South Africa's power producer's revised Coal Ash Strategy and Implementation Progress

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Abstract

Eskom has embarked on a process to increase the utilisation of the ash produced through the electricity generation process at its coal fired power stations. In the 2014/15 financial year, 119.2 million tons of coal was consumed, producing 34.4 million tons (28.9%) of ash. About 7% of the Eskom ash is sold from 6 of the 13 Eskom coal-fired power stations. Many stations are currently running out of ash storage space - expansion of the ash disposal facilities is required which could impact security of supply, due to limited ashing areas. In addition, recent legislative requirements may lead to extra requirements for ash storage facilities, requiring high capital expenditure. Increased utilisation of ash will postpone or ultimately avoid such capital expenditure. The South African legislative framework pertaining to waste management strictly governs ash utilisation. Unlocking legislation would be a key enabler to market development of ash applications. It is for this reason that Eskom has rejuvenated its Ash Utilisation Project by submitting a landmark application to department of environmental affairs on behalf of the industry. Eskom is therefore leading a strong advocacy campaign for ash utilisation and calls on ash producers and off takers to support the initiative.

Ash could play a key role in business development, job creation, skills transfer and localisation – specifically in the brick making and construction industries. The development of small brick making facilities in close proximity to power stations is ideal. It is imperative to develop new markets that consume high volumes of ash - these include road construction and agriculture/land rehabilitation. The backfilling of mines with ash provides an ideal opportunity – tied collieries are located in close proximity of power stations and could absorb high volumes of ash. At the same time this could benefit the ability to rehabilitate mines and mine closures more cost efficiently. Naturally, care needs to be taken on the environmental and health impact of this application.

Multiple benefits can be derived from dealing with ash in an environmentally responsible way. Not only will the environmental footprint be limited, new applications will reduce CO_2 emissions, acid mine drainage can be treated and mine rehabilitation supported. Eskom cost reduction benefits could eventually filter through to the electricity consumer in terms of the electricity price and satisfactory socio-economic benefits can be realised.

1. INTRODUCTION

In 2015, South African authorities escalated the use of ash to a strategic priority. It was envisaged that the utilisation of ash could allow for improved business development, increased infrastructure development, job creation, create social upliftment and allow for skills development.

In the 2014-15 year Eskom burnt 120Mt of coal in 13 power stations, producing 35 000MW of electricity and forming 34.4Mt of ash as a waste. Of this ash volume approximately 7% was sold to the construction industry for inclusion in cement or bricks. At present this ash is classified as a hazardous waste, which in turn creates negative perceptions and evokes legislative constraints as anyone who wants to utilise ash would have to apply for a Waste Management License, a costly and time consuming exercise. This constraint limits and in many respects prohibits the application of new technologies because new businesses cannot afford the initial cost. In addition, the hazardous nature of the ash requires the installation of Class C liners beneath any ash handling facility, an extremely costly requirement.

Other power station systems may also impact the availability of ash. Firstly, to preserve and protect South Africa's water resources, Eskom power stations all operate on a Zero Liquid Effluent Discharge policy. This means that all water that enters an Eskom site is retained on site, through an ever cascading quality. Saline effluents and the poorest quality water are disposed of on the ash handling facility, where the ash acts as a salt sink for the effluents. It is estimated that 74% of the fresh ash produced is required for effluent treatment. If this sink capacity is not available, leaching may occur. Thus approximately 19% of the fresh ash produced is available for reuse. If larger volumes of ash are required alternative water treatment technologies will be necessary, requiring investment. Table 1 shows the estimated volumes of ash available for use from each site.

Secondly, the use of blended coal in the power production process causes the resulting ash to have a varying quality. This variability may cause the ash to act differently based on its constituents. Finally, the dumping process of ash is classified as either wet or dry. Wet ashing transports the ash as a slurry to the handling facility where it is allowed to settle and the water recycled. Dry ashing involves the placement of "conditioned" ash. The ash is dampened with 10% water before placement, to minimise dust formation.

2. ESKOM STRATEGY

In order to manage the increased utilisation of ash Eskom has developed an ash strategy that has been approved by board (Figure 1). In terms of the strategy the scope of the programme was developed, including a programme roadmap and implementation plan. The strategy details:

- The adoption of the cost avoidance rather than the revenue recovery model.
- The development of an ash strategy per power station.
- Consultation with Department of Environmental Affairs and relative government departments, in order to change the ash classification.
- Submission of exclusion documents to government, on behalf of industry, to ease the legislative constraints on users.

- Unlock legislative constraints.
- Explore all possible ash utilisation technologies and applications.
- Collaboration with industrial stakeholders.
- Development of customer interfaces for sales, take off points etc.
- Conduct research (pilot plants, literature reviews, technology development).
- Stakeholder engagement to increase awareness of ash.

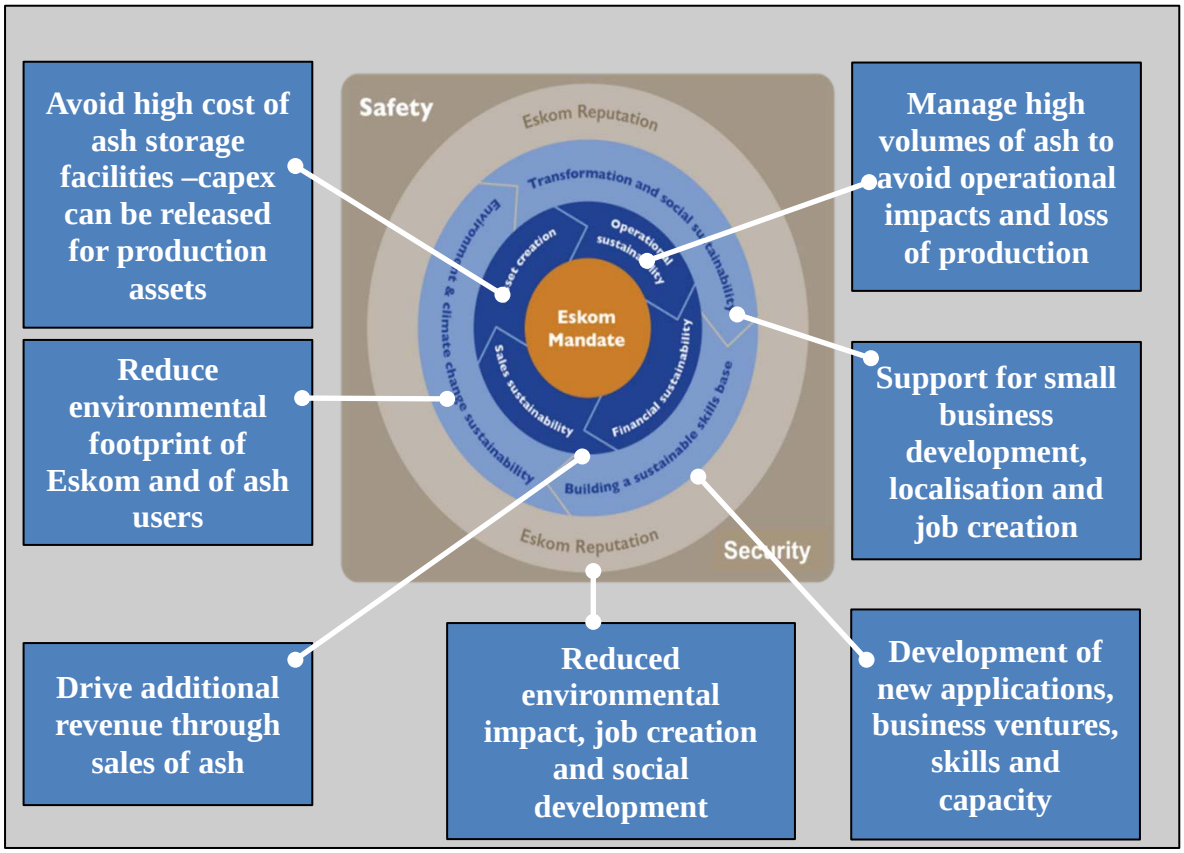
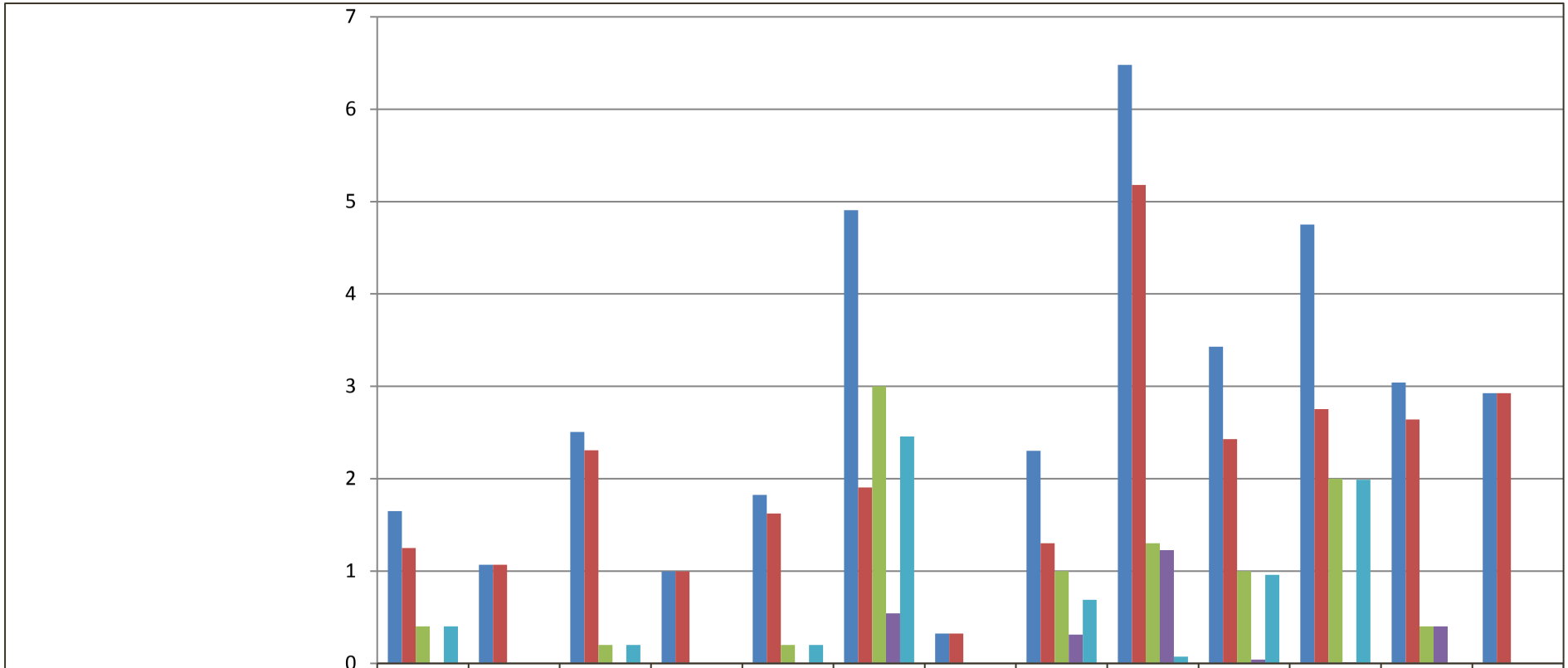


Figure 1: Eskom ash strategy.

There are significant potential benefits for Eskom in terms of ash utilisation. These include a decrease in CAPEX and OPEX values in terms of ash handling and storage. There is also a possibility of a small increase in revenue and a decrease in environmental liability. In addition, several power stations are nearing end of storage life on the ash handling facilities. This means that, if no other storage space can be found, the power station will have to shut down.



	Arnot	Camden	Duvha	Grootvlei	Hendrina	Kendal	Komati	Kriel	Lethabo	Majuba	Matimba	Matla	Tutuka
Produced(Mt)	1.6503	1.068	2.506	0.996	1.824	4.906	0.324	2.302	6.48	3.428	4.752	3.04	2.926
Ash used for effluent sink	1.2503	1.068	2.306	0.996	1.624	1.906	0.324	1.302	5.18	2.428	2.752	2.64	2.926
Saleable (Mt)	0.4	0	0.2	0	0.2	3	0	1	1.3	1	2	0.4	0
Ash Sold (Mt)	0	0	0	0	0	0.542	0	0.312	1.227	0.042	0.012	0.4	0
Opportunity for further sales (Mt)	0.4	0	0.2	0	0.2	2.458	0	0.688	0.073	0.958	1.988	0	0

Table 1: Estimated ash volumes available per power station. This table is under review and may be subject to change thus impacting ash availability, location to market and possibly market forces.

2. AVOIDED COST

Eskom's immediate focus is to increase utilisation of ash in current applications (bricks, cement etc). There is a concerted drive to increase revenue from ash sales but the benefits for avoided cost, in terms of CAPEX and OPEX, are more significant. The avoided cost has been institutionalised and is now reported.

Some of the possible areas for cost avoidance are:

- The avoidance of future CAPEX, due to the lack of or delayed liner requirements;
- Power stations where ash handling plant extensions are planned.
- Decreased volumes of ash to be handled and stored in facilities, decreasing the OPEX costs. The variable and total OPEX costs need to be determined per power station as ash handling on each site varies.

The calculation of the avoidable OPEX cost is depicted in Figure 2. The white regions of the figure indicate the fixed costs that will not vary in the short term (salaries, rent and overheads). When higher volumes of ash are utilised, causing decreased handling, a proportion of the fixed costs may become avoidable (grey regions). The variable cost (blue) indicates the costs that vary with each unit of ash handled (Fuel etc).

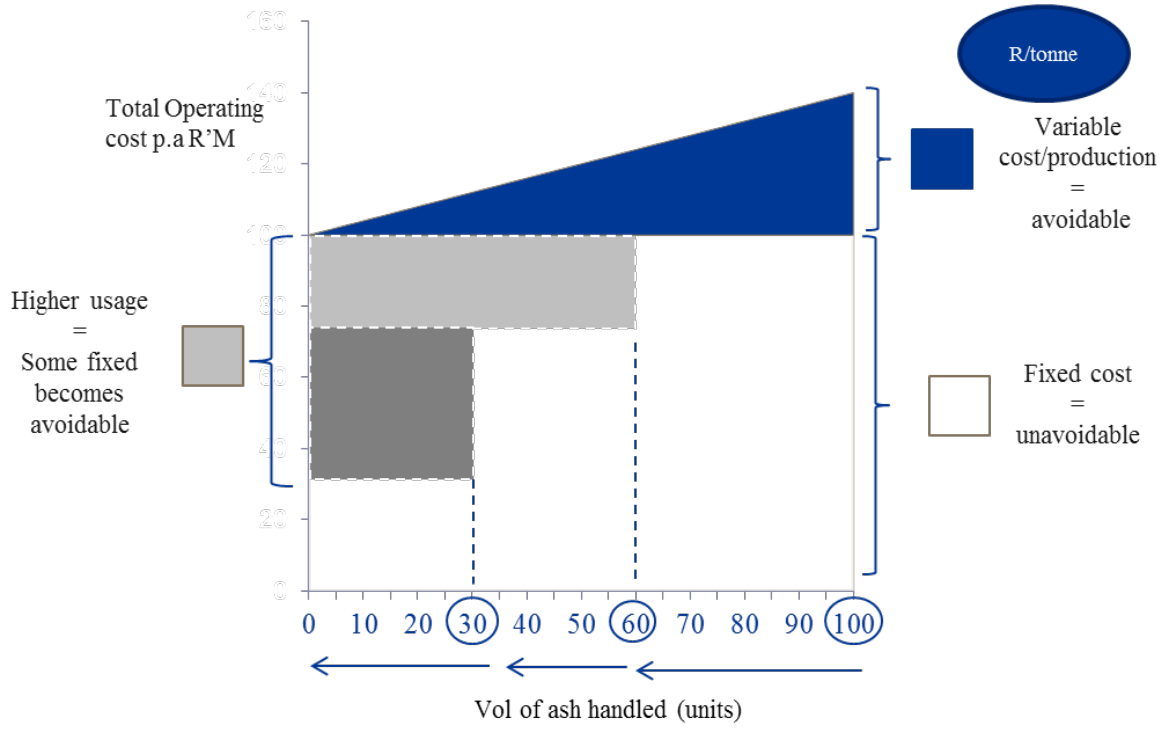


Figure 2: Avoided OPEX cost calculation.

In terms of avoidable CAPEX cost (Figure 3), the main consideration is the cost of the liner. This avoided cost is only applicable on the dry ashing systems, as the liner is placed in small sections as the dump expands. Liner costs are assumed to be variable depending on the volume of ash placed on the dump (the less ash, the

longer the intervals between expansion and lining). For calculations, it is assumed that the cost is avoided on an annual basis, whereas in reality it occurs on a 4 yearly basis.

The total cost benefit calculation is shown in Figure 4 and considers actual costs as calculated by the avoided OPEX and CAPEX calculations. The avoided CAPEX costs have been calculated based on a high level regression analysis. However a precise quantification of the pure variable component of the OPEX cost is still required with a deeper understanding of the behavior of these costs at different levels of ash utilisation.

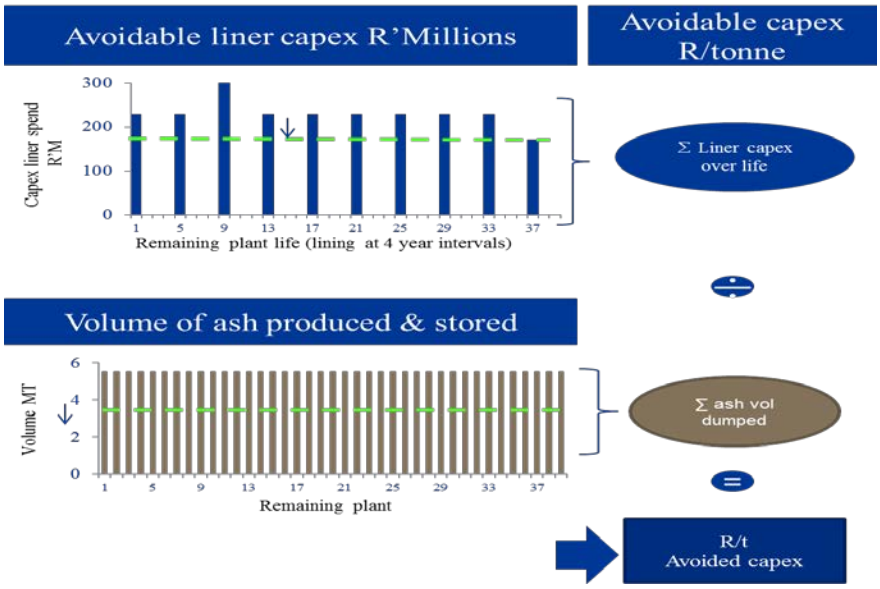


Figure 3: Avoided CAPEX cost calculation

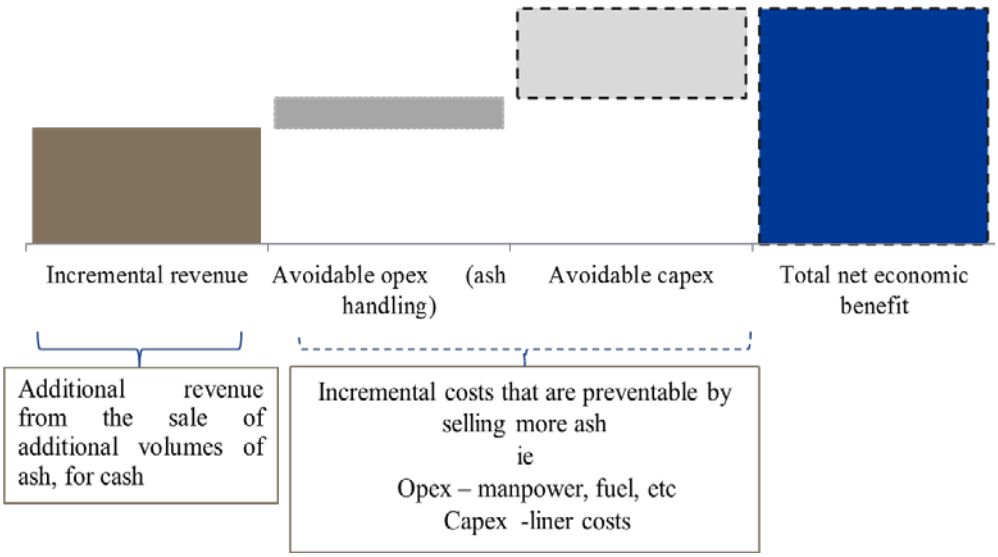


Figure 4: Total cost benefit of ash utilisation.

3. ASH LEGISLATION

All ash applications all make use of one or more of the unique properties of the material:

- Its pH, which is above 11.5 when initially produced and weathers to a minimum of 8.5 over time;
- The spherical shape of the ash particle, which improves flow characteristics and allows for effective compaction;
- The wide range of particle sizes, which increases surface area and allows for effective compaction;
- The pozzalanic nature of ash which allows for setting of the ash once wet.

There are several ash applications which are available internationally, ranging from low to extremely high cost. These include rare earth metal extraction from ash; mine backfilling, mine drainage treatment, soil amelioration, land reclamation, road construction, paint, rubber, zeolite production and geopolymers. However, cementitious uses, the inclusion of ash in cement based bricks and the use of fly ash in cement itself, are by far the biggest users in South Africa. Each technology has its own constraints, of which transportation is one of the most limiting factors. Therefore any new developments need to near to the power plants.

The classification of ash as a hazardous waste needs to be addressed in order for ash utilisation to progress. At present, companies that wish to utilise ash require a waste management license in order to operate. This license costs approximately R200 000 and requires 2 years for processing, thus making it impossible for small business to achieve.

To this end, Eskom consulted with the Department of Environmental Affairs (DEA), regarding the process of application for exclusion from waste legislation constraints for ash off-takers. It was recommended that a Regulation 9 document be submitted to obtain exclusion from the need for a waste management license, for various applications.

Eskom, through Zitholele Consulting, submitted the Regulation 9 document to cover 4 of the largest volume usage applications. These applications were mine drainage treatment and backfilling; soil amelioration and land reclamation; road construction and brick and cement development.

On consultation with the DEA, the timelines for the Regulation 9 approvals was estimated at approximately 24 months, at the earliest. Due to the urgent nature of the approval requirements for brick makers, it was decided to submit a Section 74 document for a temporary exclusion permit, from the waste management legislation. This exclusion is temporary and is terminated once a decision is finalised on the Regulation 9.

4. CLASSIFICATION OF ASH

The hazardous classification of ash in South Africa is unique worldwide and the waste type classification is the strictest in the world. Internationally ash is classified as a by-product or a resource depending on the country. According to NEMWA

(National Environmental Management Waste Act), in order to classify ash, a full ICP (Inductively Coupled Plasma) analysis and complete leaching (varying protocols) of the ash are required. Table 2 explains the LC (leachable concentration) and TC (total concentration) allowable for the different types of waste, while Table 3 expands on the allowable concentrations for each type.

Table 2: Risk assessment criteria

Criteria	**Risk Level**	**Description of Risk associated with Disposal to Landfill**
LC > LCT2, or TC > TCT2	Type 1: High Risk	Considered high risk waste with a very high potential for contaminant release. Requires very high level of control and ongoing management to protect health and the environment
LC > LCT 1 and <LCT 2 or TC > TCT 1 and < TCT 2	Type 2: Moderate Risk	Considered moderate risk waste with high potential for contaminant release. Requires high level of control and ongoing management to protect health and the environment
LC > LCT 0 and < LCT 1 or TC > TCT 0 and < TCT 1	Type 3: Low Risk	Considered low risk waste with some potential for contaminant release. Requires proper control and ongoing management to protect health and the environment
LC < LCT 0 or TC < TCT 0	Type 4: Very Low Risk	Very low risk waste with low potential for contaminant release. Requires some level of control and ongoing management to protect health and the environment

Several studies of Eskom ashes have identified that most ashes fall into the Type 3 category, low risk. These studies all indicate that the triggers are just over the TCT or LCT 0 concentrations. Table 4 shows a snapshot of the total elemental concentrations found in Eskom ashes, a robot colour coding scale has been used to identify trigger elements. In this case the main trigger elements are arsenic, barium, copper and lead. However, the concentrations detected are much nearer to the TCT 0 concentrations than the TCT 1.

Table 5 gives the acceptable total leachable concentrations for 5 Eskom ashes. In this case there are more elements that trigger the classification, including arsenic, boron, chromium, manganese, molybdenum, selenium and vanadium. This is mainly due to the leaching protocol which requires the acidification of the sample. More recent protocols like the LEAF are more indicative because the leaching is conducted at several different pH levels. When the leaching protocol is conducted, total dissolved solids and the sulphate concentrations are also trigger agents.

As part of Eskom's ash utilisation strategy, each power station's fly ash, bottom ash, fresh and weathered ash were resampled for full analysis of both total and leachable concentrations. These samples are being analysed according to SANS 10234 to determine the toxicity of the ashes and are being subjected to the LEAF (Leaching Environmental Assessment Framework) leaching protocol. The results of these analyses will be utilised to advise the Department of Environmental Affairs on the possible leaching risks of ash in non-acidic environments. They will be compared to

international results and associated risks, leading to a possible exclusion of coal combustion products from the waste classification.

Table 3: Allowable concentrations per element.

Contaminants in Waste	TCT0 mg/kg	TCT1 mg/kg	TCT2 mg/kg	LCT0 mg/l	LCT1 mg/l	LCT2 mg/l
Metal Ion Contaminants						
As, Arsenic	5.8	500	2000	0.01	0.5	1
B, Boron	150	15 000	60 000	0.5	25	50
Ba, Barium	62.5	6 250	25 000	0.7	35	70
Cd, Cadmium	7.5	260	1 040	0.005	0.25	0.5
Co, Cobalt	50	5 000	20 000	0.5	25	50
$Cr_{Total,}$ Chromium Total	46 000	800 000	N/A	0.1	5	10
Cr(VI), Chromium (VI)	6.5	500	2 000	0.05	2.5	5
Cu, Copper	16	19 500	78 000	1	50	100
Hg, Mercury	0.93	160	640	0.001	0.05	0.1
Mn, Manganese	1 000	25 000	100 000	0.4	20	40
Mo, Molybdenum	40	1 000	4 000	0.07	3.5	7
Ni, Nickel	91	10 600	42 400	0.07	3.5	7
Pb, Lead	20	1 900	7 600	0.01	0.5	1
Sb, Antimony	10	75	300	0.01	0.5	1
Se, Selenium	10	50	200	0.01	0.5	1
V, Vanadium	150	2 680	10 720	0.1	5	10
Zn, Zinc	240	160 000	640 000	3	150	300
Inorganic Anions						
TDS	N/A	N/A	N/A	1 100	12 500	25 000
Chloride	N/A	N/A	N/A	300	15 000	30 000
Sulphate	N/A	N/A	N/A	250	12 500	25 000
NO_3 as N, Nitrate-N	N/A	N/A	N/A	11	550	1 100
CN^- (total), Cyanide Total	14	10 500	42 000	0.07	3.5	7

Table 4: Total concentrations of various elements in Eskom ashes.

Element	TCT0 mg/kg	TCT1 mg/kg	TCT2 mg/kg	1 TC mg/kg	2 TC mg/kg	3 TC mg/kg	4 TC mg/kg	5 TC mg/kg
As	5.8	500	2 000	10.46	10.81	11.75	5.31	11.11
B	150	15 000	60 000	150	117	160	93	36
Ba	62.5	6 250	25 000	213.85	485.33	926.06	607.11	450.03
Cd	7.5	260	1 040	2.46	2.65	1.94	2.35	1.4
Co	50	5 000	20 000	9.15	8.14	11.64	10.3	11.27
Cr	46 000	800 000	N/A	176.04	125.65	119.15	120.13	141.95
Hg	16	19500	78 000	0.1	0.44	0.31	0.41	0.23
Cu	0.93	160	640	23.94	27.58	34.77	32.47	51.04
Mn	1 000	25 000	100 000	220	221	200	290	390
Mo	40	1 000	4 000	5.58	9.02	3.33	6.25	2.72
Ni	91	10 600	42 400	38.78	34.18	41.02	54.34	66.17
Pb	20	1 900	7 600	70.42	82.83	60.16	89.59	98.15
Sb	10	75	300	1.42	1	0.37	0.72	1.09
Se	10	50	200	1.12	1.5	1.01	1.98	1.19
V	150	2 680	10 720	77.64	117.52	70.64	71.23	110.59
Zn	240	160 000	640 000	63.06	38.61	36.06	35.36	164.03

Table 5: Leachable concentrations of various elements in Eskom ashes.

Element	LCT0 mg/l	LCT1 mg/l	LCT2 mg/l	1 LC mg/kg	2 LC mg/kg	3 LC mg/kg	4 LC mg/kg	5 LC mg/kg
As	0.01	0.5	1	0.39	0.13	0.47	0.44	0.43
B	0.5	25	50	10	3.5	13	5.1	2.2
Ba	0.7	35	70	0.14	0.32	0.23	0.27	0.19
Cd	0.005	0.25	0.5	0.002	<0.002	0.003	0.003	0.003
Co	0.5	25	50	0.005	0.007	0.02	0.02	0.02
Cr	0.1	5	10	0.39	0.05	0.27	0.86	0.1
Cr6+	0.05	2.5	5	0.03	0.02	0.07	0.06	<0.02
Hg	1	50	100	0.003	0.004	0.003	0.004	0.004
Cu	0.001	0.05	0.1	0.02	0.01	0.01	0.05	0.07
Mn	0.4	20	40	0.37	0.54	0.13	1.67	0.91
Mo	0.07	3.5	7	0.09	0.06	0.11	0.13	0.15
Ni	0.07	3.5	7	0.04	0.04	0.09	0.09	0.07
Pb	0.01	0.5	1	<0.005	<0.005	<0.005	0.005	<0.005
Sb	0.01	0.5	1	<0.02	<0.02	<0.02	0.06	<0.02
Se	0.01	0.5	1	0.026	0.032	0.019	0.05	0.02
V	0.1	5	10	1	0.34	1	1.1	0.89
Zn	3	150	300	0.02	0.04	0.07	0.03	0.12
TDS g/ℓ	1	12.5	25	7.5	8.36	8.8	7.17	6.8
Chloride	300	15 000	30 000	7.3	6	<5	3.7	<5
NO_3 as N	11	550	1100	1	0.84	0.2	0.9	0.2
Cyanide	0.07	3.5	7	0.01	<0.01	<0.01	0.02	0.01
Sulphate	250	12 500	25 000	130	270	365	188	198

Note:

	Below or equal to LCT 0
	Above LCT 0, below LCT 1
	Above LCT 1, below LCT 2
	Above LCT 2

5. CONCLUSIONS

At present coal ash is classified as a hazardous waste, due to its heavy metal concentrations. The legislation governing this classification is extremely strict and is being reviewed in association with international norms and standards.

Eskom's ash strategy aims to utilise ash to benefit from an associated avoided cost linked to the handling and storage of the ash. In order to permit ash utilisation a Regulation 9 submission has been handed to DEA to allow for the exclusion of the hazardous classification of ash, when used in brick making, cement, road construction, soil amelioration and mine backfilling.