WASTE DISPOSAL BY CEMENT KILN:
A SUSTAINABLE WASTE MANAGEMENT PRACTICE?

A review of the Waste Hierarchy and a Life Cycle Approach to Disposal by Cement Kiln

This report has been written and compiled as a component to PPC EIA application for the co-processing of secondary materials in five cement kilns in South Africa.

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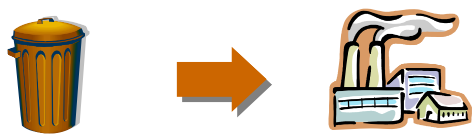

COMPILED BY:

Jonathan Sevitz
Marsh Environmental Services
A Division of Marsh Vikela (Pty) Ltd

t: 011 506 5000 / 083 391 2347
f: 086 673 3177
e: jonathan.sevitz@marsh.com

EXECUTIVE SUMMARY

It is vital that the role that the disposal of cement kiln can play in relation to the waste hierarchy, and the potential impacts and benefits of this disposal option be clearly understood.

Perceptions and perspectives of this and other waste management options, which motivated this project, included the following:

- The disposal of waste by cement kiln is not seen as recycling, but just another form of disposal (such as landfilling), and is therefore not a preferable option for waste (with only economical benefits).
- PPC is taking waste which could have been recycled.
- By creating a market for waste, PPC is giving generators an 'excuse' to generate waste, which will therefore create disincentives for the minimisation of waste generation.
- The incineration of paper and cardboard is not environmentally positive as it cannot be recycled (back into paper or cardboard products), and is therefore wasting usable resources.

This study addressed the different perspectives through a review of **Waste Hierarchy,** examining the role that disposal by cement kiln may plays in each of the respective tiers; and includes a **Life Cycle Approach** discussion on the environmental footprint of disposal by cement kiln in comparison to other waste management options.

Waste Streams

The waste streams assessed are based on the five proposed waste streams PPC propose using as secondary fuels in the cement kilns:

- Scrap tyres and rubber waste
- De-watered, treated sewage pellets
- Hydrocarbon waste (such as used oil, oil-contaminated general waste, oil-contaminated soil and coal fines)
- Plastic waste
- Biomass (such as paper waste, sawdust, wood chips and waste from bio-fuel production)

Role in The Waste Hierarchy

The Waste Hierarchy, which is generally divided into 5-7 tiers, has been grouped into three broader tiers to better define the overall approach towards waste. These tiers, each based on a separate key principle of waste management are:

- Tier 1: Avoiding Waste Generation
- Tier 2: Recovering the Value of Waste
- Tier 3: Treatment and Disposal

Disposal by cement kiln can be shown to be Tier 2, a preferred option to landfilling (Tier 3) where the reduction in waste (Tier 1) or recycling (Tier 2) of waste is not viable. The energy value of the waste utilised, thus replacing the need for other fossil fuels (coal), and the ash is needed and incorporated into the production of cement.

The roles that PPC, the generator and the landfill operators play in the waste hierarchy are illustrated in the figure below.

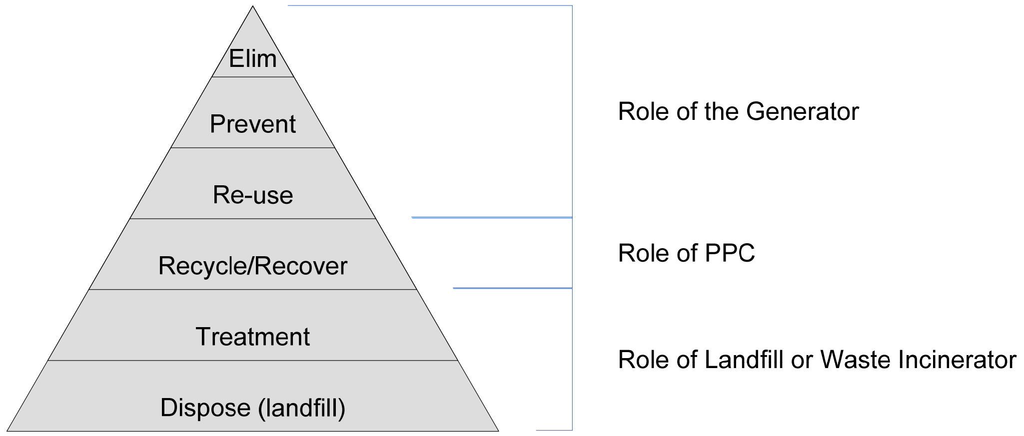

Figure A: Roles in the Waste hierarchy

Market Forces

There is a concern that because the disposal by cement kiln is expected to be a cheaper waste management option than lower tiers of the hierarchy such as landfilling, that this new option will give generators an 'excuse' to generate waste, which will therefore create disincentives for the minimisation of waste generation (the upper tiers).

Market forces are shown to be favourable for the upper tiers of the waste hierarchy (reduction and recycling), thus ensuring that where viable, industries generating the waste will benefit more (financially) from any waste minimisation and avoidance programmes than disposal by cement kiln. Depending on the waste stream, landfill fees may be higher or lower than the fees to be charged by PPC. Where landfill fees exceed the fees to be charged by PPC, disposal by cement kiln will be a cost effective option to the waste generator.

The costing of disposal options for the examples of plastics and tyres are provided below, which indicates the range of costs or savings expected for the respective waste streams.

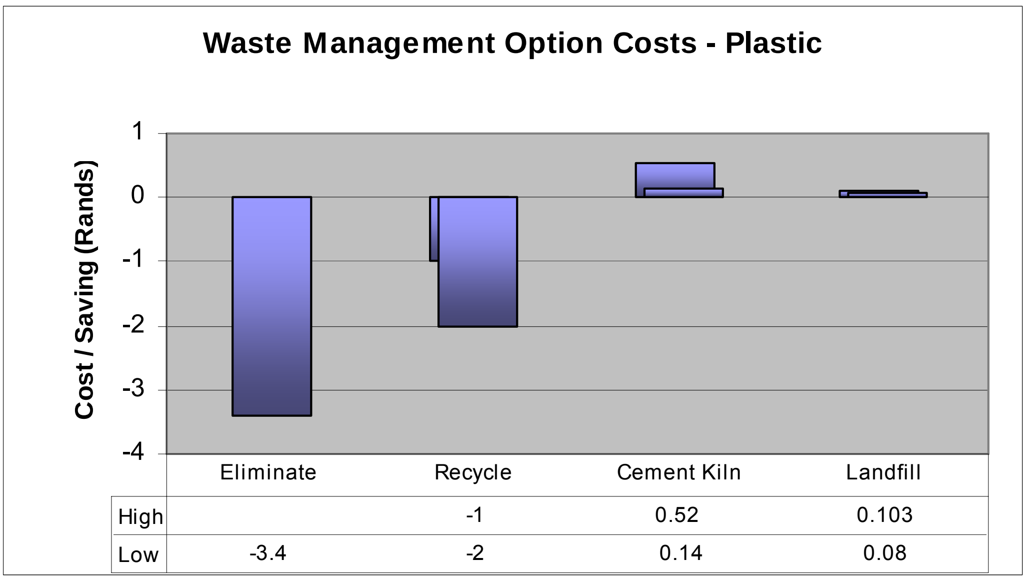

Figure B: Waste Management Costs for Plastics

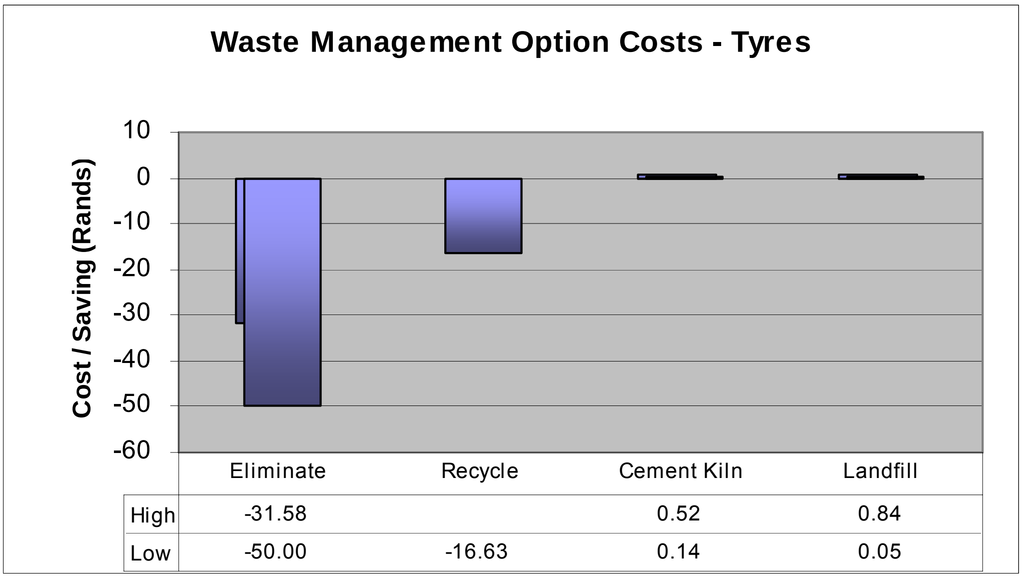

Figure C: Waste Management Costs for Tyres

The difference in savings and costs for the waste management options clearly indicate that disposal by cement kiln is not providing disincentive to recycling or reduction options.

SA Policy and Legislation

It is important the any new waste option that is introduced to South Africa, benefits waste management in South Africa as a whole, and is aligned with the policies, strategies and regulations of South Africa. It must therefore provide opportunities that push the status quo of waste management up the tiers of the waste hierarchy.

South Africa waste management legislation and policies developed over the last few years are moving away from the end-of-pipe management and encouraging waste prevention and minimisation. The National Waste Management Strategy support and encourage waste minimisation. PPC can reuse waste as an alternative fuel in cement kilns, this does not improve minimisation of generated waste but can reduce the volume of waste landfilled.

The following legislation, policies and strategies of South Africa identified holds supports for cement kiln as a waste management option. International trends further indicate that this option is practised and supported in various other countries (Europe in particular).

Table A: Legislation, policies and principles s reviewed

Legislation / Policy / Principle	Year of publication/ promulgation
National Environmental Management Act - Waste Management Principles	Act no. 107 of 1998
Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste	2nd Edition (DWAF, 1998)
Polokwane Declaration	*September, 2001*
National Waste Management Strategy (NMWS-SA)	1999 adopted NWMS
White Paper on Integrated Pollution and Waste Management for South Africa	*DEAT, Planned in NWMS,* 2000
Gauteng Provincial Integrated Waste Management Policy	*March 2006, Draft*
Sewage Sludge Guidelines	*DWAF and WRC, March 2006*

Disposal by cement kiln, which reduces the use of natural resources by means of using wastes as an alternative fuel, together with reusing the wastes will result in waste being diverted from the landfill. The use of alternative fuels in cement kilns is therefore in alignment with the objectives set in Polokwane Declaration (reducing waste disposal), and to the holistic approach embodied in the NWMS. This option adhered to the objectives of the NWMSI-project, and to the Gauteng Policy (final draft), policy no.10 (for the recovering and recycling of other materials).

Life Cycle Approach

The life cycle approach takes a wider view for each disposal option for the five waste streams proposed for disposal by PPC. All impacts (including energy, resources, emissions and land use and water) must be identified, addressed and compared for the different waste management options.

This approach is based on the principles and framework for the accepted international standards for comprehensive Life Cycle Assessments which is contained in IS0 14040 (1997), This standard outlines and describes following four iterative phases required for and LCA:

- goal and scope definition,
- inventory analysis,
- impact assessment and
- interpretation.

In general, it was established that greater impacts are avoided for the recycling options compared to disposal by cement kiln or landfilling. Although additional resources and utilities are required for recycling operations (such as water for the washing of recyclable material or electricity for a shredder), the impacts of raw material production (which would be avoided for recycling) are generally higher than the impacts of the preparation of the waste materials to be used in recycling. Both recycling/use and disposal by cement kiln generally recover energy, avoid resource extraction (including non-renewable resources), and do not have an impact on land use, when compared to landfilling. There is a greater risk of ground and water contamination from landfilling (contaminants leaching to ground), and for the soil application of sewage sludge for agricultural purposes. The consumption of water and generation of wastewater are expected to be higher for recycling activities where substantial washing of the materials is required prior to being of use in the manufacturing process.

A literature review of case studies based on Life Cycle Assessments was conducted to further provide support of the environmental footprint, including impacts and benefits, of disposal by cement kiln compared to other options.

There is no single or ideal waste management strategy that will meet the needs of every community. In addition to assessing the impacts of the life cycle stages for the different waste management options, an integrated approach to waste management must incorporate the evaluation of the relevant economic, technical, political and social factors.

An integrated waste management strategy will therefore need to strike a balance between the various tiers and waste management approaches, and continue to push industry to assess opportunities higher up in the waste hierarchy. Disposal by cement kiln offers an additional waste management option, higher up in the hierarchy than landfilling. The cement kiln recovers energy and utilises the material value of the ash in the clinker. Waste materials less suitable for recycling and which have high calorific value should be processed through energy recovery rather than landfilling. Using such residual wastes as sources of energy displacing fossil fuels such as coal and can provide a reduction in GHG emissions. The availability of this option in South Africa is expected to divert a substantial amount of waste that would otherwise have been landfilled or illegally dumped, thus improving the status of waste management in South Africa.

Although source reduction provides the maximum benefit for many impacts, this practice does not always receive the attention it deserves, and the waste manager seldom has the opportunity to implement waste minimization programmes that would reduce wastes at source. However, the financial gains from source reduction are far greater than any other option, and therefore the option of disposal by cement kiln is not expected to provide a disincentive for industry considering minimisation options.

Conclusion

The practice of employing alternative fuels in cement plants does not hinder the establishment of a sound waste management industry. The practice can co-exist alongside a vigorous and thriving materials recovery and recycling and incineration industry, without distorting the essential principles of the waste management hierarchy.

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1 INTRODUCTION

With reference to previous meetings held with PPC and interested and affected parties, it became evident that there are a number of perspectives and perceptions towards the disposal of waste by cement kiln in comparison to other waste management options. It is vital that the role that the disposal of cement kiln can play in relation to the waste hierarchy, and the potential impacts and benefits of this disposal option be clearly understood.

These perceptions or perspectives include the following:

- Disposal of waste by cement kiln is not seen as recycling, but just another form of disposal (such as landfilling), and is therefore not a preferable option for waste (with only economical benefits).
- PPC is taking waste which could have been recycled.
- By creating a market for waste, PPC is giving generators an 'excuse' to generate waste, which will therefore create disincentives for the minimisation of waste generation.
- The co-processing of paper and cardboard in a cement kiln is not environmentally positive as it cannot be recycled (back into paper or cardboard products), and is therefore wasting usable resources.

This study was therefore initiated with the aim addressing the different perspectives. This has been achieved through two key environmental management principles:

- **Waste Hierarchy**: An in-depth assessment of the different tiers of the waste hierarchy is discussed, to identify the roles that disposal by cement kiln plays in each of the respective tiers, and to determine the most appropriate tier for disposal by cement kiln;
- **Comparative Risk Assessment - Life Cycle Approach:** A life cycle approach has been used to understand the environmental footprint of the different waste management options for the five waste streams under consideration.

Legislation, policy and international trends have been used to determine the extent of support for this waste management option.

This study therefore includes the following sections:

Waste Hierarchy (sections 2 to 6):

- Defining the Waste Hierarchy Tiers and PPC's role
- Disposal options in South Africa
- Costing of the different disposal options
- Legislation, Policy and International trends

Comparative Risk Assessment - Life Cycle Approach (sections 7 to 12):

- Disposal options considered
- Life Cycle Assessment Standard
- Identification and discussion of impacts
- Discussion of impacts and disposal options
- Literature review of existing LCA case studies

The waste streams discussed in this report are based on the five proposed waste streams PPC propose using as secondary fuels in the cement kilns:

- Scrap tyres and rubber waste
- De-watered, treated sewage pellets
- Hydrocarbon waste (such as used oil, oil-contaminated general waste, oil-contaminated soil and coal fines)
- Plastic waste
- Biomass (such as paper waste, sawdust, wood chips and waste from bio-fuel production)

2 DEFINING THE WASTE HIERARCHY TIERS

The waste hierarchy classifies waste management strategies according to their desirability. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

The approach to the waste hierarchy is a widely accepted environmental concept in which waste management follows a step-wise procedure which has remained the cornerstone of most waste minimisation strategies. The tiers of the hierarchy, defined in more detail within this section, are as follows:

- Waste Prevention – the prevention and avoidance of the production of waste
- Waste Reduction – the economic reduction of the volume of waste during production (by means of different processes or clean technology)
- Re-use, recycling and energy recovery – in-house or external re-use or recycling of the wastes or use of the calorific value of the waste for energy use
- Waste Treatment – the treatment of waste to reduce waste volumes or hazardousness
- Waste Disposal – the environmentally safe disposal of waste

It is important that any new waste option that is introduced to South Africa, benefits waste management in South Africa as a whole, and is aligned with the policies, strategies and regulations of South Africa. It must therefore provide opportunities that push the status quo of waste management up the tiers of the waste hierarchy.

This section is intended to -

- accurately define the different tiers;
- identify PPC's role in each tier of the hierarchy and determine the most appropriate tier for disposal by cement kiln and

The roles that PPC, the generator and the landfill operators play in the waste hierarchy are illustrated in the figure below. Table 2-1 contains precise definitions of each tier, which are based on a number of sources. Following this table in section 2.1, the waste hierarchy concept has also been refined and explained using three tiers, each fundamentally different from the other – this section further clarifies the roles of the generator, PPC and the landfill or waste incinerator.

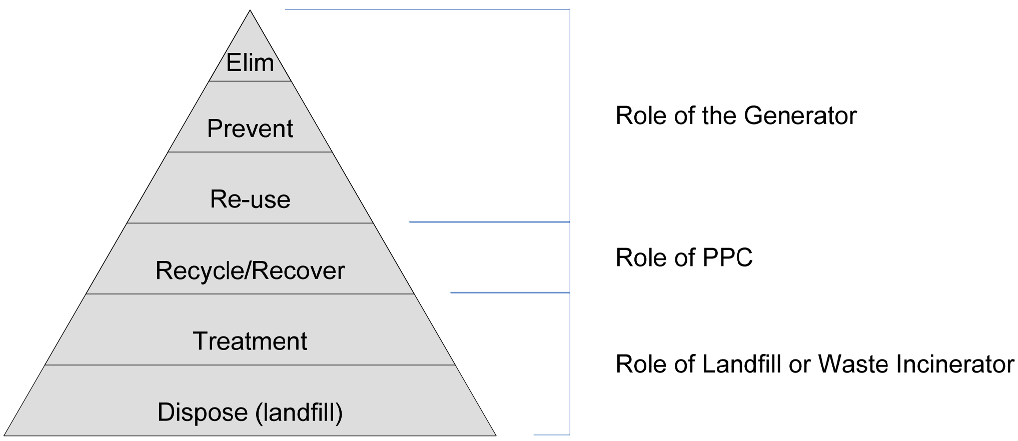


Figure 2-1: Roles in the Waste hierarchy

Table 2-1: Waste Hierarchy Definitions

Hierarchy Level and Definition(s)	Source
Abbreviations used for Source: **MR** — Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste, 2nd Edition (DWAF, 1998) **GDACE draft IWM** — Gauteng Department of Agriculture, Conservation and Environment draft Integrated Waste Management Policy **EPA** — U.S. Environmental Protection Agency **NWMS** — National Waste Management Strategy	
Elimination / Prevention	
Avoidance of waste generation is any activity that eliminates the generation of waste, at source, usually within a process.	MR
Preventing waste generation altogether (i.e. zero waste generation)	GDACE draft IWM Policy
Reduce/ Minimisation	
The reduction of the volume of waste during production by means of different processes or clean technology (usually at source).	MR
Source reduction, often called waste minimisation, means consuming and throwing away less. It encompasses any action undertaken by an individual or organization to eliminate or reduce the amount or toxicity of materials before they enter the municipal solid waste stream. This action is intended to conserve resources, promote efficiency and reduce pollution. Source reduction includes composting, purchasing durable, long-lasting goods and seeking products and packaging that are as free of toxic compounds as possible. It can be as complex as redesigning a product to use fewer raw materials in production, have a longer life, or be used again after its original use is completed. Because source reduction actually prevents the generation of waste in the first place, it is the most preferable method of waste management and goes a long way toward protecting the environment and supporting sustainable development.	GDACE draft IWM Policy
Reuse / Recover	
The return of a waste material either to the originating process as a substitute for an input material or to another process as an input material.	MR
Using an object or material again, either for its original purpose or for a similar purpose, without significantly altering the physical form of the object or material. Reuse is not recycling, because recycling alters the physical form of an object or material. Reuse is generally preferred to recycling because reuse generally consumes less energy and resources than recycling. Waste is defined as material for which no use or reuse is intended. Thus, reuse prevents objects and materials from becoming waste. Therefore, reuse is considered to be a form of waste prevention.	EPA
The recovery or re-application of a package or product for uses similar or identical to its originally intended application, without manufacturing or preparation processes that significantly alter the original package or product. Recovery can also refer to the recovery of energy from waste.	GDACE draft IWM Policy
Recycle	
The use or reclamation of a material so that it re-enters the industrial process rather than becoming a waste. Waste is processed for resource recovery.	MR
Recycling—Using waste as material to manufacture a new product. Recycling involves altering the physical form of an object or material and making a new object from the altered material. Recycling is not waste prevention because only waste can be recycled. One must generate waste in order to recycle the waste.	EPA
In the National Waste Management Strategy, the term recycling is used in its broadest sense, and refers to the related processes of resource recovery, waste re-	NWMS

use and the processing of recyclable materials recovered from both the general and hazardous waste streams. The recycling of waste forms an important part of the waste management hierarchy, one of the overriding principles upon which the NWMS is based. The recycling of waste is distinguishable from waste minimisation. In terms of the NWMS, ***waste minimisation*** comprises any activity that is undertaken *by the generator of waste* to prevent or reduce the volume and/or environmental impact of waste that is generated, treated, stored or disposed of. Waste minimisation may for example include activities taken by a waste generator relating to *internal* recycling. For the purposes of the NWMS, ***waste recycling*** only refers to initiatives aimed at the *external* recovery, re-use and/or reprocessing of post-consumer and post-production wastes. Recycling does not include the reuse of production waste.	
Treatment	
Treatment is used to remove, separate, concentrate or recover a hazardous or toxic component of a waste or to destroy or, at least, to reduce its toxicity in order to minimise its impact on the environment. These treatments would include physical treatment, chemical treatment, immobilisation, solidification, encapsulation and incineration.	MR
The reduction in hazardous character of the waste, or its volume, to ease environmental or human health risks and impacts.	GDACE
Safe Disposal (landfilling)	
To dispose of waste on land (Landfilling). Landfilling is the safe disposal of waste so that it will not pollute the environment or cause health hazards.	MR

2.1 Waste Hierarchy in Three Tiers

The Waste Hierarchy, which is generally divided into 5-7 tiers, can be grouped into three broader tiers, each based on a separate key principle of waste management. These three tiers simplify the waste hierarchy and better define the overall approach towards waste. The three tiers, illustrated in the following figure, are explained below.

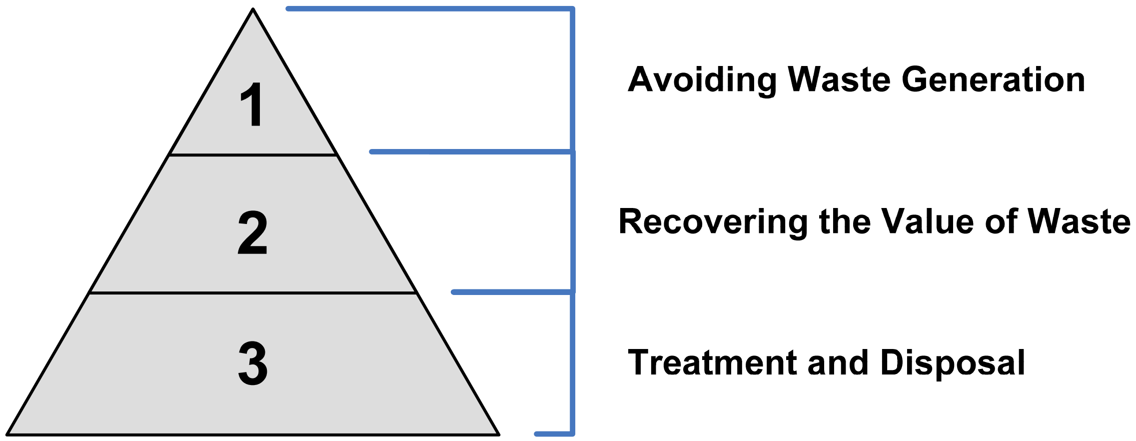


Figure 2-2: Waste hierarchy in three conceptual tiers

Tier 1: Avoiding Waste Generation

This tier, which comprises waste elimination and prevention (or reduction) is focused on the generator of the waste, and the **avoidance of some or all of the waste being generated.**

Reduction of waste is the avoidance of *part* of the waste stream, whereas elimination prevents the generation of a waste stream altogether. These “sub-tiers” are therefore just different levels of reducing some or all of a waste stream.

For example, the decision to drink tap water instead of bottled water will *eliminate* the plastic waste that is generated from bottled water. More efficient manufacturing processes that use (for example) less plastic to make the same bottle will *reduce* the quantity of waste generated.

This upper tier has far reaching environmental benefits across three key life cycle stages - the impacts are not only prevented for those impacts associated with the *disposal* of the waste (as no or less waste is generated), but also for the *processing* impacts associated with the manufacturing of products (such as chemicals, water, energy) and the *upstream processes* associated with the extraction, transportation and processing of *raw materials* required for the product, some of which will be generated as waste.

These impacts are therefore avoided altogether where waste is avoided. This will include impacts associated with energy, water, air, chemicals, effluent and resources.

Tier 2: Recovering the Value of Waste

In this tier, the value of waste is extracted and utilised. The different options of sub-tiers make use of the inherent value of the waste, to greater or lesser extent. This tier is fundamentally different from tier 1 in that this tier is only applicable **once the waste is generated**.

Although there are impacts associated with the generation of the waste (which are avoided in Tier 1), by extracting the value from the waste for use as a material in a product, the impacts associated with the extraction and production of new raw materials or products that have been replaced by the waste is now avoided. The impacts of landfilling are also avoided.

The waste can be utilised for its material (or mineralogical) and/or its energy value:

- The recycling of materials such as waste steel, glass, paper and plastic into their original or alternative use (e.g. plastic bags can be recycled to make plastic bags or plastic benches) is using the *material value*.
- The decomposing of food or garden waste for compost uses the *mineralogical value* of the waste.
- The use of waste plastics, oil and biomass to replace coal or oil as an energy source is utilising the *calorific* or *energy value*, and the impacts associated with the extraction and processing of fossil fuels are thereby avoided.

Although impacts may also be created through the processing of the waste to prepare the waste to a usable state (e.g. washing and shredding), life cycle assessments are expected to show that greater impacts are prevented through the avoided extraction and processing of the virgin materials.

Tier 3: Treatment and Disposal

This tier is focused on the safe and responsible permanent storage of waste, and adds no value to society in any manner. The treatment and disposal of wastes are purely to ensure that the wastes are managed in a safe and responsible manner such that the risks of *further impacts* are minimised.

Treatment includes the following types:

- chemical treatment, which reduces the level of toxicity;
- incineration (without energy recovery), which reduces volume and toxicity;
- compaction, which reduces volume and
- encapsulation, which immobilises hazardous elements.

The final disposal in a landfill (lined or unlined) provides a permanent storage location for the waste.

Both the treatment and disposal therefore does not provide any use, but aims to limit the impacts associated with this tier (such as air emissions, land space, transportation impacts for waste collection, leachate, etc.).

Which Tier does Disposal by Cement Kiln fall into?

The disposal of waste by cement kiln, is therefore placed into Tier 2, as the value of waste is recovered – waste is used both as a fuel (to replace the coal), and as a resource in the cement (the ash). Cement kilns cannot play any role in the reduction of the *generation of waste* (Tier 1), as they are not in a position to influence the resource efficiency of industry. Furthermore, disposal by cement kiln is not considered to be Tier 3, where no value is obtained through this tier.

2.1.1 Conclusions

Re-use, recovery and recycling involve the extraction of value from the waste, and are encouraged if waste can not be reduced or eliminated. Treatment and landfilling has no value associated with it.

Disposal of waste to cement kiln is therefore considered to be ***recovery, Tier 2**,* in that it avoids the use of virgin fuel and virgin raw materials required for the production of cement), and not on the same tier as landfilling. This places disposal by cement kiln above landfilling, a Tier 3 option, but does not assist in achieving waste reduction in any manner (Tier 1). Disposal by cement kiln is therefore not preferable to the avoidance of waste generation, but is a preferable approach to treatment, incineration (without energy recovery) and landfilling.

However, within Tier 2 there are a number of forms of recovery. The life cycle approach of section 7-12 has therefore included re-use and recycling in a comparative assessment to recovery (by cement kiln), in addition to the landfilling option, to establish the environmental footprint of these options.

Another question is then raised regarding the cost of the different waste management options, and whether they reflect the same order of the waste hierarchy tiers. Section 3 therefore explores the types of available options (and the status quo of those options available South Africa), and section 4 assesses the relative costs of the different options.

3 WASTE MANAGEMENT OPTIONS IN SOUTH AFRICA

Although there are many waste management options, not all are practised in South Africa, or only a small percentage are practised. Disposal by Cement Kiln is therefore offering an additional disposal option.

The following tables have been included to identify a set of possible waste management options (according to the tiers of the waste hierarchy, as explained in Section 2) for each waste stream. The current options that are provided in SA and status quo of these options are discussed to establish if there is a gap in the waste market in which that disposal by cement kiln may be a solution. This solution should promote the redirection of waste from the landfills, but not necessarily be more (financially) attractive than waste elimination and reduction (minimisation) programmes.

Table 3-1: Waste Management Options for the 5 waste streams

Waste Stream: Scrap tyres and rubber waste	
Option/tier	**Example**
Elimination	Alternative transport which does not use and waste tyres (e.g. trains), or uses fewer tyres (e.g. buses).
Reduction	Manufacturing longer lasting tyres Retreading tyres
Re-use	Reuse as tyres, if condition still up to standard Waste tyres reused for non-tyre uses - as e.g. leachate drainage systems for landfill engineering, playground swings
Recycle	Shredding, crumbing tyres include in surfacing for roads for asphalt, carpet underlay, street furniture and acoustic barriers. Shredding, crumbing and mixed with urethane is used to make athletic track surfaces and a variety of moulded products. Incorporation into new tyre rubber.
Recover	Material and energy recovery
Treat/Incinerate	Burn without energy recovery
Disposal	Landfilled, Stockpile, illegally dumped
Status Quo of Current Options offered in South Africa In South Africa transport options are mostly based on convenience and cost, and environmental considerations are not usually taken into account. 50% of heavy commercial tyres are retreads but very few passenger tyres are retreaded – Maxiprest and Trentyre import tyres to cover requirements for passenger tyre retreading. SA passenger tyres are driven to destruction such that they cannot be retreaded. 53% accidents are caused by tyre failures. Only 10% of tyres are recycled and reused in South Africa. There is currently one recycling plant in SA (which recycles tyres to tyres), and some various smaller operations reusing tyres to make other products like mats and rubber products. Tyres can replace between 5% and 30% of the traditional fuel (coal, oil) in cement kilns, depending on supply and demand and the regularity of supply. It was stated in 1998 that more than 28 million (approximately 60%) used tyres are dumped illegally or burnt to recover the steel wire, which is sold as scrap metal, a figure that is thought to increase by 9.3 million annually, according to the South African Tyre Manufacturing Conference (SATMC, 1998). Tyres are not readily accepted at landfill disposal sites as they are not easily compacted and	

occupy a considerable volume. Whole tyres can trap air and float to the surface of a landfill. This breaks the landfill cover and provides a home for hornets, mosquitoes, rodents, and other vectors. Illegally dumped tyres are recovered, regrooved sold to unsuspecting customers or burnt to recover steel.

Manufacturing a retread tyre for an average car takes 17 litres (4.5 gallons) less oil than the equivalent new tyre, and for commercial vehicle tyres the saving is estimated to be about 57 litres (15 gallons) per tyre. [1]

Waste Stream: Biomass	
Option/tier	**Example**
Elimination	Paper to Electronic format
Reduction	Print on both sides of paper
Re-use	Scrap paper, animal bedding instead of straw
Recycle	Paper products
Recover	Energy Composting
Treat/Incinerate	Burn without energy recovery
Disposal	Landfill

Status Quo of Current Options offered in South Africa

The use of electronic database and accounting systems can decrease the quantity of printed paper. Double-sided printing of hardcopy reports and documents reduce the number of pages by half.

38% of paper waste generated is recycled in SA. Paper can also be used as a composting component. Newspaper, for example, has a very low recycling value can be added to waste at composting sites (especially in wet composting processes).

Approximately 60% waste paper still ends up in landfill with general and household waste, every ton of paper takes up 3 cubic metres of valuable landfill space.

Waste Stream: Plastic waste	
Option/tier	**Example**
Reduction	Use less packaging material.
Re-use	e.g. Bottles or containers for further storage
Recycle	To original or alternative plastic products
Recover	Energy recovery
Treat/Incinerate	Recondition containers/drums Incinerate
Disposal	Landfill

Status Quo of Current Options offered in South Africa

In SA plastic is widely used as a packaging material. Plastic manufacturers have improved process which has resulted in requiring less virgin material to produce the plastic product.

14% of all plastics are recycled per annum (150 000 tons). Packaging plastics around 30% (of 500 000 tons for packaging). The recycling of plastic waste into outdoor furniture (Timber Plastic) is growing in SA.

Plastic drums and containers are reconditioned by drum reconditioners. Policy and legislation currently is being drafted to audit drum reconditioners in SA.

60-70% of plastic waste is landfilled and the incineration of plastic waste is generally not recommended due to potential release of VOC into the atmosphere from plastics such as PVC.

[1] Tyre Waste Arisings and Recycling Rates http://www.dti.gov.uk/sustainability/downloads/tyre.pdf.

Waste Stream:	Hydrocarbon waste (such as used oil, oil-contaminated general waste, oil-contaminated soil and coal fines)
Option/tier	**Example**
Reduction	Prevent oil spillages maintenance of appliances and machinery
Recycle	Laundering and regeneration; Used in bitumen for road construction
Recover	Energy source
Treat/Incinerate	Burn without energy recovery
Disposal	Discharged to Effluent Land-farming Landfill

Status Quo of Current Options offered in South Africa

The ROSE foundation encourages and improves the collection and recycling of used lubricating oil in SA. ROSE is now in its twelfth year of operation and has collected over 340 million litres of used oil in South Africa, through to its appointed collector, Oilkol (Pty) Ltd. While this has been an operation subsidised by the lubricants industry in South Africa, other collectors who explored the commercial opportunity were responsible for the retrieval of a further 500 million litres of used oil. Oil collected is either reprocessed into oil or used as a fuel.

Oil that that cannot be recycled is landfilled and must be disposed at an H:H disposal site, a more costly option.

Land-farming of oily sludges was common in the 1980s, and using compost, carbon, and aeration to clean up these same sites was also common in the 1980s and 1990s. Land-farming is not as widely practiced today as there is the additional risk subsequent remediation of the land-farm site and groundwater.

Waste Stream: De-watered, treated sewage	
Option/tier	**Example**
Recycle	Agricultural Use Soil rehabilitation and condition/applicators Adsorbents Nursery medium Landfill capping Pellet manufacture
Recover	Energy recovery e.g. PPC Compost
Treat/Incinerate	Ash Saleable products (Bricks and similar products)
Disposal	Landfilling Co-disposal

Status Quo of Current Options offered in South Africa

With a growing population it is not foreseen that the generation of sewage sludge will be reduced.

Guidelines for the Utilisation and Disposal of Wastewater Sludge : Volume 1, DWAF and WRC March 2006

The agricultural use of sludge is presented as the preferred management option. However, it is recognized that not all the sludge generated in South Africa can be used in agricultural practices. With current knowledge, there are three ways in which sludge management can contribute to sustainable development:

1. Utilising the calorific energy value of the sludge (e.g. in industrial furnaces and cement kilns).
2. Utilising useful constituents such as carbon and nutrients (example: agricultural use); or
3. Extracting useful constituents from the sludge (example: extraction of phosphorus). agricultural practices, is the most viable management option for South Africa, sludge not suitable for agricultural use
   - Sludge that is compromised by the contaminants such as heavy metals or organic contaminants;

- Lack of agricultural land that is available within a viable distance; and/or
- Community resistance against such practices

3.1 Conclusion

PPC does not play a role in the generation or minimisation of waste. This is the responsibility of the generator to identify and evaluate minimisation options.

Approximately forty to sixty percent of tyre, paper and plastic wastes are still disposed of at landfill sites. The development of guidelines for the management of wastewater sludge is still in the development phase but the importance of treating and reducing sewage sludge via the cement kiln as an energy source has been identified and are investigated.

Until waste management strategies and programmes are implemented by government and supported by waste generators, disposal by cement kiln can offer a viable option for diverting waste from the landfill sites. This venture must therefore be considered a component to the solution of waste going to landfill in South Africa. It is not expected to be an end or final solution to waste management. Opportunities for minimisation will still exist.

4 WASTE MANAGEMENT OPTION COSTS

There is a concern that because the disposal by cement kiln is expected to be a cheaper waste management option than lower tiers of the hierarchy such as landfilling, that this new option will give generators an ‘excuse’ to generate waste, which will therefore create disincentives for the minimisation of waste generation (the upper tiers).

The aim of this section is therefore to establish the financial costs and savings *to the generator* of waste for different waste management options for the five selected waste streams. This will therefore determine whether market forces, which are expected to favour the upper tiers, do in fact correlate with the ordered preference of waste management options of the waste hierarchy tiers.

For each waste stream, the following waste management options are costed:

- Elimination / Reduction
- Recycling
- Cement Kiln
- Landfill

These options are discussed individually, following which values are provided (based on researched information) to illustrate the types of savings and costs associated with each option.

4.1 Elimination / Reduction (Tier 1)

The biggest savings through the reduction of the amount of waste generated is not through the avoidance of landfilling costs, but that as fewer raw materials are required to manufacture a product, the costs of the raw materials are saved. Thus the true saving to the generator of the waste is calculated by summing up the following avoided costs:

Saving – Avoided cost of raw materials
Saving – Avoided processing costs (processing the materials into waste)
Saving – Avoided landfill costs
Saving – Avoided transportation costs (to the landfill, recycler or cement kiln)

Thus, for example, the cost of the elimination of rubber waste would save the generator the value of the replacement of that rubber. If fewer tyres are required (e.g. using busses instead of cars, or re-treading the tyre), the cost of the tyres itself is saved (in additional to downstream wastes costs.

4.2 Recycling (Tier 2)

For this waste management option, new (and costly) raw materials can be avoided, However, there is a cost associated with converting of waste material into a usable raw material.

Saving – Value received for waste from the recycler. The amount received from the recyclers would take into account the value of the raw materials which would be saved for the new product, less any conversion costs required to process the waste into a usable material.
Saving – Avoided landfill costs
Saving – Avoided transportation costs to the landfill
Cost – Cost of processing waste to usable form
Cost – Transportation costs to the recycler

4.3 Cement Kiln (Tier 2)

Similarly to recycling, cost of transporting and processing the waste into a usable form will be incurred, but virgin materials required for energy and cement production will be saved.

Saving – Avoided landfill costs
Saving – Avoided transportation costs to the landfill
Saving – Avoided cost of virgin materials
Cost – Cost of processing waste to usable form
Cost – Transportation costs to the cement kiln

4.4 Landfilling (Tier 3)

Landfilling will only incur costs to the generator.

Cost – Landfilling disposal fee
Cost – Transportation costs to the landfill

Based on information gathered by Marsh Vikela, the respective costs and savings for each option were obtained and are shown in the table below, including the estimated highs and lows.

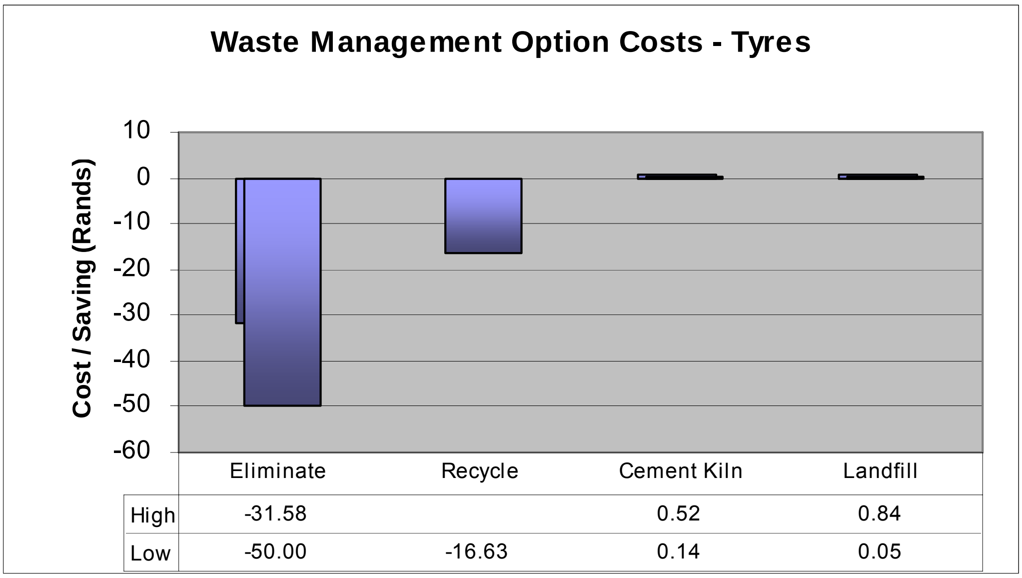
Table 4-1: Costs and savings for alternative waste management options

Waste Option	Cost for the respective Waste Management Options (units in Rand/kg)									
	Tyres		Biomass		Plastic		Oils		Sewage	
	Low	High	Low	High	Low	High	Low	High	Low	High
Eliminate	-50.00	-31.58		-14	-3.4		-20.7	-61	N/A	
Recycle	-16.63		-1	-0.3	-2	-1	-0.183		0 (compost)	7
Cement Kiln	0.14	0.52	0.14	0.52	0.14	0.52	0.52	-0.84	0.045	
Landfill	0.05	0.84	0.08	0.103	0.08	0.103	0.1402	1	0.03	0.1

Notes:

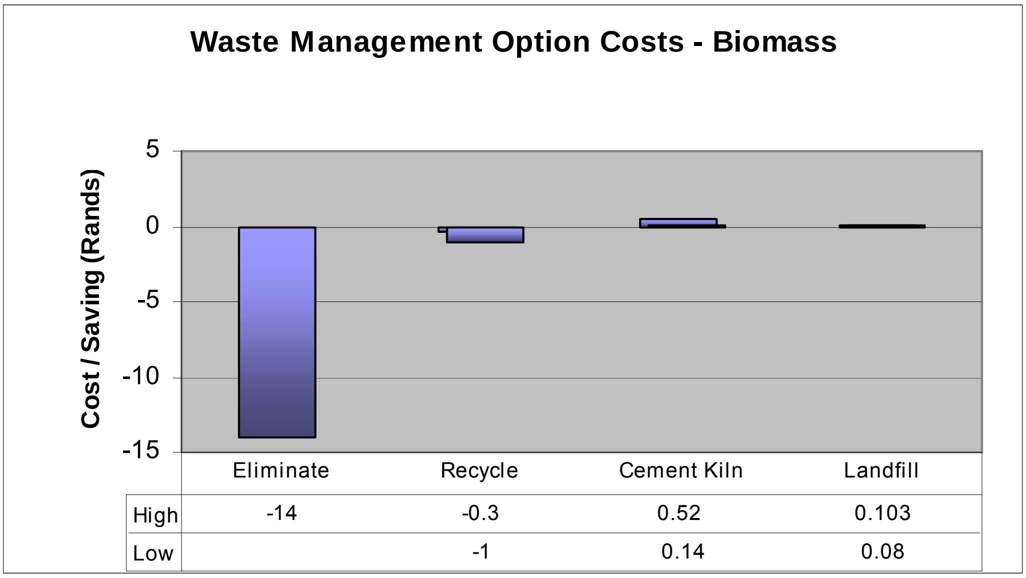
- Saving is represented by a negative value (e.g. -50 = saving of R50 per kilogram)
- Transport costs excluded for all options.
- Cost of final product (e.g. tyre) takes into account the raw materials and the associated processing costs.
- Costs for disposal by cement kiln are expected to be higher (approximately 52 c/kg) for the first five years, and decrease (to approximately 14 c/kg) thereon after for tyres, biomass and plastics.[2]

[2] Figures supplied by PPC, but actual costs will depend on a number of factors (waste size, quantity, required pre-processing etc.)



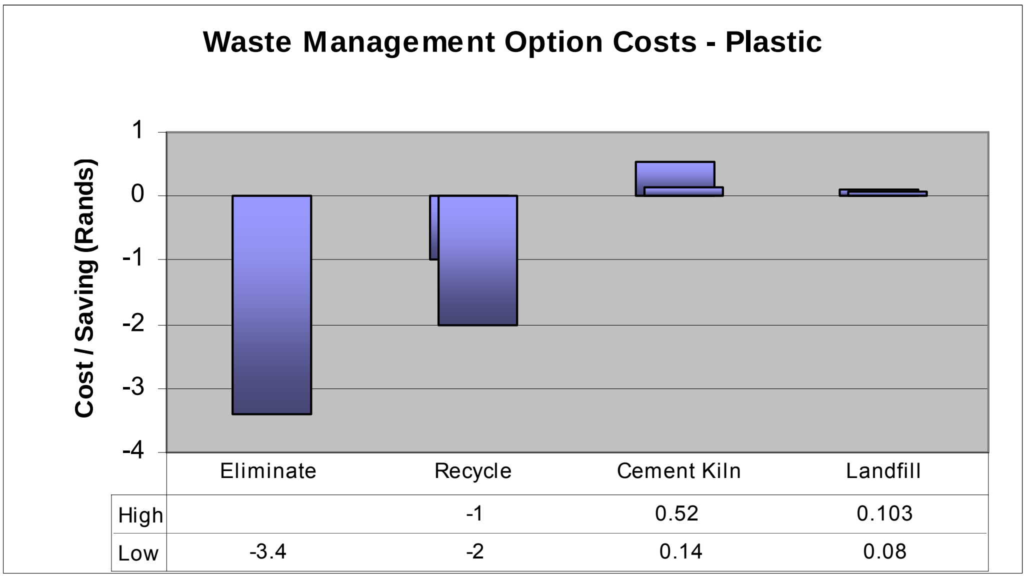
	Eliminate	Recycle	Cement Kiln	Landfill
High	-31.58		0.52	0.84
Low	-50.00	-16.63	0.14	0.05

Figure 4-1: Waste management option costs for tyres



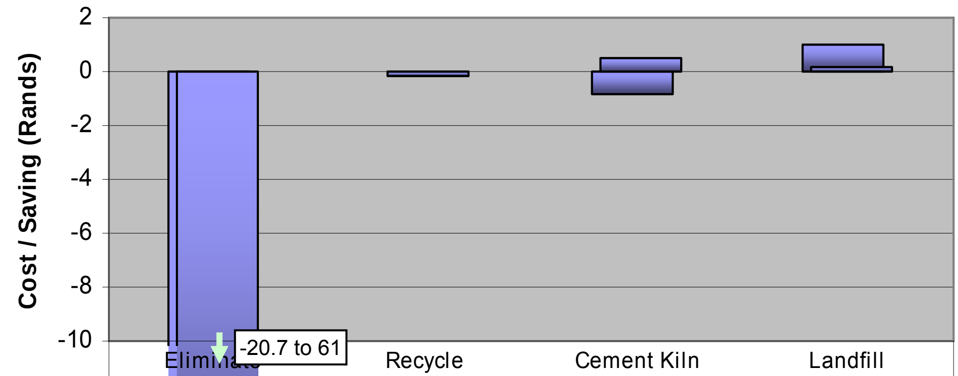
	Eliminate	Recycle	Cement Kiln	Landfill
High	-14	-0.3	0.52	0.103
Low		-1	0.14	0.08

Figure 4-2 : Waste management option costs for biomass



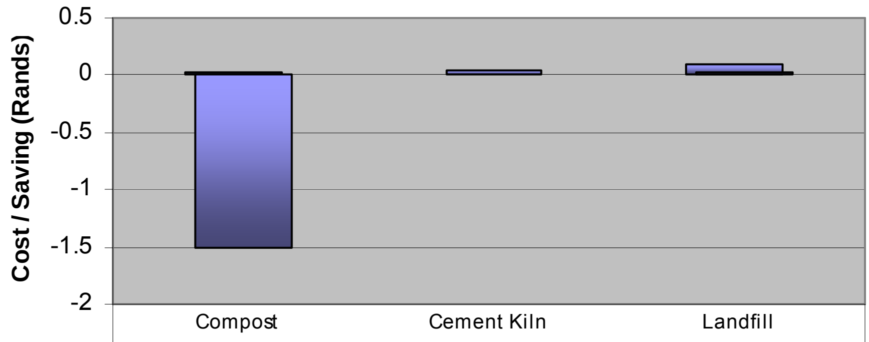
	Eliminate	Recycle	Cement Kiln	Landfill
High		-1	0.52	0.103
Low	-3.4	-2	0.14	0.08

Figure 4-3: Waste management option costs for plastics



	Eliminate	Recycle	Cement Kiln	Landfill
High	-61		-0.84	1
Low	-20.7	-0.183	0.52	0.1402

Figure 4-4: Waste management option costs for oils



	Compost	Cement Kiln	Landfill
High	0.00		0.1
Low	-1.5	0.045	0.03

Figure 4-5: Waste management option costs for sewage

4.5 Conclusion – Waste Management Cost Options

The difference in savings and costs for the waste management options are clear, and that disposal by cement kiln is clearly not providing disincentive to recycling or reduction options.

Market forces therefore favour the upper tiers of the waste hierarchy and therefore preferable options such as re-use or minimisation of waste will remain an option where opportunities exist or are created (a disincentive is therefore not created for the upper tiers).

Where recycling is not feasible (e.g. market cannot recycle tyres due to the vulcanisation process), disposal by cement kiln becomes a feasible alternative.

Where landfill fees exceed the fees charged by PPC, or where the landfilling is not feasible, disposal by cement kiln will be an acceptable option.

5 LEGISLATION, POLICY AND INTERNATIONAL TRENDS

South African waste management legislation and policies developed over the last few years are moving away from the end-of-pipe management and encouraging waste prevention and minimisation. The National Waste Management Strategy support and encourage waste minimisation. PPC can reuse waste as an alternative fuel in cement kilns, this does not improve minimisation of generated waste but can reduce the volume of waste landfilled.

The following sections summarise the waste management principles, policies and national strategies in South Africa, and the manner in which the PPC alternative fuel study conforms.

Table 5-1: Legislation, policies and principles s reviewed

Legislation / Policy / Principle	Year of publication/ promulgation
National Environmental Management Act - Waste Management Principles	Act no. 107 of 1998
Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste	2nd Edition (DWAF, 1998)
Polokwane Declaration	*September, 2001*
National Waste Management Strategy (NMWS-SA)	1999 adopted NWMS
White Paper on Integrated Pollution and Waste Management for South Africa	*DEAT, Planned in NWMS,* 2000
Gauteng Provincial Integrated Waste Management Policy	*March 2006, Draft*
Sewage Sludge Guidelines	*DWAF and WRC, March 2006*

5.1 Waste Management Principles

The key **principles** that govern this responsibility and handling of waste as described in the *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (Second Edition 1998)* and/or the National Environmental Management Act are as follows:

Duty of Care Principle – The industry that generates a waste incurs a duty of care that is owed to society. This means that the generator is responsible for the fate of the generated waste in all circumstances. The generator of the waste is ultimately responsible for ensuring that the waste is handled, stored, transported and disposed of according to the legislation and in an environmentally sound and responsible manner.

Polluter Pays Principle – the person or organisation causing pollution is liable for any costs involved in cleaning it up or rehabilitating its effects. The generator of the waste is thus liable unless able to prove that the transferral of management of the waste was a responsible action.

Precautionary Principle – all waste is assumed to be both highly hazardous and toxic until proven otherwise.

Sustainable Development – sustainable development requires the consideration of all relevant factors, including that waste is avoided, or where it cannot be altogether avoided, is minimised and reused or recycled where possible and otherwise disposed of in a responsible manner.

PPC Alternative Fuel and the Waste Management Principles
The waste generator is responsible for implementing waste minimisation and recycling plans. PPC offer an alternative to waste disposal for certain waste streams which is not viable to recycle. PPC can use the waste as an input product in their process and an energy source, thus reducing the amount of waste being landfilled.

5.2 Policy and Strategy

Polokwane Declaration

At the first National Waste Summit held in Polokwane in September 2001, the Polokwane Declaration was adopted which commits South Africa to reduce waste generation and disposal by 50% and 25% respectively by 2012 and develop a plan for ZERO WASTE by 2022. Future waste legislation will promote reuse and recycling, and require manufacturers to develop products that do not create waste and that can easily be recycled.

National Waste Management Strategy

The National Waste Management Strategy (NWMS) presents a long-term plan for addressing key issues, needs and problems experienced with waste management in South Africa. The overall objective of this strategy is to reduce the generation of waste and the environmental impact of all forms of waste and thereby ensure that the socio-economic development of South Africa, the health of the people and the quality of its environmental resources are no longer adversely affected by uncontrolled and uncoordinated waste management

The objective of integrated pollution and waste management is to move away from fragmented and uncoordinated waste management to integrated waste management. The strategy outlines a more holistic and integrated management approach that extends over the entire waste cycle from cradle to grave, and covers the prevention, generation, collection, transportation, treatment and final disposal of waste.

The management of waste will thus move away from management through impact management and remediation (end-of-pipe treatment) to establishing a waste management system which focuses on waste prevention and waste minimisation (source control)

The NWMSI-project (National Waste Management Strategy Implementation Project) is a follow-up of the NWMS strategy and focuses at implementation of Selected National Waste Management Strategy Components. The selected components are Health Care Waste, Recycling and Waste Information System.

The Immediate Objectives of the implementation project:

- 1 - Improved Health Care Waste Management: Sustainable and integrated Health Care Waste Management in South Africa, established within the frames of the NWMS, covering the full waste stream for all generators of HCW from areas with varying population densities and varying degrees of accessibility.
- 2 - Waste Information System is established and in use: A Waste Information System (WIS) has been established in DEAT with management and software in place. Minimum reporting requirements has been established for provincial and local level.
- 3 - Recycling of waste is increased and extended: In the pilot areas, new waste streams are identified, existing initiatives are expanded, and improved and new initiatives are implemented. Appropriate mechanisms are identified and developed that promote sustainable recycling by all members of the recycling chain. Appropriate mechanisms for recycling within specific circumstances will be based on an appraisal of the social, environmental and economic benefits and costs of recycling in comparison with one-way consumption and disposal.
- 4 - DEAT to take control of NWMS: The NWMS is deeply anchored in the DEAT who through capacity development and project involvement has been enabled to take full control of future implementation. Long term sustainability has been secured by DEAT staff capacitating as well as successfully tested mechanisms for dissemination of project results.

Final Draft: Gauteng Provincial Integrated Waste Management Policy

The Gauteng Provincial Integrated Waste Management Policy (final draft) is a means by which the objectives of the Constitution, the National Environmental Management Act (NEMA 2000), The Water Act (1998) and the Air Quality Act (2004) and the forthcoming National Environmental Management Waste Bill etc can be enabled at the Provincial level.

The overall goal of the development of an IWM Policy for the Province is to set out the vision, principles and strategic goals and objectives that the Gauteng Provincial Government will apply to achieve integrated and environmentally sustainable waste management in the Province, thereby ensuring that its obligations and duties in terms of the Constitution (1996) and other relevant requirements are effected.

The Gauteng IWM Policy thereby provides initiatives to meet the objectives of the NEMA at the provincial level, to provide for co-operative environmental governance by establishing decision-making principles on matters affecting the environment including the following:

- Sustainable Development;
- Integrated Environmental Management using the Best Practicable Environmental Option (BPEO);
- the Polluter Pays Principle;
- the Cradle to Grave Responsibility;
- the Precautionary Principle; and
- the involvement of Interested and Affected Parties (IAPs) and stakeholders in environmental decision making.

Each of the following policy items, described in the Policy reflects the heading of an objective, which in turn stems from the goal of the Policy:

- Policy 1: Integrated Waste Management Planning
- Policy 2: Roles and Responsibilities
- Policy 3: Waste Information Management
- Policy 4: Institutional Development
- Policy 5: Capacity Building
- Policy 6: Alignment with National Legislation
- Policy 7: Funding
- Policy 8: Avoidance and Substitution
- Policy 9: Waste Reduction and Minimisation
- **Policy 10: Waste Recovery and Recycling**
- Policy 11: Waste Collection and Transportation
- Policy 12: Waste Processing
- Policy 13: Waste Treatment and Disposal
- Policy 14: Environmental Management
- Policy 15: Selected Waste Streams

Guidelines for the Utilisation and Disposal of Wastewater Sludge

The agricultural use of sludge is presented as the preferred management option. However, it is recognised that not all the sludge generated in South Africa can be used in agricultural practices.

The principle of sustainability
These Guidelines support the principle of appropriate/sustainable use of resources. Sludge management options should not harm the environment by either the inefficient use of non renewable resources or the accumulation of a substance/compound in the environment to harmful levels. This is in line with the resolution of the World Summit on Sustainable Development held in South Africa in 2002.

Aligning South African guidelines with international trends
These sludge guidelines introduce a new sludge classification system, which is more in line with international trends and best practices.

Motivation for Developing the Sludge Guidelines
The concept of sustainability was adopted as the ideal during the development of the 2nd edition of the Sludge Guidelines. Sustainable management options include options that do not harm the environment by either the use of a non-renewable resource or a build-up of

substances in the environment to the extent that the assimilative capacity of the receiving environment has been exceeded. Unsustainable management options include disposal practices such as stockpiles, certain landfill and dedicated land disposal practices.

With current knowledge, there are three ways in which sludge management can contribute to sustainable development:

- Utilising the calorific energy value of the sludge (example: generating heat); or
- Utilising useful constituents such as carbon and nutrients (example: agricultural use); or Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 1 6
- Extracting useful constituents from the sludge (example: extraction of phosphorus).

According to the report, most agree that the second option i.e., utilising the useful constituents such as carbon and nutrients in the sludge, particularly in support of agricultural practices, is the most viable management option for South Africa. However, one also needs to be realistic and recognise that not all sludge generated in South Africa is suitable for agricultural use. For these sludges, the other two sustainable options may be considered. Factors that could exclude sludge from agricultural utilisation include:

- Sludge that is compromised by the concentration of contaminants such as heavy metals or organic contaminants;
- Lack of agricultural land that is available within a viable distance; and/or
- Community resistance against such practices.

It was therefore necessary to develop guidelines for other management options such as disposal and incineration and also provide opportunity for innovation. Each sludge management option was developed as a separate guideline volume. This simplifies the Guidelines for users, as each guideline focus on the management, technical and legislative aspects associated with a particular option. Each of the management options has different regulatory requirements and the sludge classification requirements for each option vary.

Volume 5: Requirements for thermal sludge management practices and for commercial products containing sludge

Volume 5 is divided in two parts. The first part addresses the use of thermal methods to manage sludge. The second part addresses the use of sludge to manufacture saleable products. These aspects were combined in one volume, as many of the saleable products include a thermal process in their manufacturing process. For example, the use of sludge in brick manufacturing could be seen as both a thermal process and producing a saleable product.

Volume 5 will be used for guidance on the:
Use of thermal methods to manage sludge
- **Incineration in dedicated incinerators.** This Volume addresses the requirements for the incineration of sludge with specific reference to the operational requirements and management of the air emissions and the ash residues.
- **Incineration in furnaces, cement kilns, etc.** Sludge can also be co-incinerated in industrial processes such as industrial furnaces and cement kilns. This volume addresses the requirements for these practices. This will include the use of sludge in the manufacturing of bricks.

Alignment of PPC Alternative Fuel with the Policies and Strategies

PPC, with the goal set at reducing the use of natural resources by means of using wastes as an alternative fuel, together with reusing the wastes will result in waste being diverted from the landfill. The use of alternative fuels in cement kilns is therefore in alignment with the objectives set in Polokwane Declaration (reducing waste disposal), and to the holistic approach embodied in the NWMS.

More specifically, the strategy will fit in to the *third* objective of the NWMSI-project, and to the Gauteng Policy (final draft), policy no.10 (for the recovering and recycling of other materials).

5.3 International Trends and Case Studies

International trends show current and increasing interest in the disposal of waste in incinerators with energy recovery and by cement kiln. The following examples are provided to illustrate this (data sources provided for each section):

1. Environmental Benefits of Using Alternative Fuels in Cement Production – A Life Cycle Approach, CEMBUREAU

CEMBUREAU, The European Cement Association, based in Brussels[3]

With respect to waste management, in 1997 the European Commission published a review of the Community Strategy for Waste Management originally established in 1989. The review endorses the concept of sustainable development and the principles of the waste management hierarchy, namely:

- prevention of waste;
- recovery of waste (including material recycling and energy recovery);
- safe disposal of waste;
- application of the proximity principle and self-sufficiency in waste management outlets.

(Note: This report has been used as a case study in section 12.3)

2. Paper disposal in Ireland - the options

Recent figures suggest that 21% of household waste in the Dublin Corporation area is paper. This makes an obvious target for the Government in their recent recycling plan which aims for a recycling rate of 25% in packaging paper by the year 1999. A second aim in this strategy is to raise energy recovery from paper and other packaging materials to a level of 50%. In the long term, which disposal option will prove to be the best: energy recovery, recycling or the other options of composting, animal bedding and landfill?

http://www.iol.ie/~mazzoldi/toolsforchange/zine/lun94/paper.html

3. Tyre Waste Generation and Recycling Rates

http://www.dti.gov.uk/sustainability/downloads/tyre.pdf.

Energy Recovery

There are advanced proposals for two tyre pyrolysis plants: one in Staffordshire which would utilize 65 000 tonnes of used tyres and generate approximately 15.5 MW electricity, another in Derbyshire would take around 60 000 tonnes of tyres.

An alternative energy recovery option is the incineration of tyres in cement kilns. The Used Tyre Working Group (UTWG) believes this can represent the Best Practicable Environmental Option (BPEO). Three cement manufacturers operate kilns, at around twenty UK locations, although not all of these are suitable for tyre use. Tyres are able to replace up to about 25% of the coal which would otherwise be used and also reduce nitrogen oxides emissions. The UTWG predicts the current capacity of cement kilns, of around 30 000 tonnes of tyres per annum, will grow to around 80 000 tonnes in the near-term, with a further potential capacity beyond that. In the longer term, the cement industry has indicated that it could handle around half of the UK's total tyre arisings. The UTWG believes this recovery route will be key to achieving 100% tyre recovery by 2006.

Technical and Economic Barriers to Recycling Tyres

As previously mentioned, burning tyres in cement kilns is one of the key options for recycling tyres. The Environment Agency stated in their November 1998 report 'Tyres in the Environment' that, 'from an environmental viewpoint, cement kilns are a good option for the energy recovery of used tyres'. However, several pressure groups, including Friends of the

[3] http://www.cembureau.be

Earth and 'The Campaign Against the New Kiln', claim that dioxins, particulates and similar materials are unacceptable hazards from kilns. These concerns are taken into consideration during the risk assessment process before the authorities grant permission for a kiln to burn tyres.

Note that the *Process Risk Assessment* conducted by Marsh Vikela for the purposes of the EIA discusses similar issues for the cement kilns of PPC, South Africa.

4. European Commission (EC) Directives

Landfill Directive
The EC Landfill Directive came into force on 16 July 1999, and it contains specific targets for tyres. The Directive requires the UK to prohibit landfilling of whole tyres by 2003 and the landfilling of shredded tyres by 2006 in new landfill sites. The timetable for existing landfill sites in subject to confirmation.

Incineration Directive
The EC Waste Incineration Directive is intended to prevent or reduce negative effects on the environment caused by the incineration and co-incineration of waste. Cement kilns do not fall under the auspices of this Directive unless they use waste (such as tyres) as a fuel.

5. European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste

http://europa.eu.int/eur-lex/lex/LexUriServ/LexUriServ.do?uri=CELEX:31994L0062:EN:HTML

This Directive states that energy recovery is one effective means of packaging waste recovery.

6. Scrap Tyre Recycling

Scrap Tyre Recycling - A summary of Prevalent Disposal and Recycling Methods.
Kurt Reschner, Berlin, 2006
http://www.entire-engineering.de/str/en.html (page last updated on 22-01-2006)

Scrap Tyre Disposal Statistics
The publicly available information on scrap tyre generation and disposal is fairly intransparent. The figures presented here are a compilation from several different sources. Retreadable tyre casing are not included in these figures.

Table 5-2: Scrap Tyre Disposal in EU Member States and the U.S. in 1999. All figures are in metric tons, percentage figures are rounded. Sources: Recycling Research Institute, European Tyre Recycling Association (ETRA), compilation by Kurt Reschner

Means of Disposal	EU		USA	
Tyre Derived Fuel (TDF)	508,500	22%	950,000	40%
Landfilling	1,017,100	46%	920,000	38%
Civil Engineering	228,900	10%	225,000	9%
Rubber Recycling	228,800	10%	180,000	7%
Export and Miscellaneous	279,700	12%	135,000	6%
Total:	**2,263,000**		**2,410,000**	

Tyre Derived Fuel (TDF)
The report states that the use of tyre derived fuel (TDF**)** in cement kilns, paper mills or power plants is a perfectly reasonable use for scrap tires, *if recycling is not a viable option.* While uncontrolled fires cause substantial air and ground pollution, the incineration of whole tires or tyre chips in a controlled furnace is environmentally safe. On average, the heat value of scrap tires or TDF exceeds that of coal, while the sulfur content is in the same order of magnitude or even lower. Cement kilns are by far the largest users of TDF. Some cement companies have the capacity to incinerate whole tires, thus being able to omit the comparatively expensive size reduction process.

Rubber Recycling
A concise definition of recycling would be *the re-use of a material for its originally intended purpose, e.g. old aluminium cans are used to make new ones.* In the case of scrap tires, recycling would mean the use recycled tyre rubber as a compounding ingredient for new tires. In a broader sense, recycling of tyres is referred to as grinding scrap tyres into crumb rubber while removing steel, fibre and other contaminants. In North America, the markets and applications for recycled tyre rubber ("crumb rubber") have developed tremendously in the past decade. The different markets and uses for recycled tyre rubber are discussed in greater detail in the section Products and Applications.

Landfilling
Most landfills accept whole scrap tyres only at a hefty tipping fee [not necessarily the case in South Africa) because tires are awkward to handle and difficult to compact. In some instances, scrap tires have worked their way to the top of a closed landfill, causing costly damages to the landfill cover.

Nonetheless, a significant part of the current scrap tyre generation still ends up in landfills. Since a ban on landfilling whole tires was implemented in most States, scrap tires are usually cut into pieces or shredded before landfilling in the U.S.

The EU Landfill Directive similarly bans whole tires from landfills by 2003. By 2006, tires in any shape or form will be banned from landfills in EU Member States. In order for the EU Landfill Directive to be implemented in a timely manner, new disposal routes for scrap tires need to be developed with great urgency in all EU Member States.

A variation of landfilling is monofilling, which means that scrap tires are not mixed with other waste materials, but stored at a dedicated, licensed location. Once the monofill has reached its capacity, it is covered like any other landfill to reduce the fire hazard and also prevent mosquito breeding.

Civil Engineering Applications
Tyre derived products, mostly 25mm tyre chips are sometimes used to replace conventional construction material, e.g., road fill, gravel, crushed rock or sand. The benefits of using tyre chips instead of conventional construction materials are amongst others: reduced density, improved drainage properties and better thermal insulation. The following are examples of projects where scrap tyre chips have been successfully used in civil engineering applications:

- Lightweight fill for embankments and retaining walls
- Leachate drainage material at municipal solid waste landfills
- Alternative daily cover at municipal solid waste landfills
- Insulating layer beneath roads and behind retaining walls

Civil engineering applications of scrap tires are expected to become more widespread as more and more applications can be proven to be technically and economically viable.

According to the report, it takes 3 – 4 times as much energy to produce tyre rubber, compared to the energy recovered by "thermal recycling". Consequently, the use of recycled tyre rubber for its originally intended (or related) purpose makes by far more sense than incineration, both environmentally and economically (however, only a small percentage can be recycled back into new tyres). The following list shows the main scrap tyre disposal and recycling methods, classified hierarchically, by environmental and economic preference.

Table 5-3: Scrap tyre disposal methods, ranked by environmental preference.

Rank	Processing Method	Examples
1	Use **PRODUCT** for its originally intended purpose as long as possible.	Design rubber compound and tyre geometry for maximum durability. Keep tyre properly inflated at all times to ensure maximum service life. Reuse partly word tires. Regroove or retread tyre casings.
2	Use **MATERIAL** for its originally	Grind scrap tires into crumb rubber,

	intended purpose.	separate steel and fibre. Sell rubber as raw material.
3	Use whole scrap tires for energy recovery.	Burn whole scrap tires as fuel supplement in cement kilns.
4	Use mechanically processed tires for energy recovery.	Tyre chips added to coal as fuel supplement in power plants, paper mills, cement kilns, etc.
5	Alter the chemical structure of scrap tires and use the products for energy recovery.	Pyrolysis, Supercritical Extraction.
6	Storage for possible recovery at a later time.	Monofilling.
7	Disposal without any current or future use.	Landfilling.

Some might argue that the preference list shown in Table 3 is the result of an environmentalist agenda with little footing in the real world. In fact, the international trade with partly worn tires and retreadable tyre casings shows that market participants world wide-have similar priorities. Market forces have a clear verdict on the next two options as well: recycled tyre rubber (crumb rubber) sells for 200 – 400 US$ per ton, whereas tyre derived fuel (TDF) fetches one tenth of that price. This is a clear indication that, sound environmental practices and market forces are not necessarily opposing when it comes to tyre disposal.

7. Waste Oil Recycling – Use as Fuel

UK Waste Oil Recycling *http://www.dti.gov.uk/sustainability/downloads/oil.pdf*

Use as Fuel

Waste oil that is used as a fuel in the UK must undergo basic treatment to remove water and particulates before it is fit for use as fuel known as recovered fuel oil. In the UK, the vast majority of the waste oil stream is currently used as fuel by industries such as power generation, road-stone coating and cement manufacturing.

The oil products from these processes have similar properties and emissions levels to virgin oils, but cost and volume constraints mean that these do not tend to compete directly.

The Proposed Hazardous Waste Incineration Directive (UK)

The Hazardous Waste Incineration Directive will significantly increase the stringency of emissions limits for incineration facilities, including those burning used oils. In the future, this may drastically reduce the number of facilities that will accept used oils, and hence reduce this avenue for recovered oil markets.

5.4 Conclusions

The policies, principles, legislation and international trends support recycling, recovery and reduction of waste, including disposal by cement kiln. Diverting waste from the landfill and reuse as an alternative fuel is in alignment with the waste management principles, policies, strategies, and declarations that have been developed or are being developed in South Africa and the province, and will ensure progression towards meeting of strategy objectives and waste management goals of South Africa.

6 SUMMARY AND CONCLUSIONS TO THE WASTE HIERARCHY

The discussion on the waste hierarchy is clear that disposal by cement option is preferred option to landfilling where the reduction in waste or recycling of waste is not viable. Disposal by cement kiln has an important role in waste management in South Africa. Not only is the energy value of the waste utilised, thus replacing the need for other fossil fuels (coal), but the ash elements are needed and therefore incorporated into the production of cement. Thus disposal by cement kiln results in zero waste to landfill.

Market forces have been shown to be favourable for the upper tiers of the waste hierarchy (reduction and recycling), thus ensuring that where viable, industries generating the waste will benefit more (financially) from any waste minimisation programmes than disposal by cement kiln.

As stated in the CEMBUREAU report, the practice of employing alternative fuels in cement plants does not hinder the establishment of a sound waste management industry. This practice can co-exist alongside a vigorous and thriving materials recovery and recycling and incineration industry, without distorting the essential principles of the EU’s waste management hierarchy.

The legislation, policies and strategies of South Africa holds supports for disposal by cement kiln with regards to the trends of waste management practices in South Africa, diverting waste from landfill (lower tier of the hierarchy) to alternative uses.

The previous sections (2 to 6) have focused on the benefits and impacts related to *waste management*. However, each waste management option has a wider range of impact that will have an effect on the environment. The next few sections (7 to 12) therefore takes a wider approach to each option for the different disposal options for the five respective waste streams under consideration using a life cycle approach. In these sections, all impacts (including energy, resources, emissions and land use and water) are addressed, discussed and compared.

7 INTRODUCTION TO THE LIFE CYCLE APPROACH

PPC is investigating the disposal of waste materials in five cement kilns as an alternative to conventional disposal methods such as landfilling and recycling. The potential benefits of disposal by cement kiln are reduced cost to the waste generator, reduced production costs to PPC, and a *smaller environmental impact*. Whereas the costs to the generator and PPC of the disposal options are relatively simpler to calculate, the determination of the environmental impact and whether it is less damaging than the impact of conventional disposal methods involves many complex systems that requires an in-depth study.

A comparative analysis of this nature must be able to compare like with like, and not make claims based on the *perception* of the relative environmental impacts of various alternatives. Claims made between alternatives as to which one is less environmentally damaging are often based on only a few impacts (e.g. that disposal by cement kilns is better because landfill space is saved or that landfilling is better because toxic emission are not released). The impacts of alternative disposal options (such as *recycling*, disposal by cement kiln and *landfilling)* can therefore be best understood when the impacts are considered from a life cycle perspective. Each alternative process utilises various inputs (natural resources and energy) and outputs (emissions and releases to air, water and land). Only by summing the burdens (and benefits) of all upstream and downstream processes for both competing alternatives, can the impacts truly be evaluated and compared.

For example, when a material is recycled, it is used in place of virgin inputs in the manufacturing process, rather than being disposed on a landfill, and has additional benefits. The substitution of recycled inputs for virgin inputs reduces three types of emissions through the life cycle:

- First, manufacturing processes involving recycled inputs generally required less energy than those using virgin inputs.
- Second, the use of recycled inputs leads to reductions in process non-energy emissions.
- Third, recycling reduces emissions from disposal and waste management emissions, including methane from landfills. In addition to GHG (greenhouse gas) emission reductions from manufacturing and disposal, recycling of paper products (for example) results in increase forest carbon sequestration. When paper is recycled, fewer trees are needed as an input to the manufacturing process; reduced harvest levels result in older average forest ages, with correspondingly more carbon stored. [1]

This “cradle-to-grave” approach (in which the cradle is the waste generation and the grave the final disposal for this study) is the underlying concept of Life Cycle Assessment (LCA) methodology. *Life Cycle Assessment* is an environmental management tool that evaluates the environmental impact of a product or activity across its entire life. It can be invaluable in identifying environmental “hotspots” in a product’s life cycle, as well as a tool for comparing products.

The life cycle will consists of a number of processes that includes waste generation, avoided raw material extraction, cement production, transportation, storage, final disposal.

Environmental Business Strategies has adopted a LCA approach in determining and comparing the environmental impacts of disposal alternatives.

7.1 Purpose of this study

This study is not intended to be a highly detailed Life Cycle Assessment. It is intended to compare major environmental impacts for each disposal option for the respective wastes using a life cycle approach.

This study aims to do the following:

1. highlight the multitude of impacts across the life cycle that must be considered and understanding to a life cycle approach to assessing the impacts

2. identify and discuss the impacts associated with each disposal option for the respective waste streams, and
3. conduct a literature review of existing LCA case studies and assess the applicability of the studies to South Africa and the PPC's cement kilns.

The following five waste streams proposed as secondary materials by PPC included in the study are:

1. Scrap tyres and rubber waste
2. Hydrocarbon waste *(such as used oil, oil-contaminated general waste, oil-contaminated soil and coal fines)*
3. Plastic waste
4. Biomass *(such as paper waste, sawdust, wood chips and waste from bio-fuel production)*
5. De-watered, treated sewage pellets

8 DISPOSAL OPTIONS CONSIDERED

Sections 2-6 described a number of current or possible disposal options available for each of the five waste streams for each tier of the Waste Hierarchy, as well as those options available in South Africa, and the status quo of these options in South Africa. This section includes a comparative risk assessment of *three* of these disposal options for each respective waste stream, which includes the co-processing of waste in cement kilns, and two of the more common disposal options that are practised in South Africa, which would therefore best represent the status quo. The combination of these two common options would thus represent the *no-go option* should the waste not be disposed of by cement kiln.

The two options to be compared with disposal by cement kiln have also been selected such that one option would fit into a tier *below* disposal by cement kiln in the waste (landfilling, which has been selected for all five waste streams), and one option that would fit into a tier *above* disposal by cement kiln (either use or recycle). The options selected are outlined in as follows and illustrated in the waste hierarchy diagrams below:

- Tyres
  - Recycling
  - Cement Kiln
  - Landfilling
- Hydrocarbons
  - Recycling
  - Cement Kiln
  - Landfilling
- Plastic
  - Recycling
  - Cement Kiln
  - Landfilling
- Biomass (e.g. paper, wood chips)
  - Recycling
  - Cement Kiln
  - Landfilling
- Sewage
  - Agricultural Use
  - Cement Kiln
  - Landfilling

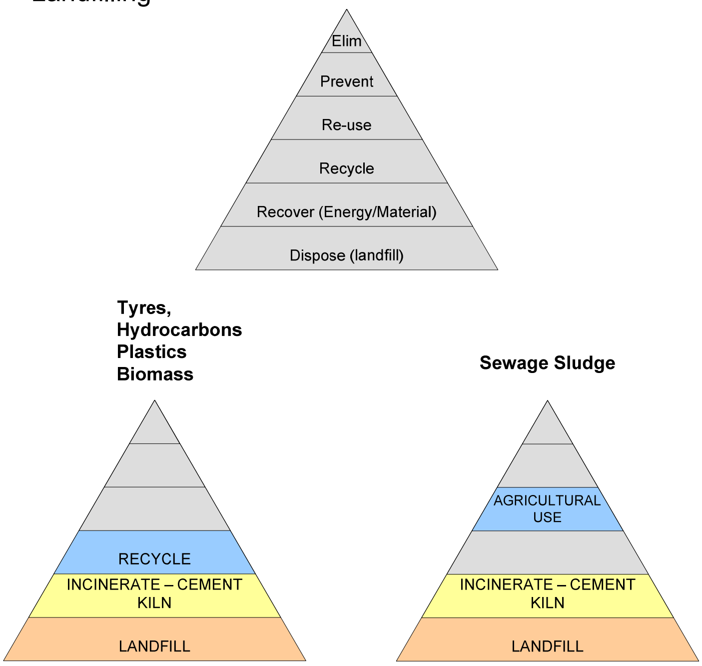


Figure 8-1: Disposal Options selected for the Comparative Risk Assessment

The following diagram illustrates an example of phases and impacts to assess for the disposal of rubber tyres:

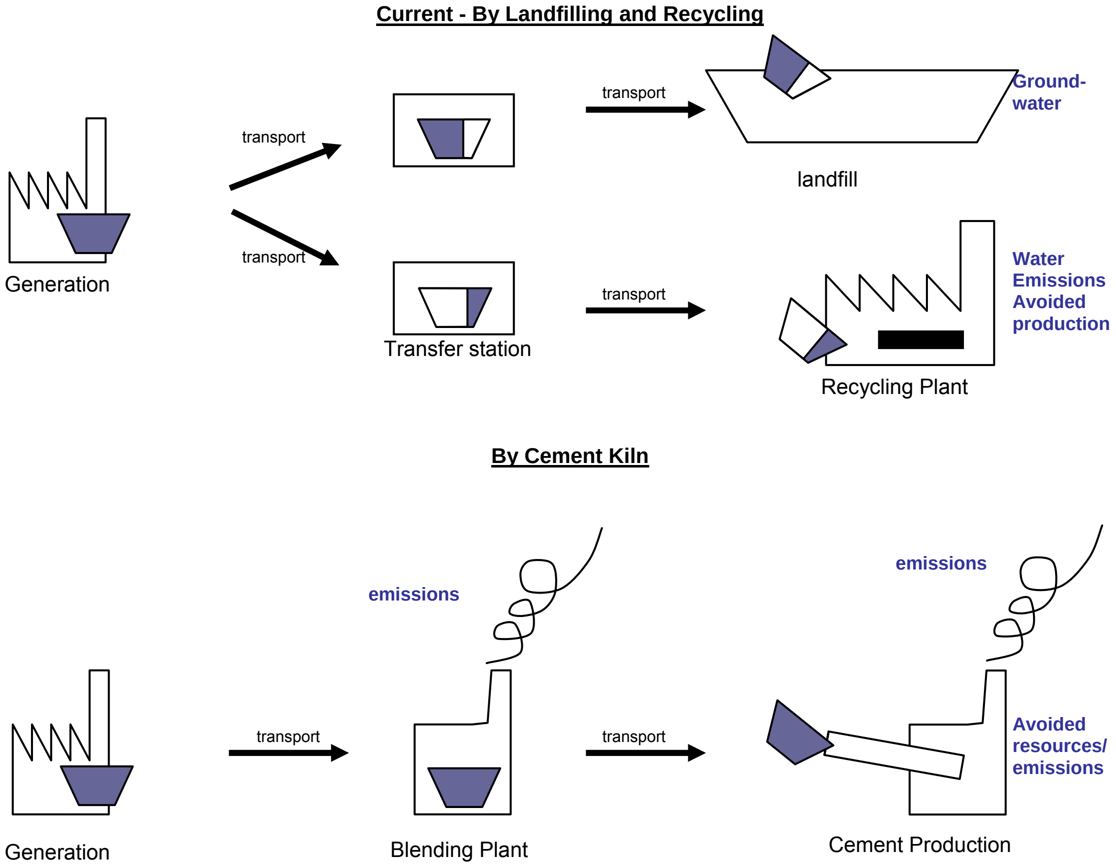


Figure 8-2: Example of life cycle phases and impacts (tyres)

9 LIFE CYCLE ASSESSMENT STANDARDS

The principles and framework for the accepted international standards for comprehensive Life Cycle Assessments are contained in IS0 14040 (1997). This standard outlines and describes following four iterative phases required for and LCA:

- goal and scope definition,
- inventory analysis,
- impact assessment and
- interpretation.

The impact assessment phase is descried in ISO 14042 (2000).

To compare products, or, in this case, alternative waste management options, the impact score for each impact category must be normalised. Normalisation divides the impact category results by a reference value, such as total world emissions for that category, and thus unitless figures of each category can be added. These normalised values for the impact categories can then be weighted relative to each other, so that a final single value can be determined to represent a product's overall impact.

However, because this final weighting step is a highly subjective matter (such as deciding whether human health issues are more or less important than damages to the ecosystem, or depletion of non-renewable resources), it is not recommended by ISO 14042 (2000) when the results are intended for public comparison. Rather, the individual impact categories should be compared against each other. Weighting would usually be used for internal use in a company for design purposes when choosing between alternatives. The designer can then select which weighting set is more appropriate for the product's and company's purposes.

Thus the 5 key impact categories selected in section 10 are not weighted, but rather discussed individually. This discussion follows the tables of comparison, tables 10-1 and 10-2.

10 IDENTIFICATION AND DISCUSSION OF LIFE CYCLE IMPACTS

The key impacts associated with each disposal option are highlighted to indicate the *changes* of impacts (increased or avoided impacts) compared against the other two options. Thus, for example, the impacts associated with electricity consumption and pigments for the manufacturing of plastic components are not included, as these impacts will be caused whether the plastic is made from virgin or waste plastics. However, the impacts associated with the type of raw materials used (renewable or non-renewable resources), and the impacts associated with the production of the plastic resin is included.

In addition to the identification of the impacts, the increase or decrease of the impact is noted (or whether the impact is considered to be a positive or negative impact). Supporting data and information for the increase or decrease is included where for the respective impact changes, and discussed accordingly.

10.1 Impacts Categories

In order to assess the wide number impacts caused by the many of inputs and outputs, a set of impact categories are defined to which the impacts are assigned.

Different methodologies have been developed for the impact assessment. Once such example, the Eco-indicator '99 method (www.pre.nl) assigns impacts to 10 different categories (e.g. global warming, resource depletion, ozone depletion etc). These categories are further assigned into three broad types of damage – damage to human health, damage to ecosystem quality, and damage to resources. For this, a detailed inventory of all inputs and outputs are required to conduct a detailed life cycle assessment.

For this project 5 key impact categories were selected (these are briefly described below). Each category may represent various impacts, and therefore an increase or decrease in a category may imply a change in all related impacts.

a) **Energy** - This category represents impacts such as acidification, climate change and respiratory effects
b) **Resources** - Both renewable and non-renewable
c) **Land use** - Use of land or change of land uses may result in the decrease of natural resources, regional effect on species in the area, as well as creating a disturbance of vegetation and the landscape
d) **Emissions** - toxic emissions, odour, etc.)
e) **Water** - Including the consumption (required for human well being), contamination of water course and generation of wastewater)

For each of the 3 disposal options selected for the five waste streams, the impacts on each of the 5 impact categories have been identified. These impacts are is described in the Table 2. This table is preceded by a summary of these impacts in Table 1.

10.2 Identification of Key Impacts

The impacts associated with the 3 disposal options of the five waste streams have been identified. Table 10-1 includes a summary of theses impacts, while Table 10-2 contains further data and information to support the description of the impact change.

Only the *key* impacts have been identified and discussed. Further impacts, such as the energy requirements (use of non-renewable resources) and emissions (CO_2, CO) associated with transportation of the wastes for each options is not included, as transportation requirements will be required for all options, and it is not expected to contribute significantly to the overall impact. Similarly the impacts associated with other processes (construction of cement kiln or recycling plant) have not been included.

Impacts that would not be affected by the selected waste management option have not been included (for example

Note: these tables only include *additional* or *reduced* impacts compared against the other waste management options. Impacts that would not be affected by the selected waste management option have not have not been included. For example the water consumed in the manufacture of final products of plastic is not relevant and thus not included, whereas water consumption for the washing of the recycled material to be used in the plastics manufacturing is relevant and must be added.

Table 10-1: Summary of impacts associated with each disposal option

Used Tyres	Energy	Resources	Land Use	Emissions	Water
Re-use or Recycling	Avoided – rubber production Increased – shredding/crumbing	Avoided (45% non-renewable)	Avoided landfill space	-	Water consumption and wastewater generation is reduced from avoided rubber manufacturing, but increases for the washing of the rubber recycling process.
Cement Kiln	Tyres can be processed whole – energy for crumbing not required. However, substantially more energy required for new rubber production. Energy requirements are equivalent for coal or wastes.	Avoided Coal (non-renewable) replaced by rubber (45% non renewable rubber) Avoided cement materials - rubber ash incorporated in cement	Avoided landfill space	Less greenhouse gas and metal emissions	-
Landfilling	-	-	Land fill space consumed	-	-

Hydrocarbons	Energy	Resources	Land Use	Emissions	Water
Re-use or Recycling	Energy avoided. 70% less energy required for reprocessing used oil than refining of crude oil	Avoided extraction of fossil fuels. Substantially less used oil is required for producing lubrication (Up to 97.6% saving compared to virgin oil)	Avoided landfill space	-	Leachate avoided
Cement Kiln	Energy requirements are equivalent for coal or wastes.	Avoided coal for energy requirements. Ash incorporated into cement	Avoided landfill space	Concern for metals, halogens, PCBs and other contaminants in the hydrocarbons that may be released.	Leachate avoided
Landfilling	-	-	Land fill space consumed	Methane generated	Leachate generated

Plastics	Energy	Resources	Land Use	Emissions	Water
Re-use or Recycling	Avoided energy use for plastic resin production.	Avoided virgin materials - non-renewable resources.	Avoided landfill space	Avoided greenhouse gases due to lower energy requirements.	Water consumed and wastewater generated to processing material into usable form (washing, shredding)
Cement Kiln	Energy requirements are equivalent for coal or wastes.	Avoided coal for energy requirements. Ash incorporated into cement	Avoided landfill space	Potential for toxic emissions	
Landfilling	-	-	Land fill space consumed		

Biomass	Energy	Resources	Land Use	Emissions	Water
Re-use or Recycling	Avoided energy use for converting trees into paper pulp.	Avoided virgin materials - renewable (paper) resources.	Avoided landfill space	Avoided greenhouse gases due to lower energy requirements. Increased carbon sequestration (storage) in the forests for paper)	Water conserved in forestry (paper). Water consumed and wastewater generated to processing material into usable form (washing, shredding) Leachate avoided
Cement Kiln	Energy requirements are equivalent for coal or wastes.	Avoided coal for energy requirements. Ash incorporated into cement	Avoided landfill space	Potential for toxic emissions	Leachate avoided
Landfilling	-	-	Land fill space consumed	Emission reduction from carbon sink for some materials (newspaper) Methane generated	Leachate generated

Sewage Pellets	Energy	Resources	Land Use	Emissions	Water
Re-use or Recycling	Additional energy may be required for the treatment in order to render the pellets useful (or convert sludge into pellets)	May replace fertilizers (and therefore the chemicals required for fertilizer production).	Avoids Landfilling Positive use to improve land capability for agricultural use.	Odour	Potential for pollution of ground and ground water and introduction of pollutants into food chain (depends on composition and constituents of sewage).
Cement Kiln	Energy requirements are equivalent for coal or wastes.	Avoided coal for energy requirements. Ash incorporated into cement	Avoided landfill space	Potential for toxic emissions	Leachate avoided
Landfilling	-	-	Land fill space consumed	Methane generated Odour	Leachate generated

Table 10-2: More detailed table of impacts associated with each disposal option

Category	Change in Impact [iv]	Supporting Data, information and further comments
WASTE STREAM 1: USED TYRES AND RUBBER		
Disposal Option 1: Recycling		
Energy	Energy avoided for the production of rubber compounds required for the intended applications. Energy required for shredding and crumbling.	25 kWh/kg of energy required for the manufacture of tyre rubber compounds is avoided as the rubber (the raw material) is no longer manufactured. However, as 1.2 kWh/kg of energy is required for the grinding of scrap tyre into crumb rubber (0.5 to 1,5 mm), a **net saving of 23.8 kWh/kg results.**[2] In terms of energy use, the re-use of tyres (as tyres) or the re-treading of tyres, whereby the manufacture of a complete tyres is altogether avoided, will result in the highest energy savings, as 32 kWh/kg of energy is required to manufacture a tyre[3]. However, because of speed, safety and other performance requirements of tyres, the tyres are generally required to be made mostly using virgin rubber compound.[4]
Resources	Resources avoided for the production of rubber compounds. This includes non-renewable (55% of the rubber) and non-renewable resources (45%)	Natural rubber is siphoned from cultivated trees on plantations. Synthetic rubber is man-made and is produced around the world in manufacturing plants that synthesize it from petroleum and other minerals (There are more than one dozen major classes of synthetic rubber which is made of raw material derived from petroleum, coal, oil, natural gas, and acetylene.) Approx 55% of passenger tyres are made from non renewable based synthetic rubber. The ratio of synthetic to natural rubber of other tyres are as follows[5]: **Tyre Type** / **Synthetic Rubber** / **Natural Rubber** Passenger Tyre / 55% / 45% Light Truck Tyre / 50% / 50% Race Tyre / 65% / 35% Off-highway Tyre (e.g. earthmover) / 20% / 80%
Land Use	Avoided landfill space	Use of rubber in other products avoids tyre disposal by landfill.
Water	Water consumption and wastewater generation is reduced from avoided rubber manufacturing, but increases for the washing of the rubber recycling process.	
Disposal Option 2: Cement kiln		
Energy	Tyres can be processed whole – energy for crumbing not	As tyres may be processed whole, energy is not required for shredding. 9 kWh/kg (32MJ/kg) of thermal energy is released when incinerating scrap tyres. This saving is not as

[iv] Increased or avoided impact compared to other options

Category	Change in Impact [iv]	Supporting Data, information and further comments
	required. Substantially more energy required for new rubber Increased energy efficiency (CV of tyres higher than coal)	significant as re-using (32 kWh/kg) or recycling (23.8 kWh/kg), but there is a net energy benefit. . [6] Other sources state a higher energy recovery of up to 32 kWh/kg Though using TDF (tyre derived fuel) reclaims some of the energy that went into making a scrap tyre, it remains the second most wasteful alternative after disposal for managing scrap tyres. That fact puts "energy recovery" near the bottom of the hierarchy of scrap tyre management alternatives, just above dumping them. Burning tyres for fuel also reclaims only a small portion of the energy it takes to produce a tyre. [7] The average calorific value of tyres [8] is generally higher than that of coal, but the use energy consumed per ton of clinker produced is equivalent for coal or wastes. CV Coal: 27 MJ/kg (26.5 used by PPC Range: 22.5 - 28) CV tyres: 32 MJ/kg CV rubber: 23 MJ/kg
Resources	Avoided coal used for energy requirements. Steel in tyre (approx 10%) replaces requirements for virgin iron ore.	Materials – 100% fossil fuel replacement (coal) using rubber of approx 55% petroleum based synthetic rubber and 45% natural (latex rubber). A 9.5kg tyre contains only five pounds of petroleum-based synthetic rubber. The rest is natural rubber, steel belts and bead wire, carbon black, cloth and a mix of other chemicals which do not contribute significantly to the heating value of an incinerated tyre. [9]
	Cement materials replaced by waste ash generated	Cement replaced – ash incorporated into cement
Land Use	Avoided landfill space	Use of rubber in other cement for fuel and materials avoids tyre disposal by landfill.
Emissions	Less greenhouse gas and metal emissions	CO_2 emissions SO_2 emissions TDF produces slightly more heating value than coal with similar emissions. Coal mixed with TDF produces less ash, greenhouse gases and metal emissions than burning coal alone.[10]
Water	Avoided potential impacts on ground and ground water in landfill	
Disposal Option 3: Landfill		
Land Use	Land fill space consumed	Area could be used for agricultural land, forests etc.

Category	Change in Impact [iv]	Supporting Data, information and further comments
WASTE STREAM 2: HYDROCARBONS		
Disposal Option 1: Recycling		
Energy	Energy avoided for the refining of crude oil. Energy require for reprocessing.	Re-refining used oil takes only about one-third the energy of refining crude oil to lubricant quality [11].
Resource	Material Avoided extraction of hydrocarbons (fossil fuels) Ash incorporated into cement.	<u>Re-refining Used Oil</u> Oil does not wear out, but it does get dirty. Through re-refining or processing, used oil can be used over and over without losing its lubricating ability. Re-refining used oil produces high-quality base stock, which is used for lubricants or other petroleum products. It takes ***42 gallons*** of crude oil to produce 2.5 quarts of lubricating oil; the same amount of lubricating oil can be produced from only ***1 gallon*** of used oil. [12] <u>Re-refining versus Processing</u> Re-refining is not the same as processing. The major difference is that re-refined used oil has sufficient quality to be used again as a lubricating oil. By contrast, processing produces a used oil of lower quality, which can be used as a fuel for producing electricity or other purposes. Processed used oil can also be blended for marine fuel or other uses. *Waste Oil Recycling http://www.dti.gov.uk/sustainability/downloads/oil.pdf*
Land Use	Avoided landfill space	Use of oils and greases in other products avoids disposal by landfill.
Water	Avoided potential impacts on ground and ground water in landfill (leachate avoided).	
Disposal Option 2: Cement kiln		
Energy	Increased energy efficiency (CV of oil lower than coal).	Used oil that does not meet specification for use may not have alternative uses for oil (without further processing), and therefore energy recovery (e.g. by cement kiln) becomes more attractive (than landfilling). The average calorific value of hydrocarbon sludges [13] is generally higher than that of coal, but the use energy consumed per ton of clinker produced is equivalent for coal or wastes. CV Coal: 27 MJ/kg (26.5 used by PPC Range: 22.5 - 28) CV Oil: >40 MJ/kg
Resources	Avoided coal used for energy requirements.	
	Cement materials replaced by	Cement replaced – ash incorporated into cement

Category	Change in Impact [iv]	Supporting Data, information and further comments
	waste ash generated	
Land Use	Avoided landfill space	Use of oils and greases in cement for fuel and materials avoids disposal by landfill.
Emissions	Emission of cement kiln	Concern for metals, halogens, PCBs and other contaminants in the hydrocarbon that may be released.
Water	Avoided potential impacts on ground and ground water in landfill (leachate avoided).	
Disposal Option 3: Landfilling		
Land Use	Landfill space consumed	Area could be used for agricultural land, forests etc.
Emissions	Methane emissions generated	
Water	Potential for Ground and ground water contamination (leachate)	Just one quart of oil can contaminate approximately 250,000 gallons of water.[14] Sludges should be disposed of at a hazardous waste landfill, but a certain amount is disposed at General landfill sites too.

WASTE STREAM 3: PLASTIC		
Disposal Option 1: Recycling		
Energy	Avoided energy use for plastic resin production	
Resources	Avoided virgin materials - non-renewable (plastic) resources.	Plastic originations from non-renewable resources (generally made from oil or coal). Further materials are avoided in the production required for plastic production
Land Use	Avoided landfill space	Use of plastic in other products avoids disposal by landfill.
Emissions	Avoided greenhouse gases due to lower energy requirements (compared to manufacturing from virgin inputs). Other process non-GHG also avoided.	
	Increased carbon sequestration (storage) in the forests for paper)	
Water	Water conserved in forestry (paper). Water consumed and wastewater generated to	

Category	Change in Impact [iv]	Supporting Data, information and further comments
	processing material into usable form (washing, shredding). Leachate avoided.	
Disposal Option 2: Cement Kiln		
Energy	Plastic: Increased energy efficiency (CV of plastics higher than coal)	The average calorific value of plastics[15] is generally higher than that of coal, but the use energy consumed per ton of clinker produced is equivalent for coal or wastes. CV Coal: 27 MJ/kg (26.5 used by PPC Range: 22.5 - 28) CV Plastic: 31 MJ/kg
Resources	Avoided coal for energy requirements. Avoided materials.	Ash incorporated into cement
Land Use	Avoided landfill space	Use of plastic in cement for fuel and materials avoids disposal by landfill.
Emissions	Potential for toxic emissions	Different emission from normal cement production, dependant on types of plastics co-processed. A detailed European study has recently documented the ability of plastics to improve combustion in a modern WTE (waste to energy) plant. The study also looked at the contribution of plastics to air emissions. This was done by intentionally adding plastics to the regular MSW (municipal solid waste) feed to the plant and carefully monitoring the release of pollutants. Plastics were shown to have no negative effect on air pollution loads to the environment. The study included a specific examination of dioxin and furan emissions. [16] Using PEF(Process Engineers Fuels) as a supplement for coal can also reduce some types of environmental emissions, particularly sulfur dioxide. Studies have also shown that PEF can reduce the yield of carbon dioxide compared to an equivalent Btu of conventional coal and biomass fuels. These properties are expected to keep attention on PEF as a renewable fuel and supplement to conventional fossil fuels.[17]
Water	Leachate avoided	
Disposal Option 3: Landfill		
Land use	Landfill space consumed	Area could be used for agricultural land, forests etc.
Emissions	-	The emissions related to plastics are insignificant.
Water	Leachate generated from degraded paper	

Category	Change in Impact [iv]	Supporting Data, information and further comments
Waste Stream 3: BIOMASS		
Disposal Option 1: Recycling		
Energy	Avoided energy use for converting trees into paper pulp.	
Resources	Avoided virgin materials - renewable (paper) resources.	Paper is a natural and renewable resource (if paper originating from sustainable forests) Further materials are avoided in the production required for paper production (water for forestation, chemicals for paper production etc.)[18] There are technical constraints to the unlimited use of recycled stock. Repulping and processing decreases fibre length and, therefore, some virgin pulp is always required to maintain the strength and quality of the finished product. A recovered fibre can be recycled only about 5 or 6 times due to the progressive deterioration of its length.
Land Use	Avoided landfill space	Use of paper in other products avoids disposal by landfill.
Emissions	Avoided greenhouse gases due to lower energy requirements (compared to manufacturing from virgin inputs). Other process non-GHG also avoided. Increased carbon sequestration (storage) in the forests for paper)	**Net** GHG emissions for the recycling of paper ranges from a saving of 0.67-0.95 MTCE (metric tons carbon equivalent) compared with landfilling of 0.58 emission MTCE and up to a saving (for newspaper) of 0.25 MTCE, and compared with combustion of 0.2-0.7 MTCE saving.[19] **GHG Emission from Recycling and Landfilling [20]** **GHG emissions if ALL residential wastes were landfilled** If all the residential waste in Canada were landfilled, food wastes would generate the greatest amount of GHG, followed by office paper, mixed paper, and corrugated box board. Some of the carbon in paper and food waste would be trapped in the landfill's "carbon sink". **GHG emissions, recycling versus landfilling** The major contributors to the reduction of GHG emissions are the paper products and aluminium sectors. The recycling of paper generates a GHG reduction 20 times greater than would be achieved if the material were sent straight to landfill.
Water	Water conserved in forestry (paper). Water consumed and wastewater generated to processing material into usable form (washing, shredding). Leachate avoided.	**Contamination of Feedstock[21]** An important factor in the utilisation of waste paper is the removal of contaminants. The level of contamination in wastepaper grades has a major effect on the complexity of the processing line and, therefore, on the cost of the final product. There are three main sources of contamination: - paper mill additives, such as mineral fillers, chemicals and polymers; - conversion process additives, such as printing inks, plastics and foils, adhesives, staples, pins and

Category	Change in Impact [iv]	Supporting Data, information and further comments
		chemicals; and - consumer and waste collection debris, such as food, micro-organisms, grit and baling wire. There is also water present, absorbed by waste paper at depots and in transit, which increases the bulk and weight of the bales. Recycled pulp can reduce the smooth running of the paper web, reduce strength, cleanliness and brightness, and vary the colour. Adhesive particles known as stickies are a particular problem arising from contact adhesives and binders.
Disposal Option 2: Cement Kiln		
Energy	Paper: Decreased energy efficiency (CV of paper lower than coal)	The average calorific value of paper [22] is generally higher than that of coal, but the use energy consumed per ton of clinker produced is equivalent for coal or wastes. CV Coal: 27 MJ/kg (26.5 used by PPC Range: 22.5 - 28) CV Paper: 13-18 MJ/kg
Resources	Avoided coal for energy requirements. Avoided materials.	Ash incorporated into cement
Land Use	Avoided landfill space	Use of paper in cement for fuel and materials avoids disposal by landfill.
Emissions	Potential for toxic emissions	
Water	Leachate avoided	
Disposal Option 3: Landfill		
Land use	Landfill space consumed	Area could be used for agricultural land, forests etc.
Emissions	Methane generation from degradation of paper Emission reduction from carbon sink for some materials (e.g. newspaper)	The impacts of newspaper and, to a lesser degree, yard waste are interesting. The act of putting these materials into landfill actually reduces GHG emissions. Research has shown that newspaper and the brush portion of yard waste do not degrade totally in landfills, even over very long periods of time. As a result, some of the carbon in these materials is stored and, thus, removed from the carbon cycle. The carbon will continue to be stored until some future action (such as mining the landfill) brings it back into the natural cycle. In this instance, the landfill is acting as a carbon sink.[23]
Water	Leachate generated from degraded paper	

Category	Change in Impact [iv]	Supporting Data, information and further comments
WASTE STREAM 4: SEWAGE SLUDGE		
Disposal Option 1: Agricultural Use		
Energy	Additional energy may be required for the treatment in order to render the sludge useful.	Sludge is usually treated before disposal or recycling in order to reduce its water content, its fermentation propensity or the presence of pathogens. Several treatment processes exist, such as thickening, dewatering, stabilisation and disinfection, and thermal drying. The sludge may undergo one or several treatments.[24]
Resources	May replace fertilizers (and therefore the chemicals required for fertilizer production).	Landspreading of sludge or sludge-derived material partially replaces the use of conventional fertilisers, since it contains compounds of agricultural value. It also contains organic matter, although under a form and at a level below that which would have a significant positive impact on soil physical properties. [25]
Land Use	Avoids Landfilling. Positive use to improve land capability for agricultural use.	Utilises useful constituents such as carbon, phosphorus and other nutrients.
Emissions	Odour	Odour control is the most important environmental dimension of sludge application to land.
Water	Potential for pollution of ground and ground water and introduction of pollutants into food chain (depends on composition and constituents of sewage).	Composted sludge however presents a more stable organic matter due to the addition of a vegetal coproduct during the process. However, landspreading also involves the application of the pollutants contained in sludge to the soil. These pollutants undergo different transformations or transfer processes. These processes include leaching to groundwater, runoff, microbial transformation, plant uptake and volatilisation and enable transfer of the compounds into the air and water, and their subsequent introduction into the food chain. Therefore outputs of sludge recycling consist of yield improvement, but also of emissions of pollution into the soil, and indirect emissions into air and water. Other emissions into the air include exhaust gases from transportation and application vehicles. [26] It contains both compounds of agricultural value (including organic matter, nitrogen, phosphorus and potassium, and to a lesser extent, calcium, sulphur and magnesium), and pollutants which usually consist of heavy metals, organic pollutants and pathogens. The characteristics of sludge depend on the original pollution load of the treated water and also on the technical characteristics of the wastewater and sludge treatments carried out.[27] From the Food and Agriculture Organization of the United Nations.[28] Sewage sludge will contain, in addition to organic waste material, traces of many pollutants used in our modern society. Some of these substances can be phytotoxic and some toxic to humans and/or animals so it is necessary to control the concentrations in the soil of potentially toxic elements and their rate of application to the soil. The risk to health of chemicals in sewage sludge applied to land has been reviewed by Dean and Suess (1985).

Category	Change in Impact [iv]	Supporting Data, information and further comments
		Sewage sludge also contains pathogenic bacteria, viruses and protozoa along with other parasitic helminths which can give rise to potential hazards to the health of humans, animals and plants. A WHO (1981) Report on the risk to health of microbes in sewage sludge applied to land identified salmonellae and *Taenia* as giving rise to greatest concern. The numbers of pathogenic and parasitic organisms in sludge can be significantly reduced before application to the land by appropriate sludge treatment and the potential health risk is further reduced by the effects of climate, soil-microorganisms and time after the sludge is applied to the soil. Nevertheless, in the case of certain crops, limitations on planting, grazing and harvesting are necessary Sludge can be treated to reduce its fermentability and health hazards resulting from its use before being applied in agriculture. The sludge must not contain non-degradable materials, such as plastics, which would make land disposal unsightly.
Disposal Option 2: Cement kiln		
Energy	Decreased energy efficiency (CV of sewage sludge less than coal)	The average calorific value of sewage sludge [29] is generally higher than that of coal, but the use energy consumed per ton of clinker produced is equivalent for coal or wastes. CV Coal: 27 MJ/kg (26.5 used by PPC Range: 22.5 - 28) CV Sewage Sludge: 12-18 MJ/kg
Resources	Avoided coal for energy requirements. Avoided materials – sludge ash incorporated into cement	Ash incorporated into cement
Land Use	Avoided landfill space	Use of sewage in cement for fuel and materials avoids disposal by landfill.
Emissions	Potential for toxic emissions	Different emission from normal cement production, dependant on types of sewage co-processed. Includes, acid gases, greenhouse gases, heavy metals, and volatile organic compounds.)
Water	Leachate avoided, and potential ground and groundwater impacts of agricultural use.	
Disposal Option 3: Landfill		
Land Use	Landfill space consumed	Area could be used for agricultural land, forests etc.
Emissions	Methane generated Odour	
Water	Leachate generated	Various compounds such as ions, heavy metals, organic compounds and micro-organisms in leachate

11 DISCUSSION OF IMPACTS AND DISPOSAL OPTIONS

In general, greater impacts are avoided for the recycling options compared to disposal by cement kiln or landfilling. Although additional resources and utilities are required for recycling operations (such as water for the washing of recyclable material or electricity for a shredder), the impacts of raw material production (which would be avoided for recycling) are generally higher than the impacts of the preparation of the waste materials to be used in recycling. Both recycling/use and disposal by cement kiln generally recover energy, avoid resource extraction (including non-renewable resources), and do not have an impact on land use, when compared to landfilling.

Emissions are expected to have a greater impact for disposal by cement kiln than recycling or the odour, methane and other gases emitted from landfills.

There is a greater risk of ground and water contamination from landfilling (contaminants leaching to ground), and for the application of sewage sludge. The consumption of water and generation of wastewater are expected to be higher for recycling activities where washing of the materials would be required prior to being of use in the manufacturing process.

Each impact category is further discussed for the various options:

11.1 Energy

The reduction of energy itself is not an environmental benefit, but rather the reduction in impacts resulting from the production of the energy. In South Africa, this implies that less coal is used, less CO_2 and SO_2 is emitted from coal-fired power stations used to generate electricity that is required for recycling operations.

Although energy is required for recycling, such as the for the reprocessing of the hydrocarbons, shredding of plastic and paper or crumbing of tyres, there is a substantial saving by avoiding the energy required for the extraction and production of raw materials, and thus recycling reduced overall energy requirements.

The cement kiln uses the products to replace the coal and utilise the energy content. Energy is therefore recovered, but not as much as the energy required manufacturing a new tyre that would be required if recycling does not take place. I.e. manufacturing of a product requires more energy than the amount of energy saved in the cement kiln.

Where energy is recovered from wastes, some waste streams such as tyres plastics and hydrocarbons have a higher calorific value than coal, and thus energy savings are greater than the use of coal alone. Sewage sludge and paper have lower calorific values, and is therefore not as energy efficient as coal.

The use of sewage sludge for agricultural purposes will require additional energy for the land application. Landfilling also requires energy for its operations.

Therefore, whereas recycling and disposal by cement kiln recovers energy or avoids energy requirements for tyres, greases, paper and plastics, and sewage sludge, additional energy is required for landfilling of all wastes, and for agricultural use of sewage sludge. It is noted that there may be some energy recover where methane is extracted for energy, and that application of sewage sludge on land will avoid energy requirements for fertilizer production.

Furthermore, where recycling is not feasible due to technical or economic reasons (e.g. the re-processing of greases may require equipment that will substantially increase recycling costs), disposal by cement kiln offers an alternative to landfilling that recovers energy instead of consuming energy.

11.2 Resources

Plastic, greases and about half of the rubber in tyres is made from non-renewable resources. Any recycling would therefore reduce the extraction of the raw materials, and therefore avoid resource depletion of non renewable materials. These materials may be able to be recycled many times over, thus avoiding resource depletion each time.

By disposing of theses wastes in the cement kiln, the wastes are replacing the coal as an energy source, and some of the cement itself, as the ash is incorporated into the cement. Thus the extraction of the non-renewable resources is avoided. The disposal of this waste by cement kiln is a once–off event, as the waste cannot be used to replace coal again. This option is therefore favourable to landfilling, where there is no recovery or reduction of resources, but recycling of the product into alternative products (that may be recycled further) would be preferred compared to disposal by cement kiln.

Construction waste may be recycled and made into cement again, but coal or waste can only be used once as an energy source.

Where suitable (with regards to the concentration of potential contaminants) the use of sewage sludge as a substitute for fertilizers use will reduce resources required for agriculture. Substituting the coal in the cement kilns with sewage sludge and paper have the effect of reducing depletion of non-renewable resource (coal) as they are a product of renewable resources, although these materials have a lower calorific value and thus are not as energy efficient as the coal.

11.3 Land Use

Use of land or change of land uses may result in the decrease of natural resources, regional effect on species in the area, as well as creating a disturbance of vegetation and the landscape.

Landfilling will have a negative impact for all waste streams. The recycling and cement kiln co-processing of all waste streams will not have any impact on land use. The use of sewage sludge will have a positive impact as it is used use to improve land capability for agricultural use (assuming that the contaminants are within acceptable standards).

11.4 Emissions

Emissions from greases, sludge and plastics may be greater than emission of burning coal alone, depending on the type and contaminates in the waste streams.

Odour and methane are the key emissions from landfills. Emission reduction in the form of a carbon sink is possible for some materials such as newspaper.

Odour may also repent a risk for the application of sewage sludge on land.

11.5 Water

There is a higher potential for leachate generation and the contamination of soil and ground water contamination from landfill options for greases and sewage sludge which are may be hazardous, whereas paper would degrade but pose less of a risk. The impacts from tyres and plastics would be negligible.

The agricultural use of sewage sludge poses a risk of contaminating soil to which it is applied as well as the groundwater below, and watercourses (from runoff), depending on the quantity and concentration of contaminants.

Emissions are expected to have a greater impact for disposal by cement kiln than recycling or the odour, methane and other gases emitted from landfills.

The consumption of water and generation of wastewater are expected to be higher for recycling activities where washing of the materials would be required prior to being of use in the manufacturing process, although overall consumption may be lower due avoidance of water required as the virgin raw materials requirements are decreased. This will be particularly noticeable in for water required for forestry.

12 LITERATURE REVIEW OF EXISTING LCA STUDIES

A number of studies on disposal of cement kiln have been reviewed. The following three studies have been assessed and commented on the most, as they are considered to be the most relevant and comprehensive studies conducted to date, and uses a life cycle approach.

Studies include:

- **Case Study 1:** **Guidelines for the Selection and use of Fuels and Raw materials in the Cement Manufacturing Process**
  Draft 2005 Version 1.0,
  World Business Council for Sustainable Development
- **Case Study 2:** **Taiheiyo's use of LCA for Technology Evaluation (part of the following report: *What LCA can tell us about the Cement Industry.***
  March 2002
  A Batelle report sub-study, Five Winds International, an Independent study commissioned by the World Business Council for Sustainable Development.
- **Case Study 3**: **Environmental Benefits of Using Alternative Fuels in Cement Production – A Life Cycle Approach,**
  CEMBUREAU, 1999

Comments on each study are provided to address the applicability to PPC and South Africa.

12.1 Case Study 1: Guidelines for the Selection and use of Fuels and Raw materials in the Cement Manufacturing Process

Draft 2005 Version 1.0, World Business Council for Sustainable Development (published 12 Jan 2006). Available at: http://www.wbcsd.org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=MTc4NTk

The guidelines contained in this document provide a practical reference for cement companies and their stakeholders to help them to understand and identify responsible and sustainable approaches to the selection and use of fuels and raw materials. They were developed by 17 major cement companies, in consultation with a range of stakeholders representing NGOs, government, academia, and community groups across the world, as part of the Cement Sustainability Initiative (CSI), The CSI is a program of the World Business Council for Sustainable Development (WBCSD). Its members, all cement companies, created it in 2000 to develop and promote practical ways for the industry to improve its environmental and social performance.

This document is divided into three sections that cover, respectively:

1. Principles for fuel and material selection
2. **The role of various fuels and materials in cement manufacture [discussed below],** and
3. Practical considerations for cement plant owners and operators

Only the second section (*The role of various fuels and materials in cement manufacture* is considered to be particularly relevant and thus has been included

The selection of alternative fuels and materials is driven by a number of interrelated considerations, including:

- Impact on CO_2 emissions and on fuel consumption,
- Impact on fuel cost,
- Impact on other emissions,
- Impact on mining and quarry activity.

Four reasons for using alternatives to conventional fuels and raw materials are discussed in the guidelines, and a summary provided below:

1. **Impact on CO_2 emissions and on fuel consumption,**
The report states that use of alternative fuels and raw materials can significantly reduce the CO_2 emissions from an individual plant, and of society as a whole.

There are three main techniques available to the industry in reducing net total and per tonne CO_2 emissions:

- Maximize the efficiency of the manufacturing process and associated equipment to use fuels and materials as efficiently as possible;
- Reduce the amount of fossil fuel used in the process by **replacing it with biomass and wastes** that would otherwise have been burned without energy recovery, and other materials having lower carbon content;
- **Replace a proportion of the clinker in cement with alternative materials** (which do not require thermal processing), reducing the CO_2 emissions per tonne of cement produced.

2. **Reducing fuel and raw material costs**
The costs of fuel are a significant part of the costs of manufacturing cement. Waste fuels may be less expensive than primary fossil fuels although costs will vary with the type of waste and local conditions. Against these lower fuel costs alternative fuels and materials must frequently be pre-treated and made sufficiently homogeneous to be used in a cement kiln. Some additional environmental equipment may also be installed to control emissions. Special control and process measures may be needed to maintain safety, quality, and environmental standards.

3. **Providing resource management services to society**
Many of the alternatives to conventional fuels, raw materials, and additives are wastes and by-products from industrial, agricultural and other processes that are generally managed through land disposal, treatment or incineration.

Organic waste disposed in landfills may release methane (a more potent greenhouse gas than CO_2), or contaminate groundwater. An incinerator produces CO_2 and residual ash (typically high in heavy metals which requires careful disposal). Most incinerators do not recover energy. A cement kiln incorporates inorganic ash into the clinker complex so there is no residual waste to be land-filled. Also, the energy produced in the kiln is used to create the high temperatures needed to make cement.

Using waste and by-products in cement production not only reduces the industry’s demand for virgin fossil fuels and raw natural materials, it also enables society to use resources more efficiently and move toward more sustainable production and consumption patterns.

4. **Reducing the need for mining and quarrying of raw materials and fuels**
Most of the fuels, raw materials, and additives traditionally used to make cement are mined or quarried. The majority of the fuels used are non-renewable fossil fuels. Extraction, processing and transport of these materials can have a significant and lasting impact on the environment, particularly on the landscape. Using wastes as a fuel or raw material reduces the exploitation of natural resources and the environmental footprint of such activities.

12.1.1 Recent Trends in the Use of Alternative fuels and Materials

The following has been extracted from the report:
“Local and national governments are recognizing that the cement industry can play an important role in efficient waste management. We in the industry are waking up to our opportunity to reduce our overall carbon dioxide emissions and to operate more sustainably in a carbon-constrained world. The substitution of fossil fuels and virgin raw materials with alternatives is a well-developed practice in a small number of countries. Some countries have been using it for almost 30 years, and some national governments

actively promote this approach. In a number of countries this practice is well understood and highly developed."

The following tables, extracted from the report, lists the countries using alternative fuels, as % of substitution and the types of alternative fuels that are being used.

Table 2: Recent patterns in the use of alternative fuels

Country or region	% Substitution[14]
Netherlands	83
Switzerland	47.8
Austria	46
Norway	35
France	34.1
Belgium	30
Germany	42
Sweden	29
Luxembourg	25
Czech Republic	24
EU (prior to expansion in 2004)	12
Japan[15]	10
United States[16]	8
Australia[17]	6
United Kingdom	6
Denmark	4
Hungary	3
Finland	3
Italy	2.1
Spain	1.3
Poland	1
Ireland	0
Portugal	0
Greece	<1%

Table 3: Types of alternative fuels (2001)

Type of fuel	Quantity in kT
Solid fuels (80%)	**3,532**
Meat and bone meal & animal fat	890
Other wastes	788
Tires	554
Plastics	210
Paper/cardboard/wood	180
Impregnated saw dust	167
Coal slurries/distillation residues	112
Sludge (paper fiber, sewage)	107
Fine/anodes/chemical cokes	89
Refuse derived fuels	41
Shale/oil shales	14
Packaging waste	12
Agricultural and organic waste	11
Liquid fuels (20%)	**841**
Waste oil + oiled water	402
Solvents and others	266
Other hazardous liquid fuels	173

Figure 12-1: Use of alternative fuels around the world

12.2 Case Study 2: Case Study – Taiheiyo's use of LCA for Technology Evaluation

This case study was a component to the following report:
What LCA can tell us about the Cement Industry, March 2002, Batelle, Five Winds International, an Independent study commissioned by the World Business Council for Sustainable Development. Report can be located at http://www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?type=p&MenuId=NzUy&doOpen=1&ClickMenu=LeftMenu

Taiheiyo Cement Corporation has utilized LCA for a variety of valuable applications, including a variety of decision-making efforts internally and for communication efforts to external parties. The company uses LCA to continually monitor its contributions to greenhouse gases (CO_2 emissions), depletion of mineral resources, use of energy resources, and shortage of final landfill sites (amount of waste used).

Internally, the company has used LCA results to evaluate:

- Thermal recycling of waste **plastic materials**,
- **Alternative Fuel Resources (AFR),**

- Ecocement production, and,
- Recycling processes for incinerator ash from urban waste.

The LCA was used as an input to calculating the environmental and economic costs of using waste and by-products in cement production processes. In 2000, the company completed LCA profiles for three types of their most common products:

1. Portland Cement (PC) – production of Ordinary Portland Cement (OPC) utilizing some waste and by-product as alternative fuels and raw materials
2. Average of all kinds of cement – including blended cements
3. Virgin Portland Cement (VPC) – OPC without using any waste or by-product as alternative fuel or raw material

The life cycle boundaries included mining of resources, to the gate of shipping the cement, to use. The impacts were measured using the following indicators:

- Global Warming (CO_2 emissions)
- Depletion of mineral resources
- Depletion of energy resources
- Shortage of final landfill sites.

The LCA results show that as a result of using wastes and by-product materials, the company reduced its burden in the following categories:

- CO_2 - 2.77 million tons or 14% per ton of cement
- Energy Resources - 70 000 tons heavy oil equivalent or 9% per ton of cement
- Mining Resources - 7.14 million tons or 20% decrease per ton of cement.

The results of the profiles are shown in Figures E-1 to E-4 and Tables E-1 to E-4 below, excerpts from Taiheiyo's 2000 Environmental Report.

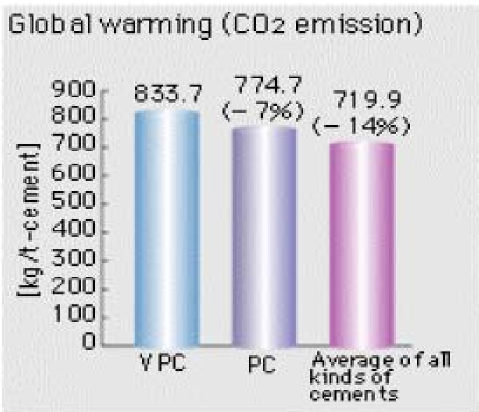


Figure E-1. Global Warming

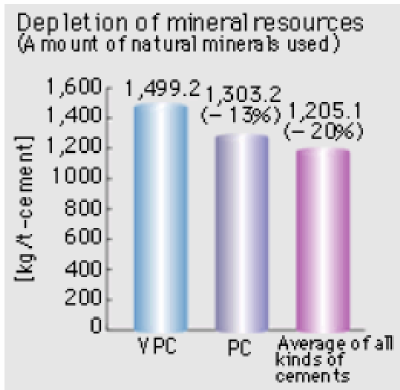


Figure E-2. Depletion of Mineral Resources (Amount of natural minerals used)

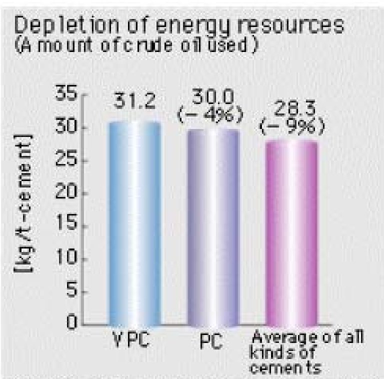


Figure E-3. Depletion of Energy Resources

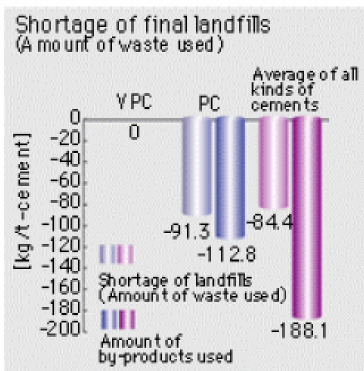


Figure E-4. Shortage of Final Landfills

Figure 12-2: Graphical Illustration of Impacts (Extract: Taiheiyo's use of LCA for Technology Evaluation)

Table E-1. Global warming				
	VPC	PC	Average of all kinds of cements	Unit
Mining of raw material	2.8	2.5	3.7	$kg\text{-}CO_2$/ t-cement
Transportation	0.7	2.0	2.3	
Production	283.8	243.6	225.5	
In-house power generation	61.2	60.9	57.5	
Decarboxylation	480.7	461.2	426.4	
SS transportation	4.5	4.5	4.5	
Total	833.7	774.7	719.9	
Difference with VPC		-59.0	-113.8	

Table E-2. Depletion of energy resources				
	VPC	PC	Average of all kinds of cements	Unit
Coal	98.9	82.2	77.4	kg/t-cement
Crude oil	18.4	19.4	18.3	
Total	31.2	30.0	28.3	kg-crude oil equivalent /t-cement
Difference with VPC		-1.2	-2.9	

Table E-3. Depletion of mineral resources				
	VPC	PC	Average of all kinds of cements	Unit
Limestone	1191.72	1144.6	1058.4	kg/t-cement
Clay	235.6	79.6	73.6	
Silica stone	20.6	75.4	69.7	
Gypsum	31.1	3.6	3.4	
Iron material	20.2	0	0	
Total	1499.2	1303.2	1205.1	
Difference with VPC		-196.0	-294.1	

Table E-4. Shortage of landfill sites				
	VPC	PC	Average of all kinds of cements	Unit
Recycled by-products		-112.8	-188.1	Wet-kg/t-cement
Shortage of landfills (recycled waste)	0	-91.3	-84.4	

Note: Production of PC in FY1999: 22.48 million tons, Production of all kinds of cements in FY1999□F24.3 million tons, VPC: Virgin cement, PC: Ordinary Portland cement

Figure 12-3: Table of Impacts (Extract :Taiheiyo's use of LCA for Technology Evaluation – Graphical Illustration of Impacts)

12.3 Case Study 3: Environmental Benefits of Using Alternative Fuels in Cement Production – A Life Cycle Approach

Environmental Benefits of Using Alternative Fuels in Cement Production – A Life Cycle Approach, CEMBUREAU (The European Cement Association, based in Brussels[v]). 1999.

12.3.1 Introduction to the Study

The key arguments of this study regarding the potential additional impacts and impact reductions have been extracted from the study such that a more direct comparison can be made with disposal by cement kiln in the South African context. Where possible, the sections have been discussed to clarify the relevancy and applicability to PPC.

The study claims that the *utilisation of wastes in the cement industry*, principally as alternative fuels but also as supplementary raw materials, is compatible with the general principles of waste management at both European Union and national levels, and with existing EU and national policies on energy efficiency, climate change and waste

[v] http://www.cembureau.be

management. Two reasons why the use of such materials is *considered by the industry to be fully compatible with the principles of sustainable development are provided as follows*:

1. **Cement Manufacturing Process**
   In terms of the cement manufacturing process, the use of alternative fuels and raw materials has the *potential to reduce emissions* to the environment relative to the use of conventional fossil fuels, and *conserve non-renewable resources*.
2. **Waste Management System**
   In terms of the waste management system, cement kilns offer a safe alternative to conventional disposal of waste in *dedicated waste incinerators or in landfills*, again resulting in overall benefits by *reducing environmental burdens and reducing the need for dedicated treatment capacity*.

The sections below explore the relevancy and applicability of emissions, conservation of non-renewable resources, and disposal alternatives such as landfilling in further detail. Disposal by dedicated waste incinerators are not included in the assessment, as this is not common practise in South Africa.

In the study LCA techniques were used to determine benefits of utilising waste materials in cement kilns and were examined under three headings:

a) climate change and carbon dioxide reductions (replacing coal with biomass or solvents) [*relevant]*
b) disposal by waste incineration versus recovery in cement kilns [*not relevant]*
c) recycling versus recovery in cement kilns (for plastics and oils) [*relevant]*

Waste incineration is not considered common waste management practise in South African for the five waste streams under consideration, and therefore has not been considered. The first two sections - CO_2 reductions for biomass and the comparisons of recycling and recovery in cement kilns for plastics and oils - are relevant and have therefore been assessed in the following sections.

12.3.2 Climate change and carbon dioxide reductions

The study states that the industry has demonstrated that the substitution of conventional fossil fuels with alternative fuels based on waste can make an important contribution to sustainable development through the reduction of the global burden of greenhouse gases such as carbon dioxide. The global CO_2 emissions are reduced, but the reductions occur in other industry sectors than the cement industry.

LCA techniques were applied to two scenarios for two waste streams, biomass (which would include sewage and paper) and solvents (not relevant to PPC).

These scenarios compared waste incineration (with and without energy recovery) against waste disposal by cement kiln. A net CO_2 reduction was shown for both waste streams. However, as the wastes in South Africa are more likely to be landfilled or recycled, the comparison of disposal by cement kiln to incineration is not relevant.

Therefore, the CO_2 emissions was considered for the five different waste streams to be disposed by PPC for the landfilling, recycling and disposing by cement kiln. Table 12-1 lists the life cycle stages to consider for the landfilling and recycling options. The formula for net CO_2 emissions are also shown. The net emissions are calculated from by summing the emissions from the use of coal (mining and transportation of coal, coal emission in the cement kiln, and the emissions generated if the waste is landfilled or recycled), and subtracting the emission from the waste (in the cement kiln) and emissions from mining and transporting raw materials in the case of recycling.

Table 12-1: Life cycle stages to consider

Cement Kiln vs. Landfilling	Cement Kiln vs. Recycling
A. Mining & transportation of coal (1 ton)	A. Mining & transportation of coal (1 ton)

B. Coal in cement Kiln C1. Landfill emissions D. Wastes to Cement Kiln (replace 1 ton coal)	B. Coal in cement Kiln C2. Recycling emissions D. Wastes to Cement Kiln (replace 1 ton coal) E. Mining & transport of raw materials
Calculation of net CO_2 release/reduction of Emissions:	
(A+B+C1) - D	(A+B+C2) – (D+E)

The key emissions are expected to arise from the cement kiln, and thus only the differences in the emission generated by the cement kiln have been calculated in this study (i.e. life cycle stages B and D as listed above). However, a more accurate calculation would need to include all life cycle stages. For example, transportation emissions included in the CEMBUREAU report indicated that the transportation of coal (stage A as listed above) generates 191 kg CO_2 per ton of coal.

The CO_2 emissions for the waste disposal by cement kiln, calculated and shown in table ***Table 12-2*** below were calculated based on the quantity of waste required to replace 1 ton of coal (in terms of energy value). As shown in the table and graph below, the use of biomass and sewage will generate more emissions per ton of coal replaced (red blocks), and fewer emissions for tyres, hydrocarbons and plastics (green blocks).

Table 12-2: Carbon dioxide emission from wastes disposed by cement kiln in comparison to emission from Coal

CO_2 emissions	**Units**	**Coal**	**Tyres**	**hydrocarbons ***	**Plastics ***	**Biomass**	**Sewage**
Calorific Value[1] = CV	**(GJ/t):**	26	32	40	31	16	16
Combustion Emissions[vi] CO_2 emissions per giga joule = CE	**kg CO_2/GJ**	93	85	80	75	110	110
CO_2 emissions per ton waste = CV x CE	**kg CO_2/t**	2418	2720	3200	2325	1760	1760
Tons waste required to replace 1 ton coal = CV_{coal} / CV_{waste}	**Tons equivalent**	1	0.8	0.7	0.8	1.6	1.6
CO_2 Waste Emissions to replace 1 t coal = kg CO_2/t x CV_{coal}/CV_{waste}	**kg CO_2/t coal**	**2418**	**2210**	**2080**	**1950**	**2860**	**2860**

* Further life cycle impacts for oil and plastics discussed in sections below

[vi] Sources of data:

a) Preparing a Process Industry Greenhouse Gas Emission Inventory Mike Ruby Envirometrics, Inc. Seattle WA www.pnwis.org/2004%20Events/GHG/RubyAll.pdf
b) CV values from table above
c) Environmental Benefits of Using Alternative Fuels in Cement Production – A Life Cycle Approach, CEMBUREAU

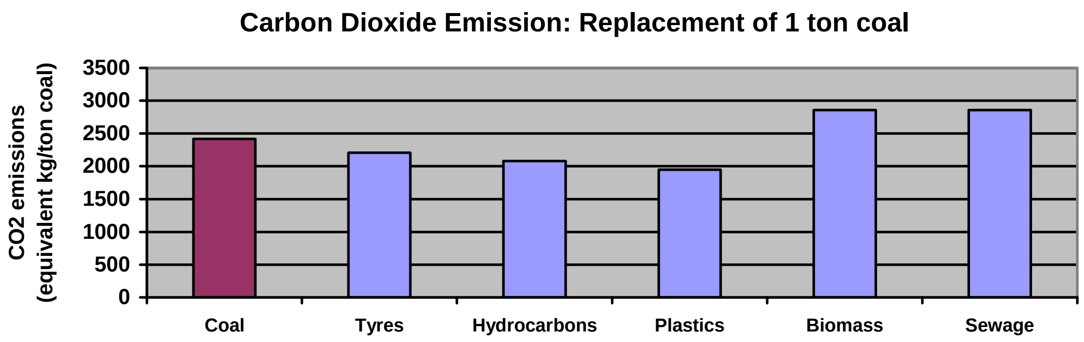


Figure 12-4: Carbon dioxide emission from wastes disposed by cement kiln in comparison to emission from Coal

The net benefit from replacing coal with plastics or oils (hydrocarbons) are discussed in the next section comparing recycling and disposal by cement kin.

Energy and Material Savings
The manufacture of cement is an energy intensive operation, and the cost of energy represents a significant part of the total production costs. On an EU wide basis, cement production totals approximately 170 million tonnes per year. With an average energy consumption equivalent to the combustion of 120 kg of coal per tonne of cement, the level of production utilises the equivalent of 20 million tonnes of coal.

Using a life cycle approach, the report demonstrates the overall environmental benefits that fuel substitution can deliver when the cement industry participates as a legitimate player within the Community's waste management infrastructure. The study states that t*he use of waste in European cement kilns saves fossil fuels equivalent to 2.5 million tones of coal per year.*

In comparison to PPC, approximately 160kg of coal is used to produce a ton of cement or 180 kg of coal per ton of clinker. Overall approximately 670 000 tons coal per year is consumed in production [vii]. This may be less efficient, but still comparable to the EU cement kilns. PPC has set initial targets to reduce virgin coal by 10% but, according to PPC, through experience and time the international experience is closer to 25%. *Thus PPC could save up from 67 000 tons (10%) to 167 500 (25%) tons of coal per year.*

12.3.3 Recycling versus recovery in cement kilns

The study used LCA techniques to assess the recycling of waste plastics and waste oils versus the utilization of waste plastic in cement kilns as a heat source.

Plastics
Using the analysis conducted by the Fraunhofer Institute for emissions of CO_2, energy use, and the generation of hazardous waste, the following statements were made:

1. **Materials**
Utilising 1 kg of waste plastics in cement kilns, displacing an equivalent amount of fossil fuel in thermal units results in avoided emissions relating to the mining, handling, transportation and use of coal at the kiln;

2. **CO_2 Generation**
The use of waste plastics in cement kilns as a substitute fuel results in the largest net reduction in CO_2 generation of the three management options, relative to landfilling. For waste incineration, the offset from avoiding external energy generation is insufficient to counterbalance the avoided burden through not having to mine,

[vii] Information supplied by PPC

transport and use coal at the cement kiln. Hydrogenation and conversion of waste to plastic goods itself is an activity that uses energy, resulting in a small net saving in CO_2 generation.

Overall, the cement kiln option outperforms the remaining options, maximising the beneficial use of waste plastics relative to conventional incineration or conversion into chemical goods. This is illustrated in the following figure:

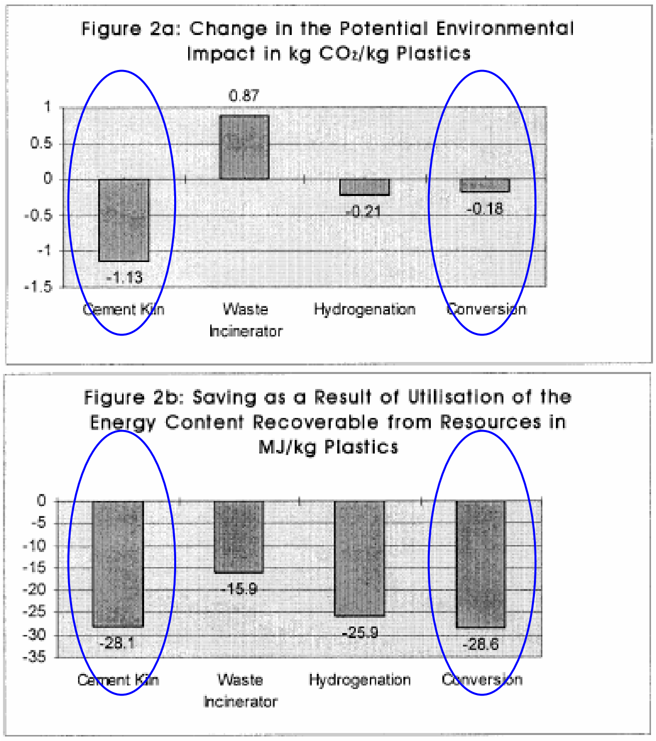


Figure 12-5: Change in potential impacts – Cement Kiln vs. Conversion

3. Energy Recovery:
Apart from waste incineration, which is a relatively inefficient converter of latent energy, the other management options offer comparable benefits in energy utilization relative to landfill.

4. Hazardous Waste
The cement kiln, hydrogenation and conversion options do not produce hazardous waste, since any waste products are recyclable.

Waste Oils
The use of waste oils in cement kilns, displacing a conventional fuel such as coal and the reprocessing of waste oil into lubrication products was also assessed in the study.

The use of waste oil in cement kilns will necessitate the processing of crude oil into virgin lubricating oil products to replace the products that would have been made from the recycling process. Therefore the environmental burdens associated with crude oil processing were added to the environmental burdens resulting from the use of waste oils in cement kilns. Conversely, the reprocessing of waste oils into lubricating oil products would mean the continuation of fossil fuel procurement and use at the cement kiln. Therefore the environmental burdens associated with coal extraction, processing and use in cement kilns were added to the environmental burdens resulting from reprocessing operations. The LCA results for CO_2 emissions and energy use are displayed in Table 6 of the study:

Table 6 Environmental burdens associated with the management of waste oils

Activity	CO_2 Emitted (kg/t waste oil)	Energy Used (MJ/t waste oil)
Reprocessing of Waste Oil		
• Mining & transport of coal	551	4,300
• Waste oil refining	149	2,115
• Coal in cement plants	4,023	462
• TOTAL	4,732	6,877
Waste Oil in Cement Kilns		
• Crude oil procurement	124	1,434
• Crude oil refining	246	2,676
• Waste oil in cement kilns	2,536	17
• TOTAL	2,905	4,121

Figure 12-6: Environmental burdens associated with the management of waste oils

As with the utilisation of waste plastics in cement kilns, the use of waste oils as supplementary fuel outperforms the alternative waste management option of reprocessing. Emissions of CO_2 and overall energy utilisation are approximately 60% lower for the cement kiln option than when the waste oil is reprocessed into lubricating oil products.

12.3.4 Summary of Environmental Benefits Provided by Cement Kilns

The analyses demonstrate the clear benefits the cement industry can provide in CO_2 reduction through integrating cement kilns within an overall waste management strategy, either through the use of alternative fuels, or through the use of materials such as industrial by-products as additional cement constituents.

Given the similarity between the types of cement kilns, coal required per ton product and emissions generated, the conclusions are thus expected to apply to PPC's cement kilns in South Africa.

The studies shows that the waste materials which the industry has utilised as alternative fuels, which would either have been landfilled or combusted in dedicated incinerators, has the following benefit when their use in cement kilns replaces fossil fuels:

- maximises the recovery of energy while ensuring their safe disposal;
- produces overall environmental benefits by reducing releases to air, water and land;
- prevents resource depletion of valuable non-renewable fossil fuels and
- obviates the need to build dedicated incineration facilities.

The important contribution that the cement industry can make to a nation's waste management infrastructure has been therefore been explicitly recognised by several European governments.

13 CONCLUSIONS

There is no single or ideal waste management strategy that will meet the needs of every community. In addition to assessing the impacts of the life cycle stages for the different waste management options, an integrated approach to waste management must incorporate the evaluation of the relevant economic, technical, political and social factors.

An integrated waste management strategy will therefore need to strike a balance between the various tiers and waste management approaches, and continue to push industry to assess opportunities higher up in the waste hierarchy. Disposal by cement kiln offers an additional waste management option, higher up in the hierarchy than landfilling. The cement kiln recovers energy and utilises the material value of the ash in the cement. Waste materials less suitable for recycling and which have high calorific value should be processed through energy recovery rather than landfilling. Using such residual wastes as sources of energy displacing fossil fuels such as coal and can provide a reduction in GHG emissions for certain waste streams. The availability of this option in South Africa is expected to divert a substantial amount of waste that would otherwise have been landfilled or illegally dumped, thus improving the status of waste management in South Africa.

Although source reduction provides the maximum benefit for many impacts, this practice does not always receive the attention it deserves, and the waste manager seldom has the opportunity to implement waste minimization programmes that would reduce wastes at source. However, the financial gains from source reduction are far greater than any other option, and therefore the option of disposal by cement kiln is not expected to provide a disincentive for industry considering minimisation options.

As noted by CEMBUREAU, the practice of employing alternative fuels in cement plants does not hinder the establishment of a sound waste management industry. The practice can co-exist alongside a vigorous and thriving materials recovery and recycling and incineration industry, without distorting the essential principles of the waste management hierarchy.

14 GLOSSARY

Carbon Dioxide (CO_2)
A colourless, odourless gas that is a product of fossil fuel combustion and is a normal part of the ambient air CO_2 is a GHG that traps infrared radiation and contributes to global warming.

Carbon Equivalent
A metric measure used to compare the emissions of the different greenhouse gases based on their global warming potential, and most commonly expressed as metric tons of carbon equivalents (MTCE).

Carbon Sequestration
The uptake and storage of carbon. Trees and plants absorb carbon dioxide, release the oxygen and store the carbon. Fossil fuels continue to store carbon until burned.

Carbon Sinks
Forests, oceans, landfills and other reservoirs that take in and store more carbon than they release. Carbon sinks can serve to partially offset GHG emissions.

Energy Recovery
The process of burning waste in a combustion unit and recovering the heat released to make steam or generate electricity. Energy recovery is sometimes called the 4th "R".

Fossil Fuel
Combustible geologic deposits of organic materials, formed from decayed plants and animals that have been converted to crude oil, coal, natural gas, or heavy oils.

Global Warming
The progressive, gradual rise of the earth's surface temperature linked to increased anthropogenic emissions of greenhouse gases, and responsible for changes in global climate patterns.

Greenhouse Gas (GHG)
Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, halogenated fluorocarbons, ozone, perfluorinated carbons and hydrofluorocarbons.

Methane (CH4)
A hydrocarbon GHG with a global warming potential estimated at 21. Methane is produced through the anaerobic (without oxygen) decomposition of waste in landfills, as well as during animal digestion, decomposition of animal wastes, production of natural gas and petroleum, coal production, and incomplete fossil fuel combustion.

Recycling
Recycling involves the reprocessing of a waste stream into a new product, raw material, or something else that is useful and marketable.

Reduction
Reduction involves design or processing modifications that limit processing waste, minimize material utilization, extend durability or reduce in some other way the total amount of material that must be disposed of eventually.

Reuse
Reuse involves using an item over again for either the same or a different purpose. Cloth diapers, refillable beer bottles and rechargeable batteries are all examples of reuse.

Reference: some of the above definitions were adapted, in part, from the U.S. Environmental Protection Agency's on-line Global Warming Glossary, available at
<http://www.epa.gov/globalwarming/glossary.html#C>

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