that the company intensifies its environmental education and training programmes so that they include all employees and the public instead of people in management and other positions that deal with environmental management. It is advisable that the company identifies training needs which will enable employees at all levels to become aware of the company's environmental policy and potential environmental impacts of their work activities. Employees and the public should also be clear about the nature, causes and impacts of environmental issues and risks associated with the business of the company and should have a broader understanding of the relationships between environmental conservation and economic development, and the implications of more sustainable living options (Lozt, 1998). Environmental education and training of employees and environmental education of the public can therefore be utilised by the company as a social strategy for greenhouse gas emissions reduction and indirectly- climate change mitigation.

The various government departments also have an important role to play in the environmental education and training of employees and the public for effective environmental management. This will also assist in making the various government projects aimed at air quality management and environmental management to be a success. For example, the National Climate Change Response Strategy for South Africa can be a success if the public knows about climate change, its implications, adaptation and mitigation.

It also recommended that the company uses other corporate strategies such as voluntary and negotiated agreements as part of its corporate greenhouse gas emission reduction strategies. Voluntary and negotiated agreements can also play a significant role in national greenhouse gas emission reduction strategies. They typically involve an agreement with the government to reduce emissions in exchange for relief from possible future regulation. In some cases, companies or industry associations unilaterally commit to voluntary reductions in order to improve their environmental performance and image or out of fear of more costly mandatory controls. However, voluntary agreements have had mixed success in various countries. For example, according to the WBCSD (2002), in the United States these have been largely ineffective, while in Germany, they have resulted in progress and financial/regulatory relief for the cement industry. The WBCSD (2002) however, also states that many voluntary agreements result in relatively small reductions compared to the reductions that would be required to stabilise the concentrations of greenhouses.

It is also recommended that cement companies must progressively pursue cost –effective carbon dioxide reduction by expanding the sales of cement with lower clinker content, for example composite cement with fly ash or blast furnace slag, increasing the use of alternative fuels (bio-based, low carbon, or waste fuels that provide a net carbon dioxide emissions reduction). Cement companies should also initiate energy efficiency enhancements like improving equipment and phasing out of inefficient plants. To enable additional, long-term, cost-effective carbon dioxide reductions, the cement industry must undertake or support retrofitting and development of its plants at a much higher level than today. Examples of such ventures can include co-producing electricity and cement in low carbon dioxide facilities and the capturing and sequestering of carbon dioxide (Humpreys and Mahasenan, 2002).

7. REFERENCES

Anderson, J.E., 2007: *Green Cement: Finding a Solution for a Sustainable Cement industry,* University of California Press, Berkeley, USA.

Athanasiou, T., 1996: *The Age of greenwashing,* in *Divided planet: The Ecology of the Rich and Poor,* University of Georgia Press, Athens, GA.

Barker T., I. Bashmakov, L. Bernstein, J.E. Bogner, P.R. Bosch, R. Dave, O.R. Davidson, B.S. Fisher, S. Gupta, K. Halsnaes, G.J. Heij, S. Kahn Ribeiro, S. Kobayashi, M.D. Levine, D.L. Martino, O. Masera, B. Metz, L.A. Meyer, G.J. Nabuurs, A. Najam, N. Nakicenovic, H.H. Rogner, J. Roy, J. Sathaye, R. Schock, P. Shukla, R.E.H. Sims, P. Smith, D.A. Tirpak, D. Urge-Vorsatz, and D. Zhou, 2007. *Technical Summary*, as cited in *Climate Change 2007: Mitigation,* Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer, eds. Cambridge University Press.

Baumert, K and Pershing, J., 2004. *Climate Data: Insights and Observations,* Pew Centre on Global Climate Change, Washington DC.

Bhandari, P., 2006: *India's Pragmatic Approach to Climate Change*, Science Development Network. SciDev. Net.

Beg, N., J.C Morlott J.C.,*et al*, 2002*: Linkages Between Climate Change and Sustainable Development,* Climate Policy, 2, pp129-144.

Bethlehem, L., and Goldblatt, M., (eds) 1997*: The Bottom Line: Industry and the Environment in South Africa*, University of Cape Town Press.

Bernstein, L.J., Roy, J., Delhotal, K.C., Harnisch, J, Matsuhashi, R., Price, L., Tanaka, K., Worell, E., Yamba, F., 2007: *Industry,* as cited in *Climate Change 2007: Mitigation,* Contribution of Working Group III to the Fourth Assessment Report of the Integovernmental Panel on Climate Change (Mezt, B., Davidson, O.R., Dave, R., Bosch, P.R., Meyer, L.A (eds), Cambridge, United Kingdom and New York, NY, USA.

Boyle, A and Freestone, D (eds), 1999: *International Law and Sustainable Development: Past, Achievement and Future Challenges,* Oxford University Press.

Bouille, D., and Mezt, B., 1998: *Assessment of South African Climate Change Policy Programme*, United Nations Development Programme.

Braconnot, P., Gillet P and Luo, Y., 2007: *Understanding and Attributing Climate Change:* as cited in *Climate Change 2007: Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Mezt, B., Davidson, O.R., Dave, R., Bosch, P.R., Meyer, L.A (eds), Cambridge, United Kingdom and New York, NY, USA

Brundtland Commission, 1987: *Our Common Future*, Oxford: Oxford University Press.

Burgess, D 2001: *A General Introduction to the Design of Questionnaires for Survey Research*, Information Systems.

Building Research Establishment Limited, 2005: *Best Practice Guides* (www.bre.co.uk), Cement and Concrete Institute (CNCI*)*, Marker Review, 2001: CNCI.

Business and Sustainable Development, 2007: *A Global Guide,* International Institute for Sustainable Development.

Chandler, W., Secrest, T., Logan, J. and Schaffer, R., 2002: *Climate Change Mitigation in Developing Countries*, Pew Centre on Global Climate Change.

Chandler, W., Schaeffer, R., Zhou, D., Shukla, P.R., Tudela, F, Davidson, O., and Alpan-Tamer, S, 2002. *Climate Change Mitigation in Developing Countries: Brazil, China, South Africa, Mexico, India and Turkey,* Pew Centre on Global Climate Change, Washington DC.

China Statistical Bureau, 2005: *Statistical Bulletin of the National Economy and Social Development* (http://www.stats.gov.cn).

Climate Action News Network, 2005: South African Newsletter, Volume 13, pp 12.

Coon, C.E., and Backgrounder, J.D., 2001: *Research on Energy and the Environment: Why Bush is Right to Abandon the Kyoto Protocol*, Heritage Foundation.

Constitution of the Republic of South Africa, 1996.

Davidson, O., Tyani, L., Okesse, Y.A., 2002: *Climate Change, Sustainable Development and Energy: Future Perspectives for South Africa*, Energy and Development Research Centre, University of Cape Town.

Department of Environmental Affairs and Tourism (DEAT), 1999*: National Inventory of Greenhouse Gases,* DEAT, Pretoria.

DEAT, 2004: *Linking EIAs and Environmental Management Systems,* Integrated Environmental Management Information Series 20, Department of Environmental Affairs and Tourism, Pretoria.

Department of Minerals and Energy (DME) 2003: *Overview of South Africa's Primary Industrial Minerals Imports and Exports,* DME, Pretoria.

Devereux, S and Edwards, J., 2004: *Climate Change and Food Security*, IDS III Bulletin. Institute of Development Studies, Volume 35 No.3, pp6.

Dovers, S., and J Handmer, 1993: *Contradictions in Sustainability*, Environmental Conservation, Series 20 (3) pp217-222, Centre for Resource and Environmental Studies, Australian National University (ANU).

Emilio Lèbre La Rovere and André Santos Pereira, 2005: *Brazil & Climate Change: A Country Profile,* Science Development Network.

Environment Australia, Department of the Environment, 1998: *Dust Control,* ISBN 0642545707 of the series 0642194181.

Environment Canada, 2004: *Cement Production*: *Guidance Manual for Estimating Greenhouse Gas Emissions,* Greenhouse Gas Division, Environment Canada.

Field, T., 2006: *Bringing Public Participation in Environmental Decision-Making into Focus through the Lenses of Environmental Rights and Regulation,* Support Document: Law and Society Summer Institute, USA.

Gibbons, P., 1997: *Polozzans for Lime Mortars in the Building Conservation Directory*.

Glazeskwi, J., 2000: *Environmental Law in South Africa*, Butterworths Publishers. Durban.

Grubb, M., Brewer, T., Muller, B., 2003: *A Strategic Assessment of the KyotoProtocol-Marrakech System,* Royal Institute of Internal Affairs, Briefing Paper 6, pp66.

Hardi, P. and Zdan, T. (eds), 1997: *Sustainable Development Principles In Practice*, International Institute of Sustainable Development (IISD).

Hanks, J., 1998: *Achieving Industrial Sustainable Development in South Africa: What Role for 'Self-Regulatory' and 'Co-Regulatory Instruments'*, South African Journal of Environmental Law and Policy, pp298.

Haskins, L.M., 2007: *Two Waste Treatment Breakthroughs Could Alter Industrial Disposal Practices: Originators Believe,* Enviro- Net.

Hendricks, C.A., Worell, E. and de Jager, D., 2002: *Emission Reduction of Greenhouse Gases from the Cement Industry*, International Energy Agency (IEA).

Hengchen, W., 2004: *Cleaner Production and Circular Economy for Cement Industrial Sector in China*, China-Canada CP Project.

Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K. and Johnson, C.A. (2001): as cited in *Climate Change 2001: The Scientific Basis*, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Howells, M., 2002: *South Africa Country Studies: Baselines and Greenhouse Gas Mitigation Options for Bulk Energy*, Energy Research Institute, University of Cape Town.

Humphreys, K. and Mahasenan, M., 2002: *Toward a Sustainable Cement Industry: Climate Change*, World Business Council for Sustainable Development.

Hunter, D., Sulzman, J. and Zaelke, D., 2002: *International Environmental Law and Policy*, New York Foundation Press.

Integrated Pollution Prevention and Control (IPPC). 2001: *Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries*, European Commission.

Intergovernmental Panel on Climate Change (IPCC), *2001: Climate Change 2001: The Scientific Basis,* Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change (IPCC), 2007: *Climate Change 2007: The Physical Science Basis*.

Intergovernmental Panel on Climate Change (IPCC), 2007: *Summary for Policymakers*, as cited in *Climate Change 2007: Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Metz, B., Davidson, P.R., Bosch P.R. and Meyer L.A (eds), Cambridge University Press, United Kingdom and New York, NY, USA.

Jodha, N.S., 1996: *Property Rights and Development*, (in Hanna, S.S. et al) (eds), *Rights to Nature,* Beija International Institute of Ecological Economics.

Kapp,M.B., 2006: *Ethical and legal issues in research involving human objects: Do you want a piece of me?* Journal of Clinical Pathology 2006, Volume 59, pp10, BMJ Publishing Group Ltd and Association of Clinical Pathologists.

Liebenberg-Enslin, H., Thomas, R., Walton N and van Nierop, M, 2007: *Vaal Triangle Priority Area Air Quality Management Plan- Baseline Characterisation*, Airshed Planning Professionals.

Lozt, H., 1999: *Environmental Education and Training in Industry: Changing Orientations and Practice?* Southern African Journal of Environmental Education, Volume 19 pp 25-27.

Marsh Environmental Services, 2007: *PPC Riebeck Environmental Technical Review*.

Mail and Guardian, 2007, *Zimbabwe Throws SA Cement a Lifeline*, (http://www.mg.co.za/article/2007-01-26).

McCaffrey, R., 2003: *The Cement's Industry's Role in Climate Change*, Global Cement and Lime Magazine.

McRae, H., 2005: *Can Kyoto Really Save the World*, The Independent, Countercurrents Organisation.

Mezt, B., Davidson, O.R., Dave, R., Bosch, P.R., Meyer, L.A (eds), 2007. *Climate Change 2007*: Contribution of Working Group III to the Fourth Assessment Report of the Integovernmental Panel on Climate Change (Cambridge, United Kingdom and New York, NY, USA.

Mining and Manufacturing Systems, 2007: *Cement Production and Demand*.

Mokrzycki, E and Bocheczyk, A.U., 2003: *Alternative fuels for the Cement Industry*, Mineral and Energy Economy Research Institute of the Polish Academy of Sciences.

National Research Council (NRC), 2001: *Climate Change Science: An Analysis of Some Key Questions*, National Academy Press, Washington, DC.

Pachauri, R.K., 2004: *Climate Change and its Implications for Development: The Role of the IPCC Assessment*, Institute of Development Studies Bulletin, Vol 35 pp3-5.

Parker, L. and Blodgett, J., 2005: *Greenhouse Gas Emissions: Conflicting Situations, Conflicting Perspectives*, Congressional Research Service, The Library Congress.

PPC Dwaalboom Expansion Project, 2005: "Batsweledi": Analysts and Media Presentation.

PPC, 2006: *Environmental Impact Assessment for the Proposed Secondary materials Co-Processing Programme*, PPC Background Information Document.

Pereira, A.S, and Oliveira, B.L., 2005*: Carbon Dioxide Avoided Emissions and other Environmental, Social and Economical Benefits brought by Energy Saving through Recycling in Brazil*, Science Direct, Energy Policy.

Raganathan, J. and Bhatia, P., 2003*: Accounting for Business Greenhouse Gas Emissions: In Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*, World Resources Institute.

Resnik, D.B., 2007: *What is Ethics in Research and Why is it Important?* National Institute of Environmental Health Sciences.

Rogner, H.H., Zhou, D., Bradley, R., Crabbe, P., Edenhofer, O., Hare, B., Kuijpers, L., Yamaguchi, M., 2007: *Introduction,* as cited in *Climate Change 2007: Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Integovernmental Panel on Climate Change (Mezt, B., Davidson, O.R., Dave, R., Bosch, P.R., Meyer, L.A (eds), Cambridge, United Kingdom and New York, NY, USA.

Ruth, M., Worell, E. and Price, L., 2002: *Evaluating Clean Development Mechanisms Projects in the Cement Industry Using a Process Step Benchmarking Approach*, Energy Analysis Department, University of California.

Sathaye, J.A, Andrasko, K., Makundi, W., 2002: *Concerns about Climate Change Mitigation Projects: Case Studies in Brazil, India, Mexico and South Africa*, Environmental Energy Technologies Division: Enerst Orlando Lawrence Bekerly National Laboratory.

Sathaye, J., Najam, A., Cocklin, C., Heller, T., Lecocq F., Llanes-Regueiro, J., Pan, J., Petschel-Held, Rayner, S., Robinson, J., Schaeffer, R., Sokona, Y., Swart, R., Winkler, H., 2007*: Sustainable Development and Mitigation*, as cited in *Climate Change 2007: Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Integovernmental Panel on Climate Change (Mezt, B., Davidson, O.R., Dave, R., Bosch, P.R., Meyer, L.A (eds), Cambridge, United Kingdom and New York, NY, USA.

Sathaye, J and Schumacher, K., 1999: *India's Cement Industry, Productivity, Energy Efficiency and Carbon Emissions*, Environmental Energy Technologies Division.

Scheraga, J and Gramsch, A 1998: *Risks and Opportunities and Adaptation to Climate Change*. Climate Research, Volume 10, pp85-95.

Schmidt, C., 2000: *The Kyoto Protocol: Just a lot of hot air?* Environmental Health Perspectives, Volume 108, No 8, pp362-365.

Smit, B. (1993*): Adaptation to Climate Variability and Change*, Report of the Task Force on Climate Change Adaptation, Guelph, Environment Canada.

Smit, B., Burton, B., Klein, R.J.T., and Wandel, J., 2000, *An Anatomy of Adaptation to Climate Change and Variability*, Climatic Change ,Volume 45 (1), pp223-251.

Soule, M.H, Logan, J.S and Stewart, T.A., 2002*: Toward a Sustainable Cement Industry: Trends, Challenges, and Opportunities in China's Cement Industry,* Anataike Information Development Co. Batelle.

Southern African Institute for Environmental Assessment, 2006: *Public Participation in Environmental Assessments*, Southern African Institute for Environmental Assessment, SAIEA.

Stakhive, E.Z., 1994: *Managing Water Resources for Adaptation to Climate Change*. Engineering Risk in Natural Resources Management, Volume 275, pp243-393.

Stewart, T.R., 1991: *Global Climate Change: A Pyschological Perspective*, University Centre for Policy Research, University of Albany.

United Nations, 1987: *Report of the World Commission on Environment and Development.* General Assembly Resolution 42/187, 1987.

Sustainable Energy Society of Southern Africa, 2007: *South Africa and Climate Change*.

Suzuki, D. and McConell, A., 1997: *The Sacred Balance*: *Rediscovering our place in nature*, David Suzuki Foundation and Greystone Books, Vancouver.

Tickner, J., Raffensperger, C., Myers, C., 2001: *The Precautionary Principle in Action: A Handbook.* Science and Environmental Health Network.

United States Environmental Protection Agency (US-EPA), 2007: *Portland Cement Manufacturing:* Mineral Products Industry-AP42, Fifth Edition, Volume 1, US-EPA.

Vogel, C., 2005: *"Seven Fat Years and Seven Lean Years"? Climate Change and Agriculture in Africa*, IDS III Bulletin, Institute of Development Studies, Volume 36, No. 2 pp15.

Wakumonya, N. and Spalding- Fecher, R., 1999: *The Convention on Climate Change, Kyoto Protocol and South Africa: Obligations and Opportunities*, The Energy and Research Centre, University of Cape Town.

World Bank, 1996: "*Pollution Prevention and Abatement: Cement Manufacturing*", Draft Technical Background Document, Environment Department, Washington DC.

World Bank, 1998: *Cement Manufacturing: Pollution Prevention and Abatement Handbook*, World Bank Group.

World Business Council for Sustainable Development (WBCSD) (2002): *Guidelines for the Selection and Use of Fuels and Raw Materials in the Cement Manufacturing Process,* Batelle.

World Council for Sustainable Development, 2002: *Towards a Sustainable Cement Industry,* Batelle.

Yamin, F., 2004: *Overview on Climate Change*, Institute of Developmental Studies Bulletin, Volume 35 pp102-105.

Yap, N.T., 1996*: Cleaner Production and Consumption in Eastern and Southern Africa: Challenges and Opportunities*, Weaver Press.

Young, O. R., 2002. *The institutional dimensions of environmental change: fit, interplay and scale,* Cambridge University Press, Cambridge, UK.

http://cdiac.ornl.gov/trends: 2005 Energy Management Policy – Guidelines for Energy Intensive Industry in India. Bureau of Energy Efficiency

http://climatechange.sea.ca, 2006

http://ec.europa.eu/environment, 2007

http://environment.about.com, 2007

http://portal.unesco.org, 2007

http://socialresearchmethods.net, 2007

http://www.sessa.org.za, 2007

http://unfcc.int/source/docs, 2007

http://www.analytitech.com, 2007

http://www.cdphe.state.co.us, 2007

http://www.dme.gov.za, 2007

http://www.epa.gov/climatechange, 2007

http://www.globalissues.org, 2007

http://www.google.co.za, 2007).

http://www.greenhouse.gov, 2007

http://www.iigcc.org/docs

http://www.mwatch.org, 2007

http://www.saiea.com, 2007

http://www.weblakes.com, 2007

http://www.weforum.org, 2007

http://www.scidev.net, 2007

http://en.wikipedia.org/wiki/Trade secrets, Wikipedia, 2006:

http://wrightreports.ecnext.com/coms2/reportdesc, Wright Reports

APPENDIX A

QUESTIONNAIRE FOR PPC (CEMENT COMPANY)

1) What strategies are currently in place for the reduction of greenhouse gas emissions and to what extent have these been fuelled by sustainability concerns?

2) How effective have these strategies been in reducing greenhouse gas emissions due to the company's activities?

3) What are the long- term consequences, both negative and positive, of the company's choice of greenhouse gas reduction strategies for its business operations?

4) Do you think that greenhouse gas emission reduction response measures will eventually have a significant impact on the future strategy and technology choice of the company and if so, why?

5) Do you see climate change as posing potential risks and/or opportunities to your company? Please provide information to explain your answer.

6) What do you think of the Kyoto Protocol's concept of Clean Development mechanisms and of what benefits do you think it will bring the company?

7) How is the company working with the Department of Environmental Affairs and Tourism (DEAT) and the Department of Minerals and Energy in reducing its greenhouse gas emissions and in what areas do you mostly require each department's input?

8) How do the company's greenhouse gas reduction strategies fit in with the requirements of the new Air Quality Act of 2005, the National Climate Change Response Strategy, the National Environmental Management Act of 1998 and ISO14001? Where are the differences and why have these occurred?

9) What are the main challenges and constraints experienced by the company during its greenhouse gas reduction efforts?

10) What are the risks involved in carrying out a self-regulatory approach towards environmental management?

<u>QUESTIONNAIRE FOR THE GOVERNMENT DEPARTMENTS (DEAT and DME)</u>

1) What strategies are currently in place for the reduction of greenhouse gas emissions and to what extent have these been fuelled by sustainability concerns?

2) How effective have these strategies been in reducing greenhouse gas emissions due to cement production and other industrial activities?

3) Is the Kyoto Protocol’s concept of Clean Development Mechanisms useful or not to South Africa’s efforts of greenhouse gas reduction. Please give reasons why this is so?

4) How is the Department working with or assisting cement producing companies and other industries reduce their greenhouse gas emissions?

5) What are the main challenges and constraints experienced by the department in its climate change mitigation efforts targeted at making industry sustainable?

6) Is the adoption of a self-regulatory approach towards environmental management by industry useful to the department/government and why is this so?

Table A: Checklist for Dust Control (After Environment Australia, 1998)

ISSUE	OUTPUTS	PERFORMANCE MEASURES	IMPROVEMENT
Information and Planning			
HAVE YOU, determined the sources of dust in the operations?	Potential sources of dust identified in the EIA	Comprehensive list of individual sources	Sources considered for each stage of the mine (i.e. exploration, construction, operation, decommissioning, rehabilitation and closure)
HAVE YOU attempted to characterise the types of dust and quantities produced (modelling)?	Estimates of dust types and levels to be produced Dust emission inventory and determination of dust emission factors	Estimates based on typical measured levels for a mining plant. Dust inventory is derived by analysing the mine plan to establish potential dust sources and estimate the level of dust-producing activity associated with each source. Emission factors are derived by assessing the quantifiable activities or aspects which generate dust, such as vehicle size, speed and distance travelled on haul roads.	Estimates, inventory and emission factors made for all potential sources for each stage of the mine (emission factors are only applicable when emissions are to be modelled).
DOES YOUR characterisation of the types and quantities of dust include diffuse dust sources?	All types and locations of dust emissions can be ranked and controls planned in a systematic manner	Quantitative estimates of dust emission rates from different classes of mining activity and land surface types	Use of models to produce estimates of dust types and levels across a wide range of operating and climatic conditions
HAVE YOU undertaken an impact assessment?	Identification of sensitive receptor areas Assessment of maximum levels to avoid impacts, significant concerns or discomfort	Assessment identifies dust levels likely to be experienced by workers and at key locations.	The potential health risk from dust is related to the size of dust particles. Mine dust lies in the range of 1-100 µ
HAVE YOU developed a draft management strategy, based on the impact assessment?	Incorporates input from the community and the regulatory authorities Addresses all environmental and social issues likely to arise from dust at the proposed project	Initial planning should include development of a draft management strategy which: • Identifies all the potential sources and risks • Sets out objectives for environmental protection and risk minimisation • Provides a framework for evaluating different options and choosing a design which reflects site conditions and environmental sensitivities	Consultation with key stakeholders during preparations of the draft management strategy
HAVE YOU devised approaches to mitigate impacts to acceptable levels?	Strategy incorporates "built in" design features to minimise the generation of dust at source	Strategy includes addressing the mitigation of dust	The EIA and mine plan for the project set out in a framework based upon: Mine design to avoid the generation of dust

ISSUE	OUTPUTS	PERFORMANCE MEASURES	IMPROVEMENT
			Systems design and management to minimise the generation of dust during operations Treatment of dust problems through active monitoring and response, and redesign of strategies if required.
Information and Planning Continued			
HAVE YOU considered the probable regulatory requirements?	Level to which targets in the strategy conform to standards and regulations taking into account estimates of inputs from all probable sources of dust.	Dust strategy describes relevant standards and regulations	
ARE THE target levels developed in consultation with the community?	Documented agreement on maximum permissible levels between company and key community group/s	Maximum dust levels explained and agreed with the community	Establishment of formal and frequent consultation with the local community early in the planning process.
DO THE provisions of the dust management plan also apply to the decommissioning, rehabilitation, and closure stages?	Smooth transition from operational to decommissioning stages, with low risk of exceedance of dust control targets.	Decommissioning, rehabilitation and closure plans for all include provisions for control of dust.	Plans incorporate provisions which must reflect the specific activities involved at the end of mining.
Management and Operation			
HAVE YOU prepared an operational dust management plan?	Dust management plan	The management plan: • sets out targets and management strategies for all issues identified in the impact assessment and in community consultations • must be integrated with other operational plans into an overall environmental management system	ISO 14001 accreditation may help to demonstrate the environmental commitment to regulators and other stakeholders.
IS the management plan known and understood by all staff including plant operators?	Staff awareness of the management plan and its contents	Relevant documentation must be available to staff, regulators and auditors.	Management plan available to staff, staff instructions on the control of dust, regular checks on effectiveness of operational systems, dust included in environmental awareness training seasons.
HAVE YOU selected appropriate options to minimise the generation of dust?	Few significant issues related to dust at site	Evidence of good design to reduce dust generation through mine design, choice of equipment, and work practices Consistent application of good design across all	The use of computer modelling to investigate the control measures needed to achieve targets.

ISSUE	OUTPUTS	PERFORMANCE MEASURES	IMPROVEMENT
		types of dust sources, including road transport outside the mining area.	
HAVE YOU incorporated design features to mitigate the potential impacts from the dust generated at site?	Few significant issues related to dust at the site	Evidence of installation of engineering works, equipment modification etc to minimise dust Any significant dust sources identified via monitoring have been objectively evaluated and remedial action taken.	All reasonable measures taken to reduce from all fixed and mobile equipment
DO YOU have operational systems to control dust in all areas with dust potential?	Procedures described in the mine plan and EIA implemented correctly, and dust control targets achieved.	The EIA and related manuals will set out procedures for dust management in all relevant areas of the site	Documented procedures need to cover all mining activities.
Management and Operation Continued			
IS THERE documentation to demonstrate that the dust management plan is carried out properly?	Assurance to managers that dust control targets for the operation are being met.	Regular reports (monthly) of dust management activities and assessment against control targets and requirements of the management plan.	Standard operating procedures for staff working in dusty areas, operating dusty equipment, and involved in drilling and blasting activity, setting out responsibilities, and methods for limiting and reporting dust levels and incidents.
DO YOU have a system in place to incorporate improvement?	Continual improvement and reduced probability of recurrence of undesirable dust events	Evidence of review and update of systems and equipment where unsatisfactory dust levels have been recorded.	Assessment of the adequacy of dust control should be incorporated in annual environmental audits of the project.
Monitoring and Assessment			
IS THERE a monitoring regime in place which addresses all of the possible areas for environmental and social impact from dust identified at the planning stage?	The level of performance of dust control and potential impacts on workers, the public and environment is well known to managers	Comprehensive monitoring regime which includes measurement of levels in worker areas and areas of the community sensitivity. Monitoring regime sets out: • Parameters to be monitored • Monitoring locations • Monitoring interval • Data and data analysis requirements for monitoring reports • Reporting interval	Reporting and record keeping includes: Recording intervals Location of attended and unattended monitoring instruments Comparison of monitoring results with those from modelling (if applicable)
ARE environmental and community targets set, and are the	Low probability of community concern provided dust is controlled to within levels agreed by the community.	Control targets agreed with the community are set out in the management plan and monitoring	Tools for effective dust monitoring include: Baseline sampling

ISSUE	OUTPUTS	PERFORMANCE MEASURES	IMPROVEMENT
layout, techniques, frequency, quality and sensitivity of monitoring and sampling appropriate to these targets?		regime and are used as key benchmarks to evaluate adequacy of performance in regular monitoring reports.	Control site sampling Dust deposition gauges (provides long term data) High volume samplers (quantitative data over 24hr periods) Continuous particle monitors (provides data relevant to sort term events) Size-selective samplers (samples dust in size fractions) Personal exposure samplers (worn by workers)
IS monitoring undertaken in accordance with appropriate standards?	High level of assurance or the reliability of dust monitoring results	Evidence that monitoring techniques accord with appropriate standards	Measures outlined in the South African National Standards, SANS 1929:2004 are recommended.
Monitoring and Assessment Continued			
DOES monitoring include meteorological data?	Proactive management of site activities can be undertaken to avoid significant dust events in periods of bad weather.	Routine collection of data on predicted rainfall, temperature and wind velocity	The erection of a site specific meteorological is highly recommended.
ARE data collected in accordance with the requirements of the monitoring regime?	Low risk of regulatory non-compliance or of community concerns regarding dust.	Monthly and annual reports of dust data, which cross refer to monitoring requirements	
ARE the data analysed and regularly reported to the regulatory authorities?	Assurance that all regulatory requirements for dust are being met continuously	Regular reports (i.e., monthly) provided, where deemed necessary.	Dust control performance is reported against community-agreed targets in public reports.
ARE non-compliance issues or abnormalities in the data routinely recorded?	Management aware of any areas of poor performance Management provides an ongoing measure of effectiveness of the current system and past improvements	Register of non-compliance and unplanned events, indicates time of event, time of action, type of action, result and interaction with authorities.	Regulatory authority advised immediately of all non-compliance and sign cant unplanned events.
IS THERE a system in place for significant dust events or issues to be addressed to reduce prospects of recurrence?	Reduced risk of recurrence of significant dust events	Evidence that entries in the register of non-compliance and unplanned events are investigated properly and appropriate remedial action is identified and implemented promptly.	Standard deadline set for completion of actions to remedy dust events. Number of entries in the register and speed of actioning improvements can be used as reporting criteria to staff, management, regulators, and the community.

ISSUE	OUTPUTS	PERFORMANCE MEASURES	IMPROVEMENT
IS liaison with the community maintained in relation to dust issues?	Good community relationships maintained	Documentation of regular community liaison that addresses issues of dust.	Community meetings / stakeholder forum held regularly with dust standing as an agenda item. Special meeting held immediately after a significant event raising community concern
IS a complaints register maintained and are complaints investigated?	Areas of poor dust control are addressed quickly so that the risk of recurrence is minimised Good community relationships must be maintained.	Documented complaints register which records details of complaints and any follow-up action.	Register records date, time, and type of event, which is the subject of the complaint; follow-up action, risk of recurrence. Reporting back to the complainant