CHAPTER TEN - TECHNO ECONOMIC & ENVIRONMENTAL MODELLING OF BENEFICIATION PATHS

In this Section the background for the techno-economic modelling method are described. The section describes the process of evaluating the (10.4.1) process results to determine the optimal process route and flow chart (section 10.4.2 to 10.4.4). In Section 10.5 the cost estimation results and method are described, followed by a cost benefit analysis through the financial modelling of multiple low to high grade export production scenarios. In Section 10.7 a perspective on the results in Section 10.6 is given with the emphasis on the South African economy.

10.1 Introduction

The advent of low quality export coal demand has brought a new dimension of possibilities to the South African coal industry. Products traditionally only of value to the domestic utilisation or combustion industry, now have the potential to be exported with only minor amounts of upgrading required through beneficiation. With regards to lower grade quality export, the questions needing to be answered are:

1. What specification/s could be deemed to be lower grade quality export?
2. Is there an environmental and sustainability benefit with an economic upside?
3. Is there an economic benefit, and if so what are the minimum criteria?
4. Which value adding solution could be adapted to each of the three coal types which are part of this investigation?

Various process models (for a range of thermal coal export products) were calculated at high level to determine the following requirements:

1. CAPEX (Data summarised in Appendix B. See Tables B1, B2, B3)
2. OPEX (Data summarised in Appendix C. See Tables C1, C2, C3)
3. NPV at each scenario (10 year base) (Data summarised in Appendix D. See Table D1, D2, D3)
4. Electricity Requirement and Carbon footprint (Data summarised in Appendix A. See Table A1, A3 and Tables 22-24)

In this Section 10 the Techno-economic evaluations will be discussed with reflectance on the environmental aspects.

10.2 Product Quality and Market

The product qualities modelled were based on API4 forward prices. The current price at the time of modelling was US$ 96/ton for a RB1 product (6000 kcal/kg NAR CV). See Figure 153, Tables 22-24 gives a summary of the thermal products marketed out of RBCT.

Figure 153: *Steam Coal Index FOB Prices for RB1, until July 2012.*

The lower quality export prices were adjusted linearly per GJ/ton with an additional discount of 10 US$ /ton. The adjustment is due to the lower CV of low grade products and then higher ash content.

An additional transport cost for higher volume lower grade export product was factored in the costs. The transport costs addition are summarised in Tables 22-24. Possible savings in discards management volumes were however not factored in.

10.3 Methodology for Economic Analysis

The parameters indicated in Table 21 were used in the economic analysis. It should be noted that although individual cost benefit models were developed, final financial modelling was done based on industry pricing. This model has updated PPI, CPI and tax rates.

Table 21: *Main Economic Assumptions for preparation plant scenarios*

Parameter	Assumption
Internal rate of return (after taxes)	10%
General plant depreciation period	5 years
Discount rate (for Greenfields project)	12%
Income tax rate	39%
Electricity cost	53 cents/kWh
Working capital	Based on industry data and Wood-Mackenzie report
Plant availability	6 000 hours per year

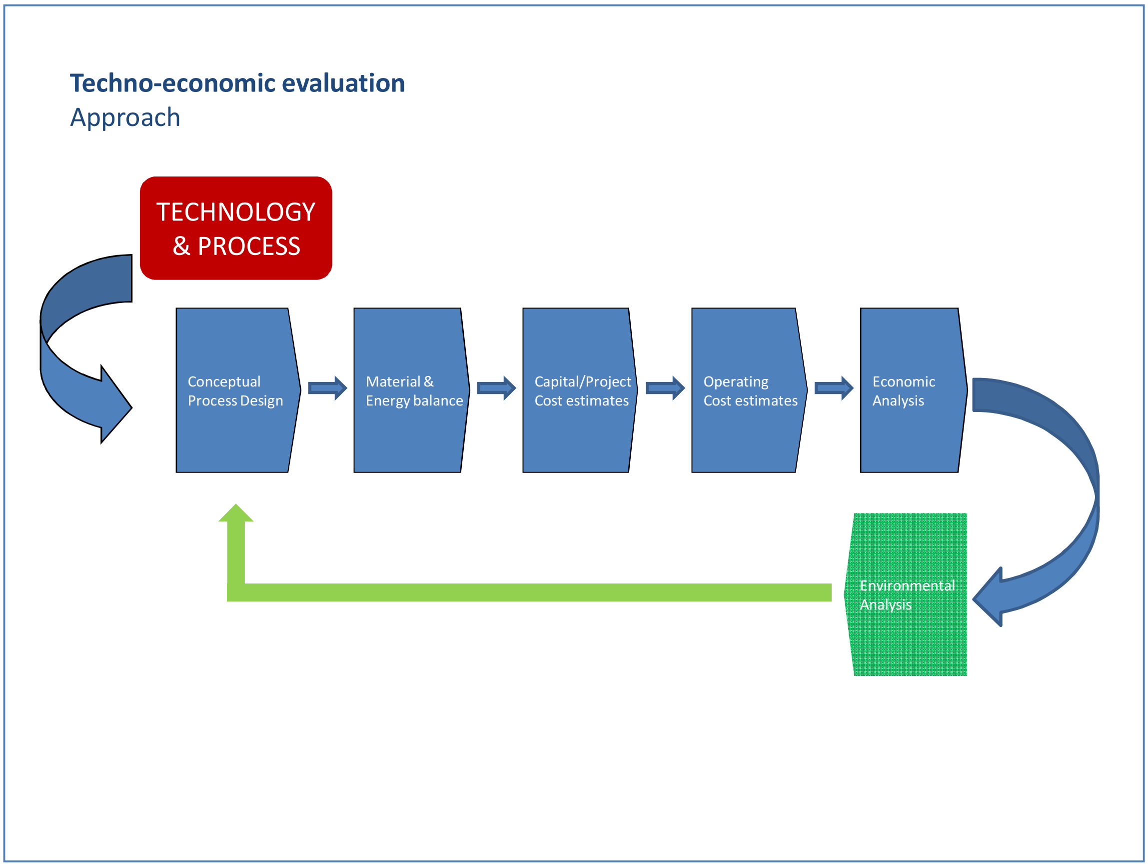

Figure 154: *Techno-economic approach for process models.*

Figure 154 indicates the methodology that was followed in the techno-economic approach. The final phase of the approach involved the environmental analysis, which included:

1. The power requirements of each process and the individual carbon footprint
2. The calculated emission rates resulting from the thermal coal production of both CO_2 and SO_2
3. The calculated emission rates per unit energy

10.4 Modelling Results and Discussion

10.4.1 Process Results

The process results indicated that conventional dense medium plants result in the highest comparative yields and recoveries, compared to water Jigs and dry processing. The CAPEX and OPEX of dry processing units are, however, lower and are less resource dependant, on water and electricity. The coal prices unfortunately cause reductions in recovery to have the greatest impact on margin.

As Strydom (2010) stated, global trends towards environmentally sustainable ore processing have resulted in a great deal of interest in the development of dry processing alternatives to conventional processing techniques.

The OPEX parameters are illustrated in detail in Tables 22, 23 and 24.

Table 22: *Operating cost summary with carbon footprint - Witbank Coalfield No. 4 Seam * Transport, Port and Overhead Costs obtained from Wood-Mackenzie 2012 report*

	Witbank Coalfield No. 4 Seam Export Operating Cost Economic Parameters for 500 tph Plant (tph = tons per hour)									
	Mining	Preparation	Transport	Port	Overheads	CHPP Power Requirement		Electricity Cost	CHPP Carbon Footprint	
	Cost (R'/ROM Ton)		Cost (R'/Saleable Ton)			kW	kWh	R'000 per annum	CO_2 tons	Reference
DMS Cyclones (All)	R 164.95	R 22.41	R 141.19	R 38.95	R 25.68	3 605	12 978	41 270	11 161	*WoodMackenzie & Industry
DMS BATH + DMS Cyclones (All)	R 164.95	R 21.14	R 141.19	R 38.95	R 25.68	3 146	11 326	36 015	9 740	*WoodMackenzie & Industry
WATER JIGS + DMS Cyclones (All)	R 164.95	R 15.82	R 141.19	R 38.95	R 25.68	3 311	11 921	37 908	10 252	*Sanders (2002)
DRY FGX + DMS Cyclones	R 164.95	R 12.27	R 141.19	R 38.95	R 25.68	2 497	8 989	28 585	7 731	*Länger et al. (2010)
DRY XRT SORTER + DMS Cyclones	R 164.95	R 11.75	R 141.19	R 38.95	R 25.68	2 197	7 907	25 146	6 800	* Von Ketelholdt (2009)
Three Product Cyclone	R 164.95	R 25.62	R 141.19	R 38.95	R 25.68	3 695	13 302	42 302	11 440	*Industry (Adapted from Umlalazi Plant)
DMS Cyclones + Dry Screening	R 164.95	R 13.91	R 141.19	R 38.95	R 25.68	2 343	8 436	26 826	7 255	*WoodMackenzie & Industry
DMS BATH + Dry Screening	R 164.95	R 13.27	R 141.19	R 38.95	R 25.68	2 045	7 362	23 410	6 331	*WoodMackenzie & Industry
WATER JIGS + Dry Screening	R 164.95	R 7.11	R 141.19	R 38.95	R 25.68	3 018	10 863	34 545	9 342	*Sanders (2002)
DRY FGX + Dry Screening	R 164.95	R 8.84	R 141.19	R 38.95	R 25.68	1 389	5 000	15 900	4 300	*Länger et al. (2010)
DRY XRT SORTER + Dry Screening	R 164.95	R 8.58	R 141.19	R 38.95	R 25.68	788	2 837	9 021	2 440	* Von Ketelholdt (2009)

Table 23: *Operating cost summary with carbon footprint - Waterberg Upper Ecca. * Transport, Port- and Overhead Costs obtained from Wood-Mackenzie 2012 report*

	Waterberg Upper Ecca - Operating Cost Economic Parameters for 500 tph Plant (tph = tons per hour)											
	Mining	Preparation		Transport		Port	Overheads	CHPP Power Requirement		Elect Cost	CHPP Carbon Footprint	
		Export	ESKOM	Export	ESKOM			kW	kWh	R'000 per annum	CO_2 tons	Reference
	Cost (R'/ROM Ton)			Cost (R'/Saleable Ton)								
DMS Cyclones (All)	R 164.95	R 33.21	R 36.90	R 269.85	R 4.29	R 38.95	R 25.68	3 605	12 978	41 270	11 161	*WoodMackenzie & Industry
DMS BATH + DMS Cyclones (All)	R 164.95	R 26.46	R 27.00	R 269.85	R 4.29	R 38.95	R 25.68	3 146	11 326	36 015	9 740	*WoodMackenzie & Industry
WATER JIGS + DMS Cyclones (All)	R 164.95	R 10.36	R 11.26	R 269.85	R 4.29	R 38.95	R 25.68	3 311	11 921	37 908	10 252	*Sanders (2002)
DRY FGX + DMS Cyclones	R 164.95	R 18.23	R 19.81	R 269.85	R 4.29	R 38.95	R 25.68	2 497	8 989	28 585	7 731	*Länger et al. (2010)
DRY XRT SORTER + DMS Cyclones	R 164.95	R 18.57	R 19.14	R 269.85	R 4.29	R 38.95	R 25.68	2 197	7 907	25 146	6 800	* Von Ketelholdt (2009)
Three Product Cyclone	R 164.95	R 40.59		R 269.85	R 4.29	R 38.95	R 25.68	3 695	13 302	42 302	11 440	* Industry

Table 24: *Operating cost summary with carbon footprint - Free State Coalfield, (Vereeniging) Colliery. * Transport and Overhead Costs obtained from Wood-Mackenzie 2012 report*

	Free State (Vereeniging) - Operating Cost Economic Parameters for 500 tph Plant (tph = tons per hour)								
	Mining	Preparation	Transport	Overheads	CHPP Power Requirement		Elect Cost	CHPP Carbon Footprint	
	Cost (R'/ROM Ton)				kW	kWh	R'000 per annum	CO_2 tons	Reference
DMS Cyclones (All)	R 109.80	R 12.65	R 0.00	R 6.89	3 605	12 978	41 270	11 161	*WoodMackenzie & Industry
DMS BATH + DMS Cyclones (All)	R 109.80	R 12.86	R 0.00	R 6.89	3 146	11 326	36 015	9 740	*WoodMackenzie & Industry
WATER JIGS + DMS Cyclones (All)	R 109.80	R 8.57	R 0.00	R 6.89	3 311	11 921	37 908	10 252	*Sanders (2002)
DRY FGX + DMS Cyclones	R 109.80	R 9.57	R 0.00	R 6.89	2 497	8 989	28 585	7 731	*Länger et al. (2010)
DRY XRT SORTER + DMS Cyclones	R 109.80	R 7.97	R 0.00	R 6.89	2 197	7 907	25 146	6 800	* Von Ketelholdt (2009)

10.4.2 Tailoring the Process to Specific Needs

The simplified lower cost processing of ROM to produce a low grade export product in the future is viable. This is however highly dependent on Life of Mine (LOM), ROM quality and railing availability. The lower level beneficiation could entail screening, crushing and a dry de-stoning operation only with additional product handling logistics. The dry processing would allow for optimal NAR benefit, which would mean higher yield achievement. See results in Tables 22, 23 and 24.

With the deterioration in ROM reserve quality there has been a consequent decline in the quality of the ROM fines. The result is that the spiral circuit fails to meet product quality specification, in order to mitigate the low fines quality, higher quality products from the cyclones and drum fractions have to be produced. By utilising technology to enable the production of fines at specified quality an overall yield improvement could be established through yield optimisation of the coarser drum and cyclone circuits. The fines qualities currently are above specified quality within a possible future low grade thermal coal export production framework.

10.4.3 Flowchart Selection

The flow chart selection was conducted based on criteria explained in Section 8. Mainly equipment and circuits that are common to industry were selected with their applicable circuits.

10.4.4 Size of Equipment and Amount Needed

The equipment was selected based on design tonnages from the modelling exercises and through the use of the MINTEK Manual (Ruhmer 1996). Equipment sizing was done at a high level and was mainly theoretical. The equipment sizing based on capacity are summarised in Section C1 in the Appendix.

10.5 Cost Estimating Results

10.5.1 Methodology for Economic Analysis

The methodology of the techno-economic analysis was to develop process models for the various coals with a high level design, calculate costing on the models, and evaluate through DCF models and determine the cost benefit in the form of an $NPV_{10years}$. Table 25 serve to illustrate the benchmark cost breakdown of thermal coal production from the resource to the market.

Table 25: *Illustrating the contribution to operating costs of various stages in thermal coal production.*

	Contribution to Total Thermal Export Cost
Mining	61%
Preparation	10%
Transport	19%
Port	3%
Overheads	6%
Royalty	1%

10.5.1.1 Methodology for Major Equipment Costs

Major equipment was costed mainly on industrial costs which included installation. It is the opinion of the author that installation and transport costs are not always included in the total procurement price, and this could be significant. Details of the major equipment and equipment sizing are given in Appendix C.

10.5.1.2 Methodology for Sensitivity Analysis

The purpose of the cost sensitivity analysis exercise was to do a base comparison between different design preparation plants and variable NAR CV grade thermal export quality products (4000-6000 NAR CV). The base costs and exchange rate were not varied to provide an economic sensitivity analysis as the reference point for comparison between the scenarios were required to be consistent.

10.5.2 Capital Costs for Plant

Detailed accounting of equipment found in each process area can be found in the Appendix, Section C1 and C2.

The cost estimation was done by using the MINTEK (Rhumer *et al.* 1995) Metallurgical Equipment Costs (1996) manual and industrial quotations for similar sized equipment. For both methods factorial costing was done to determine the capital cost of each unit. The overall method uses the equation:

$$y = a + bx + cx^2$$

Where y = cost estimated for 1996

a, b & c = constants used by MINTEK

x = size or capacity

As the cost estimated by this equation was done for the year 1996, it had to be converted to the year 2005 by using cost indexes given in *Chemical Engineering*. The 2012 Chemical Engineering cost price index was 381.7 in 1996 (the MINTEK costing base) and 596.1 for 2012.

$$y_{2012} = y_{1996} \times \frac{CPI_{2012}}{CPI_{1996}}$$

Where y = Cost price of the year

CPI = Cost price index

To estimate the capital cost of the plant MINTEK ((Rhumer *et al.* 1995) suggests using the Lang-factor approach which is summarised in Table 26. An adjusted factor of a solids handling plant was used due to the fact that the coal plant designed is a solid-liquid handling plant. For a solid-liquid handling plant the single Lang-factor is 3.63.

The factors derived gave the following capital costing (example):

Table 26: *Lang-factors Capital Costing – MINTEK (Rhumer, 1995)*

	Factor	**Costs (R'000 000)**
Equipment	1.00	511 04.37
Erection of items	0.15	53 715.66
Structural and Buildings	0.26	93 107.14
Civils	0.22	78 782.96
Piping and ducting	0.25	89 526.09
Electrical	0.26	93 107.14
Instruments	0.17	60 877.74
Installed plant	2.31	66 946.72
CAPEX		587 167.8
Contingency	3.3	51 104.37

The prescribed size or capacity used by MINTEK is within certain boundaries. Some of the equipment is above MINTEK's maximum capacity for the given cost estimation, for these cases a scaling factor was used according to the equation.

$$C_2 = \left(\frac{T_2}{T_1}\right)^n \times C_1$$

Where C1 = Cost of maximum capacity given

C2 = Cost of equipment above maximum cost

T1 = MINTEK's maximum capacity given

T2 = Capacity of the design coal plant equipment

n = 0.67 (this is known as the two-thirds rule)

10.5.3 Operating Costs for Plant

A summary of the CAPEX & OPEX estimations of the different plants are given below in the case of each coalfield:

Table 27: *Comparison of CHPP CAPEX and OPEX estimations*

	Witbank Coalfield No. 4 Seam		Waterberg Upper Ecca - EXPORT		Waterberg Upper Ecca - Domestic		Free State (Vereeniging)	
	PLANT CAPEX	PLANT OPEX	PLANT CAPEX	PLANT OPEX	PLANT CAPEX	PLANT OPEX	PLANT CAPEX	PLANT OPEX
	R Million	R/ton	R Million	R/ton	R Million	R/ton	R Million	R/ton
DMS Cyclones	R 548.30	R 22.41	R 548.30	R 33.21	R 548.30	R 36.90	R 548.30	R 12.65
DMS BATH + DMS Cyclones	R 501.70	R 21.14	R 392.04	R 26.46	R 392.04	R 27.00	R 392.04	R 12.86
WATER JIGS + DMS Cyclones	R 274.52	R 15.82	R 274.52	R 10.36	R 274.52	R 11.26	R 274.52	R 8.57
DRY FGX + DMS Cyclones	R 288.67	R 12.27	R 288.67	R 18.23	R 288.67	R 19.81	R 288.67	R 9.57
DRY XRT SORTER + DMS Cyclones	R 305.88	R 11.75	R 305.88	R 18.57	R 305.88	R 19.14	R 305.88	R 7.97
Three Product Cyclone	R 111.53	R 25.62						
DMS Cyclones + Dry Screening	R 557.66	R 13.91						
DMS BATH + Dry Screening	R 557.66	R 13.27						
WATER JIGS + Dry Screening	R 111.53	R 7.11						
DRY FGX + Dry Screening	R 111.53	R 8.84						
DRY XRT SORTER + Dry Screening	R 566.07	R 8.58						

In Table 27 the CAPEX for the plant configurations are consistent for the Waterberg Upper Ecca and Free State Vereeniging instances, with the major equipment remaining the same. The plants were designed for 500 tons per hour (tph) capacity.. They only varied in terms of sizing dimensions, but the throughput capacity of the equipment remained the same. The equal capital costing base was also allowed for in order to compare profitability estimates between the coalfields.

10.5.4 Transport Costs

It is known that beneficiation could reduce the transport costs associated with thermal coal transport significantly. In essence improved unit energy per ton can be railed with lower induced risk. It is for this reason that low grade export coal can be looked at with a greater degree of scepticism due to the fact that a lower comparative energy per unit ton transported will be observed, and indeed a large transport carbon footprint.

South Africa's railway infrastructure has recently been assessed as requiring serious upgrading and the available capacity needs to be carefully scrutinised before large volumes of low grade export are to be shipped. As in the case with the Waterberg Upper Ecca, the sheer cost of railage is too high to justify low grade export production whilst obtaining higher yields and therefore product saleable volumes, but below the threshold.

10.6 Cost Benefit Analysis

The graphs below contain the economic value of different process options with the production of various products from traditional 6000 NAR CV to low grade ≤ 5500 to as low as 4000 NAR CV products.

(A) **Witbank Coalfield No. 4 Seam –** Cost Benefit for different processing scenarios and thermal grade products (low to high)

The energy recovery and economic values (NPV) that can be obtained through the processing of the Witbank Coalfield No. 4 Seam with the various coal beneficiation pathways are depicted in Figure 155 to 165. The optimal product and beneficiation pathway is shown in Figure 160, where the coarse fraction is processed with DMS Cyclones (coarse size fraction wash) and dry screening of the medium-to-fines size fraction to produce a 5400 kcal/kg NAR CV product.

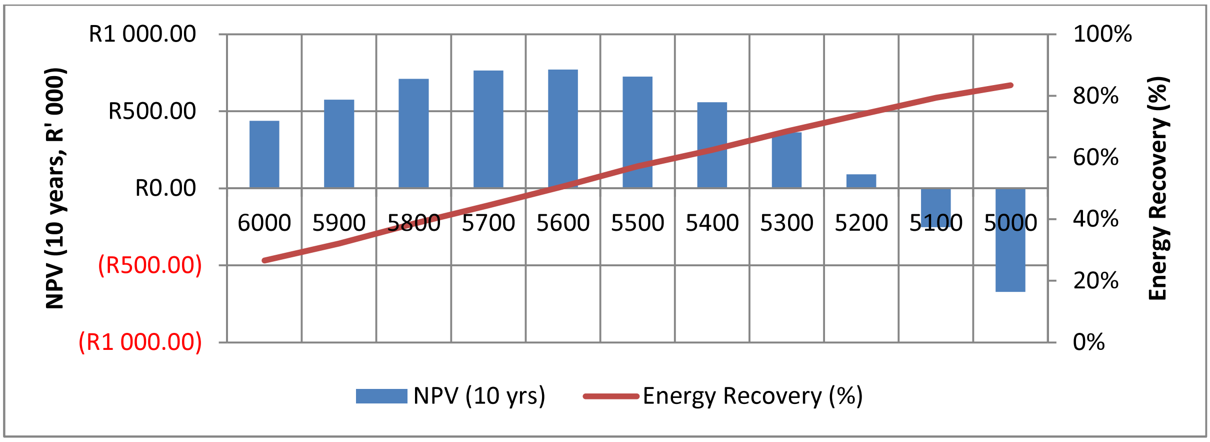

Figure 155: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for Conventional Dense Medium Cyclones for the coarse and medium sized fractions.*

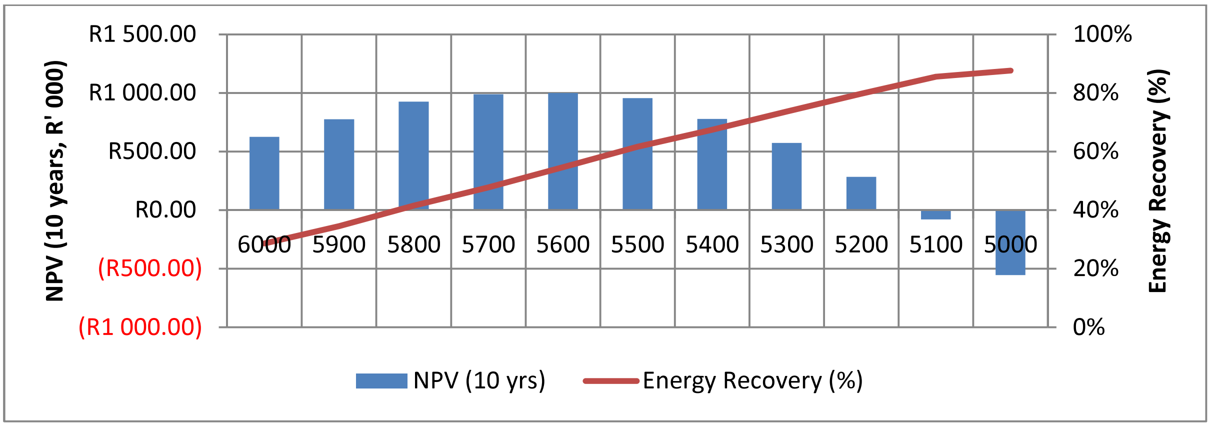

Figure 156: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for Conventional Dense Medium Bath for the coarse fraction & DSM Cyclones for the medium fraction.*

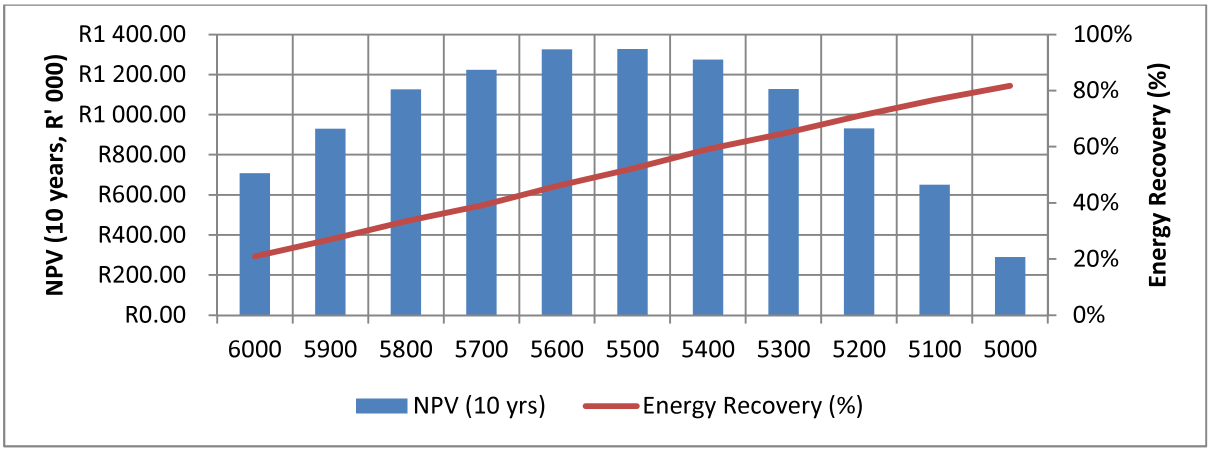

Figure 157: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for Conventional Jigs for the coarse fraction & DSM Cyclones for the medium fraction.*

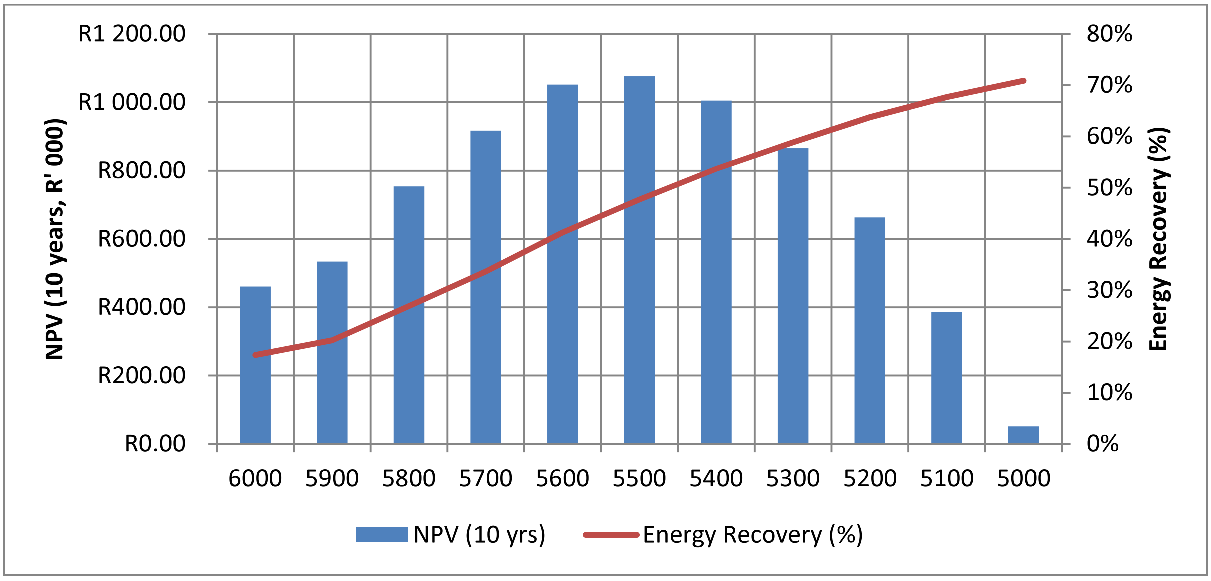

Figure 158: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for dry FGX Separation for the coarse fraction & DSM Cyclones for the medium fraction.*

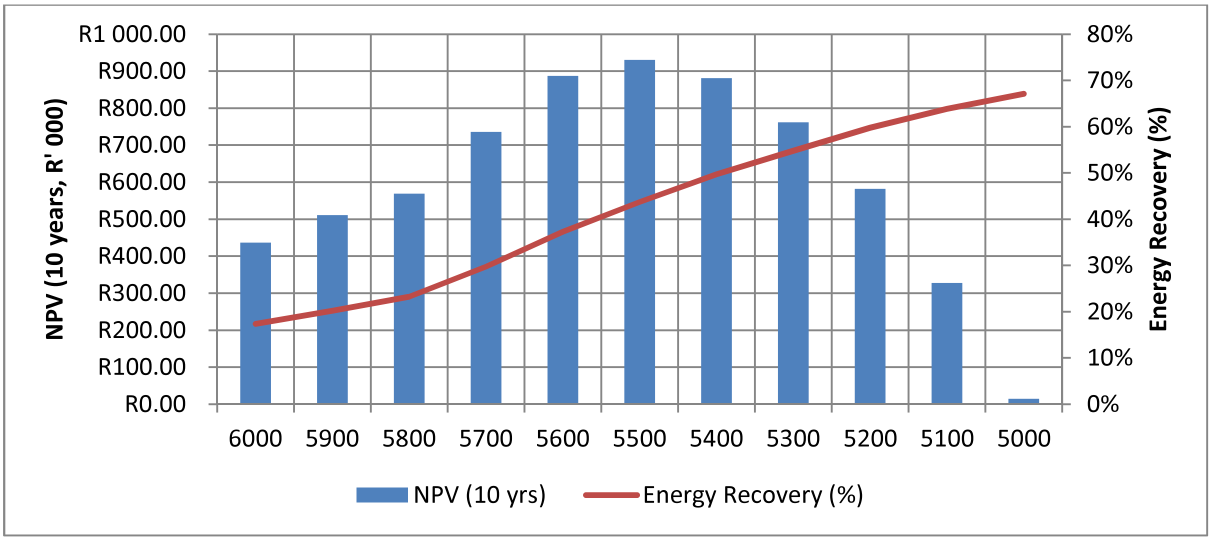

Figure 159: *Witbank Coalfield No. 4 Seam Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for dry XRT Sorting for the coarse fraction & DSM Cyclones for the medium fraction.*

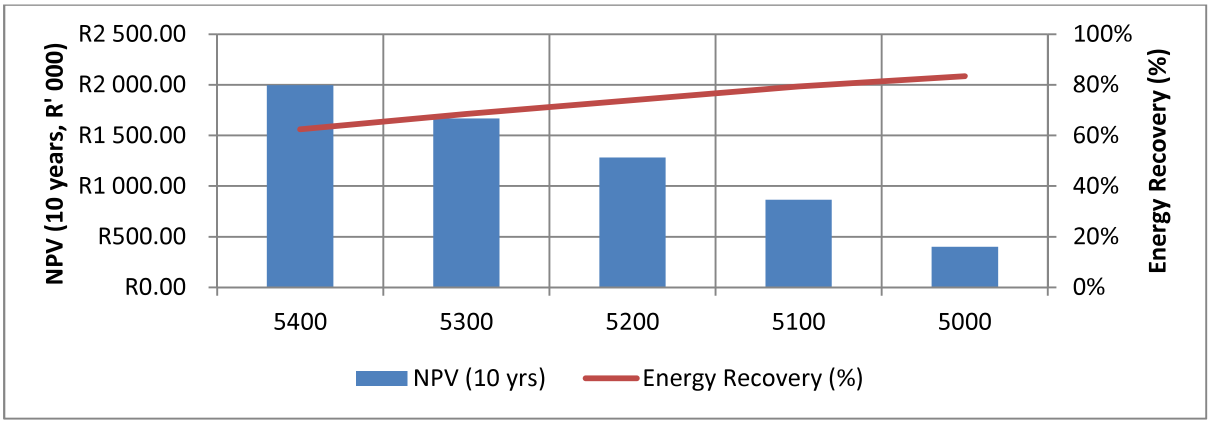

Figure 160: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for dry screening of medium to fines fraction with coarse fraction wash with DSM Cyclones only.*

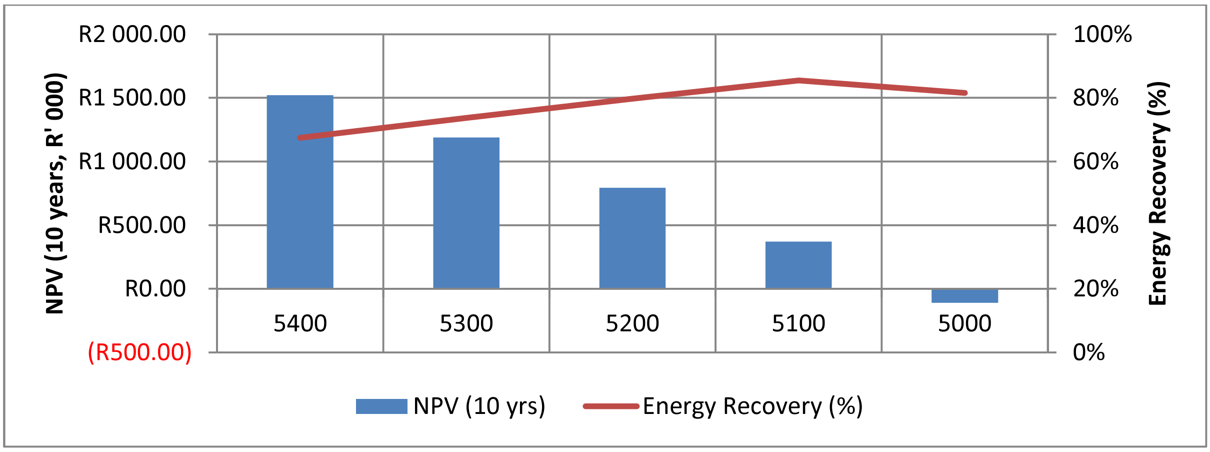

Figure 161: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for dry screening of medium to fines fraction with coarse fraction wash only with DMS bath only.*

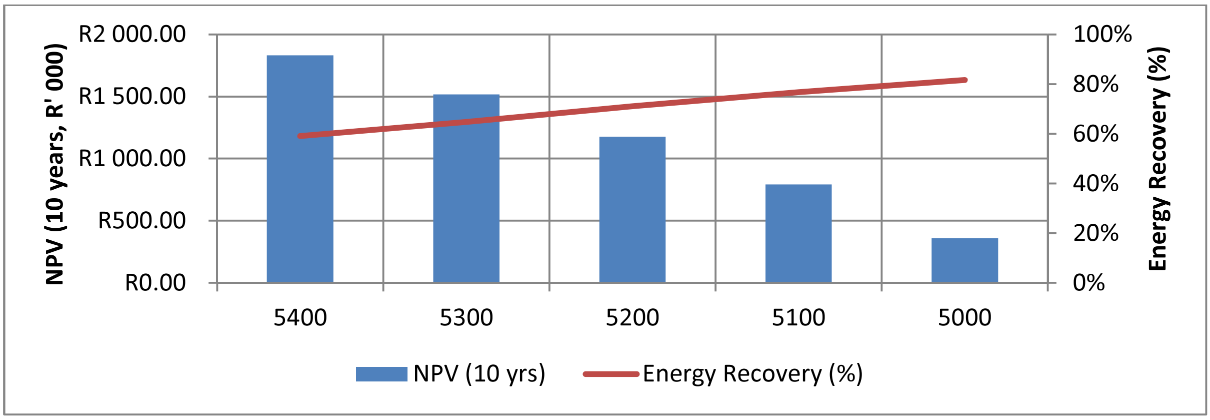

Figure 162: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for dry screening of medium to fines fraction with coarse fraction beneficiation with ROM and Batac Jigs.*

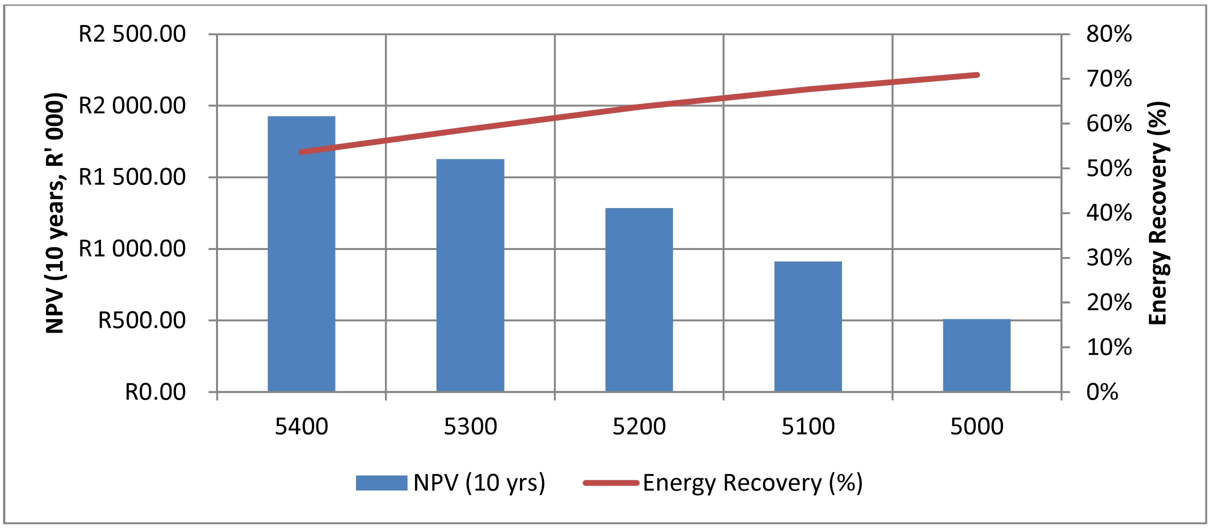

Figure 163: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for dry screening of medium to fines fraction with coarse fraction beneficiation with a FGX separator.*

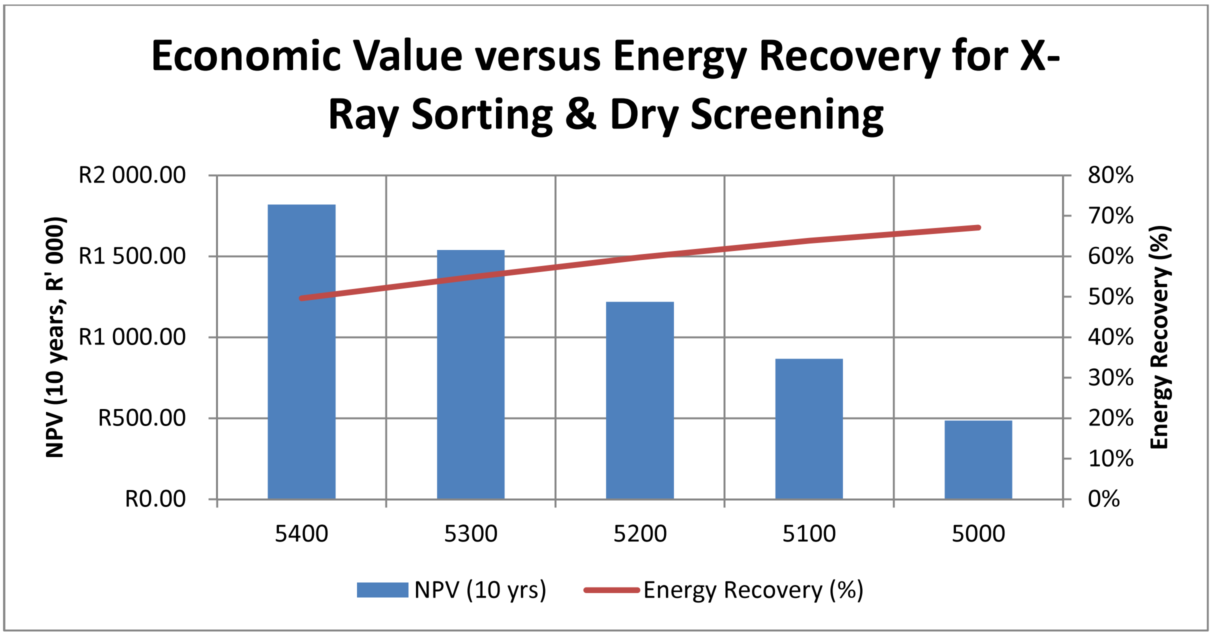

Figure 164: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Grade Thermal Export Products for dry screening of medium to fines fraction with coarse fraction beneficiation with a XRT Sorter.*

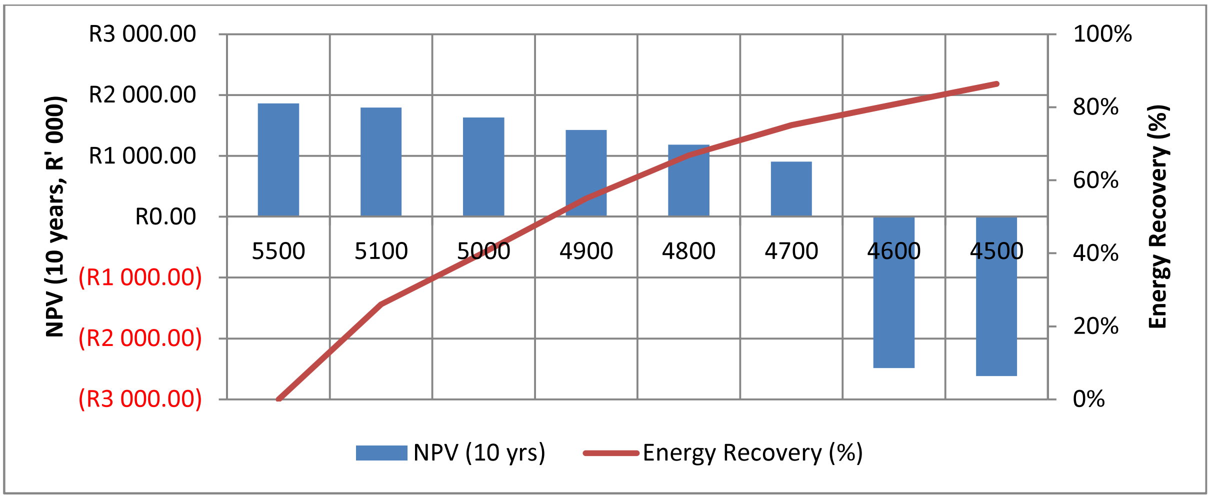

Figure 165: *Witbank Coalfield No. 4 Seam - Economic Value versus Energy Recovery for Different Lower Grade Thermal Products as a Secondary Product (5500-4500 NAR), and a 6000 NAR Primary Product.*

(B) **Waterberg Upper Ecca** – Cost Benefit for different processing scenarios and thermal grade products (low to high grade exports)

The energy recovery and economic values (NPV) that can be obtained through the processing of the Waterberg Upper Ecca with the various coal beneficiation pathways in the case of exports are depicted in Figure 166 to 169. The optimal product and beneficiation pathway is shown in Figure 168, where the coarse fraction is processed with an FGX separator (coarse size fraction) and processing of the medium-to-fines fraction is achieved using DSM cyclones. The optimal product that can be produced is a 5400 kcal/kg NAR CV product.

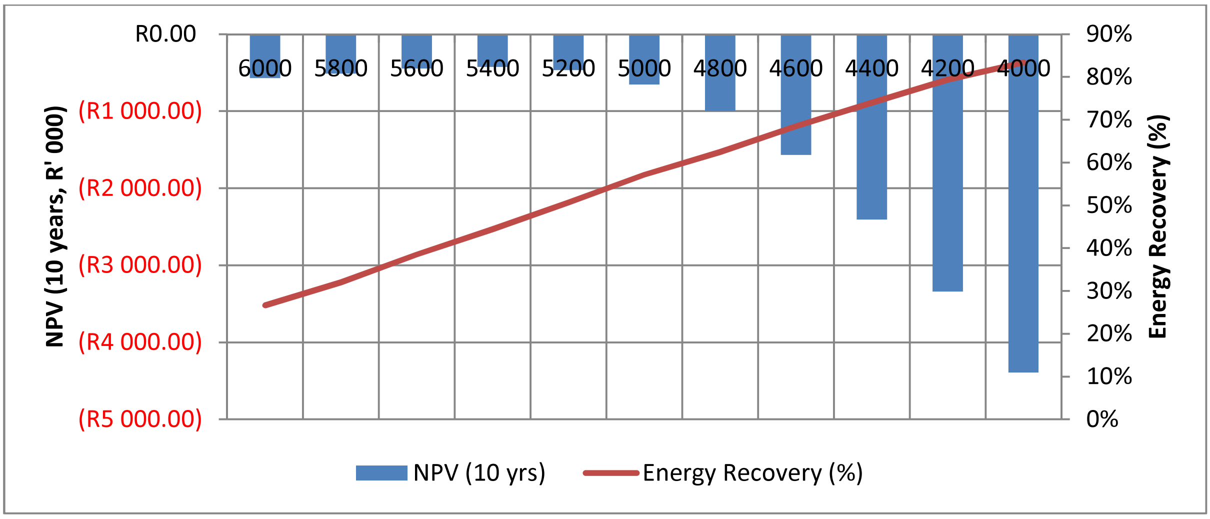

Figure 166: *Waterberg Upper Ecca - Economic Value versus Energy Recovery for Conventional Dense Medium Cyclones*

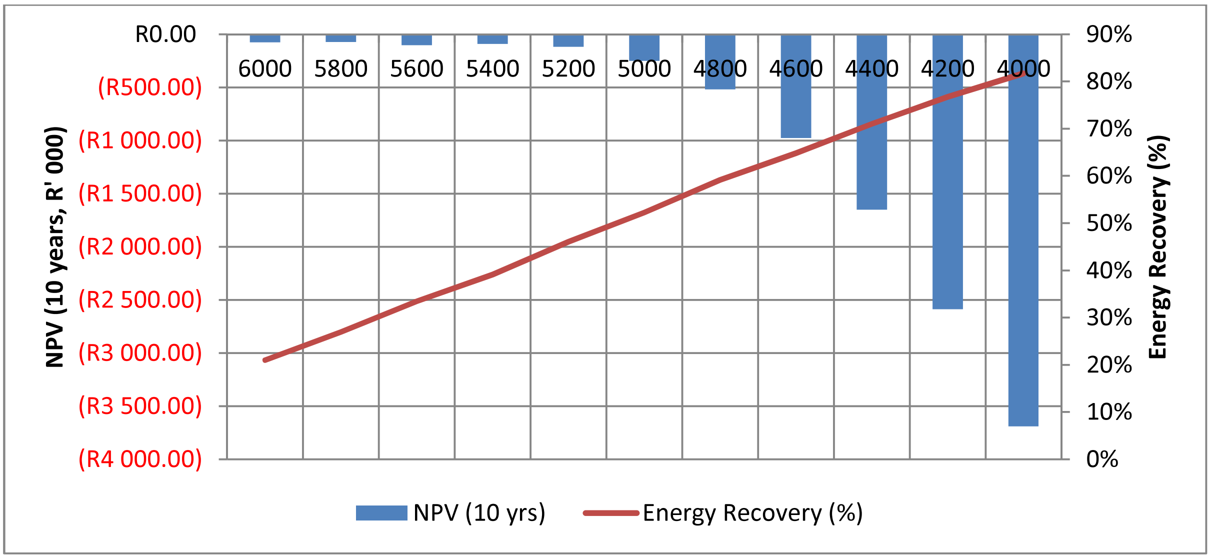

Figure 167: *Waterberg Upper Ecca - Economic Value versus Energy Recovery for Jigs & Cyclones*

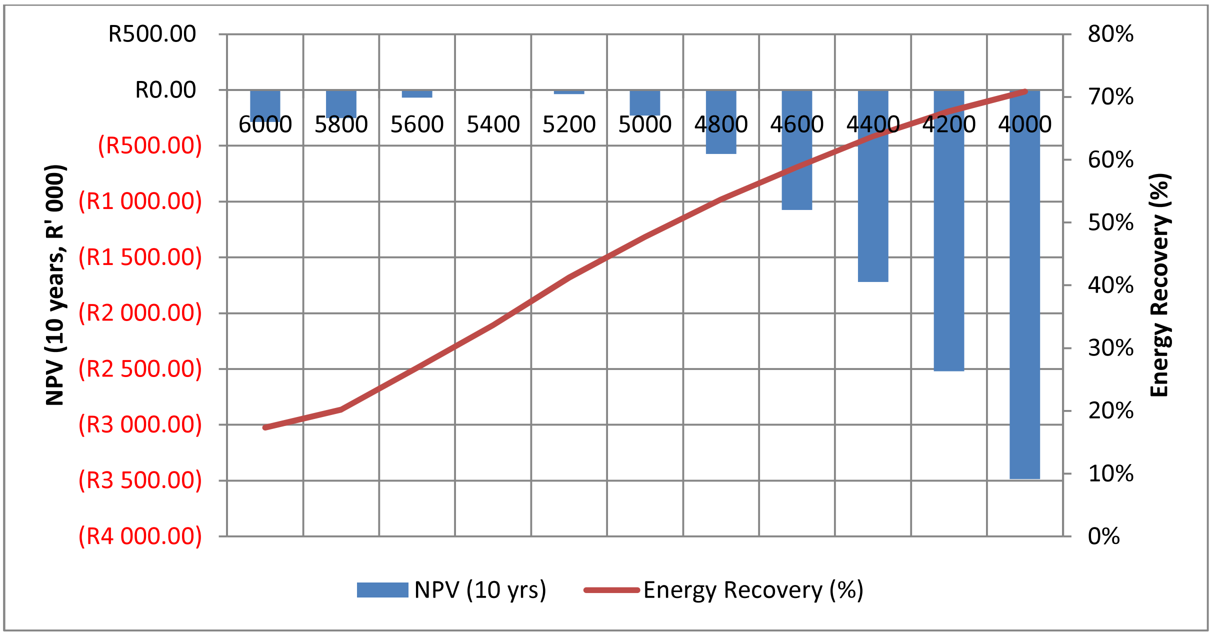

Figure 168: *Waterberg Upper Ecca - Economic Value versus Energy Recovery for FGX & Cyclones*

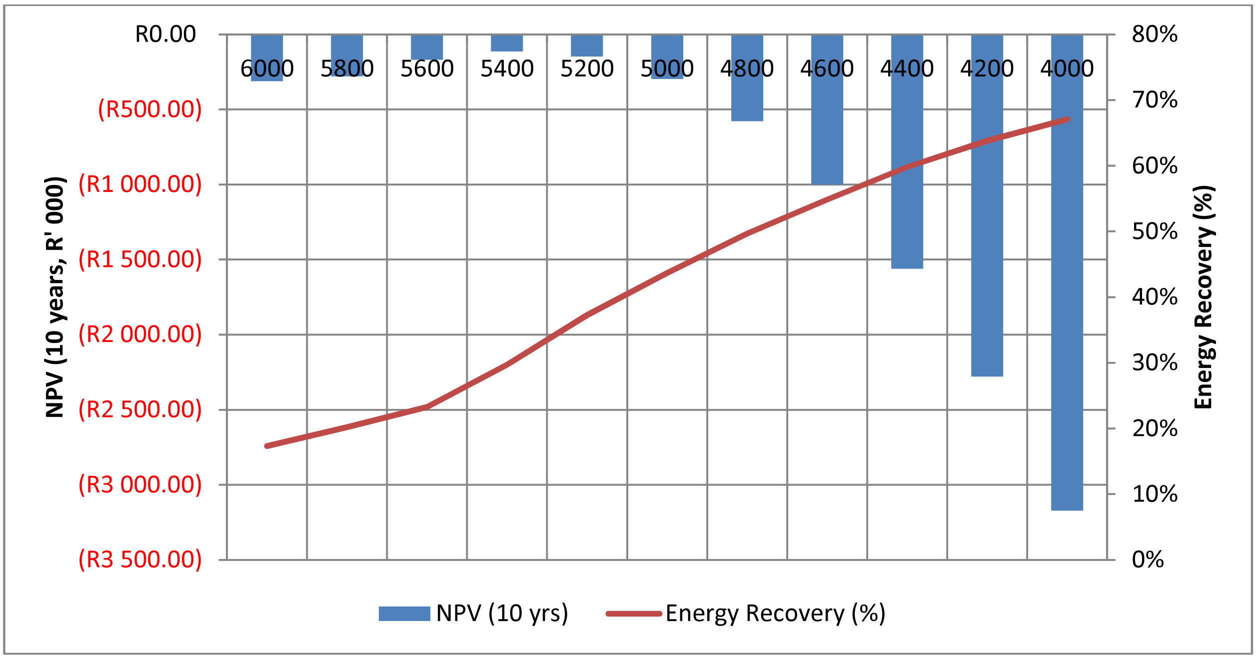

Figure 169: *Waterberg Upper Ecca -Economic Value versus Energy Recovery for XRT Sorter & Cyclones*

(C) **Waterberg Upper Ecca** – Cost Benefit for different processing scenarios and thermal grade products (Domestic product production)

The energy recovery and economic values (NPV) that can be obtained through the processing of the Waterberg Upper Ecca with the various coal beneficiation pathways in the case of domestic production are depicted in Figure 170 to 174. The optimal product and beneficiation pathway is shown in Figure 172, where the coarse fraction is processed with Jigs (coarse size fraction) and processing of the medium-to-fines fraction is achieved using DSM cyclones. The main product that could potentially deliver the highest economic value (NPV) is a 4000 kcal/kg NAR CV product.

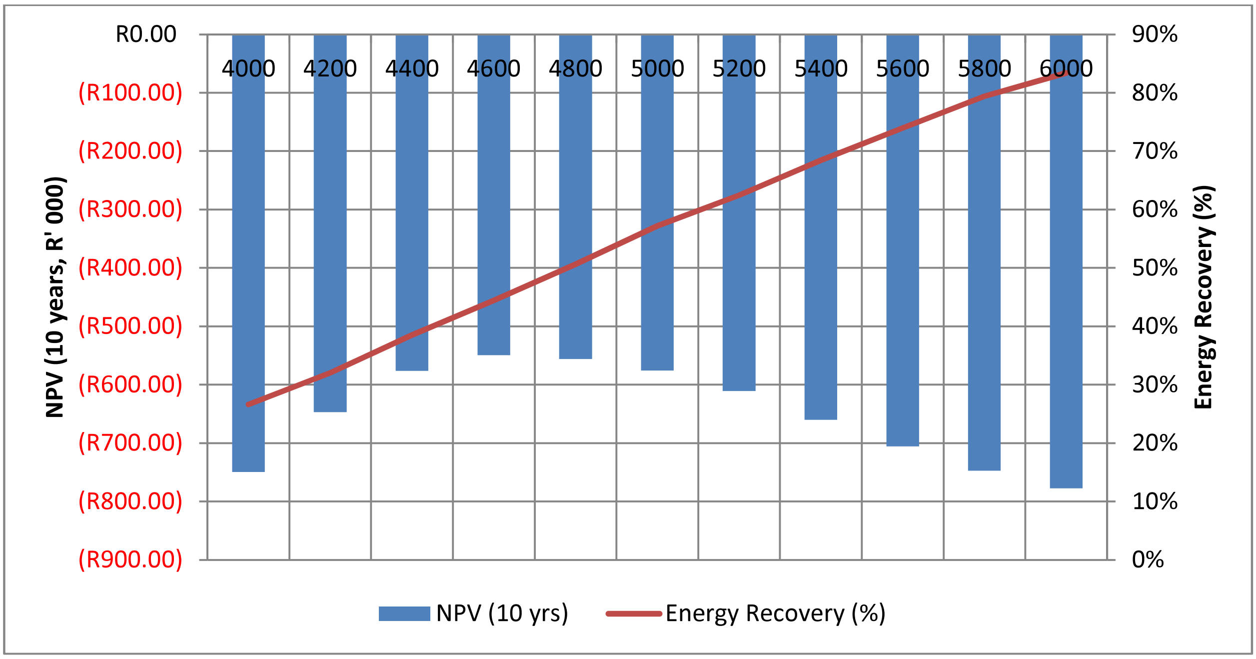

Figure 170: *Waterberg Upper Ecca - Economic Value versus Energy Recovery for Conventional Dense Medium Cyclones for domestic thermal production*

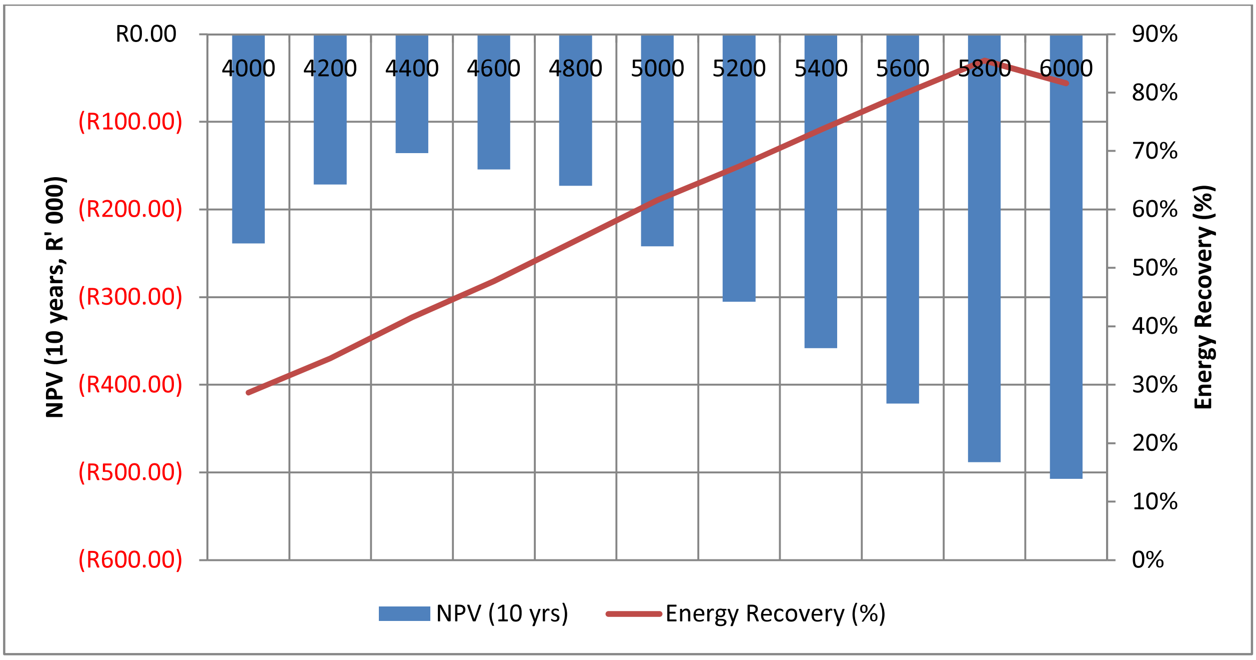

Figure 171: *Waterberg Upper Ecca - Economic Value versus Energy Recovery for Conventional Dense Medium Bath & Cyclones for domestic thermal production*

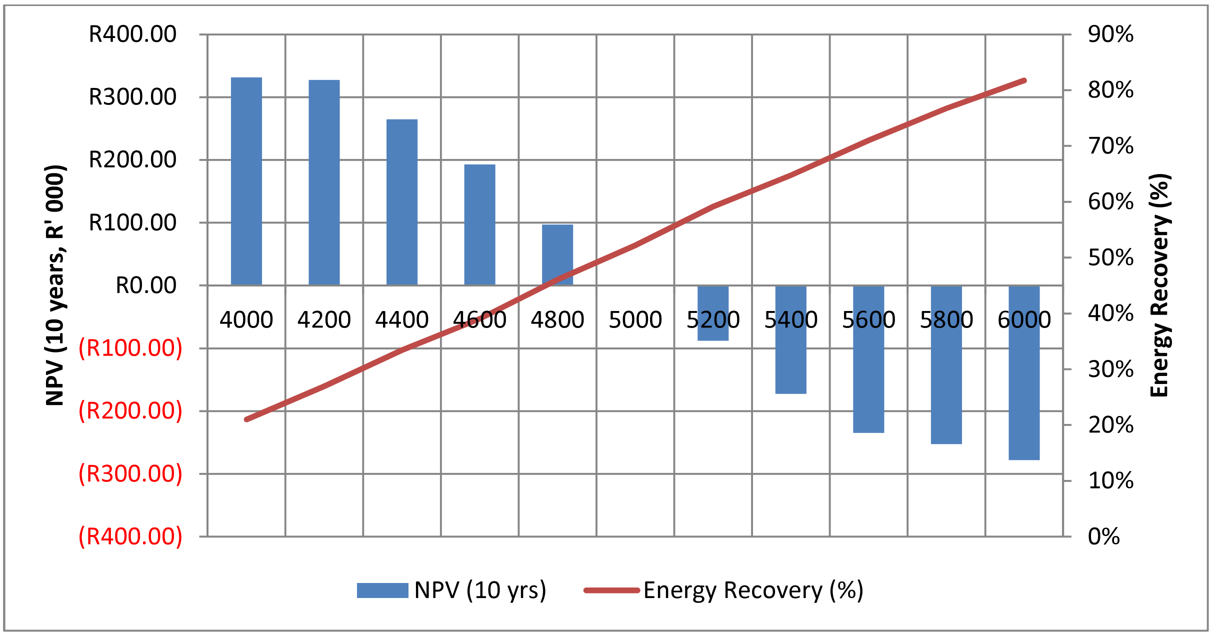

Figure 1721: *Waterberg Upper Ecca - Economic Value versus Energy Recovery for Jigs & Cyclones for domestic thermal production*

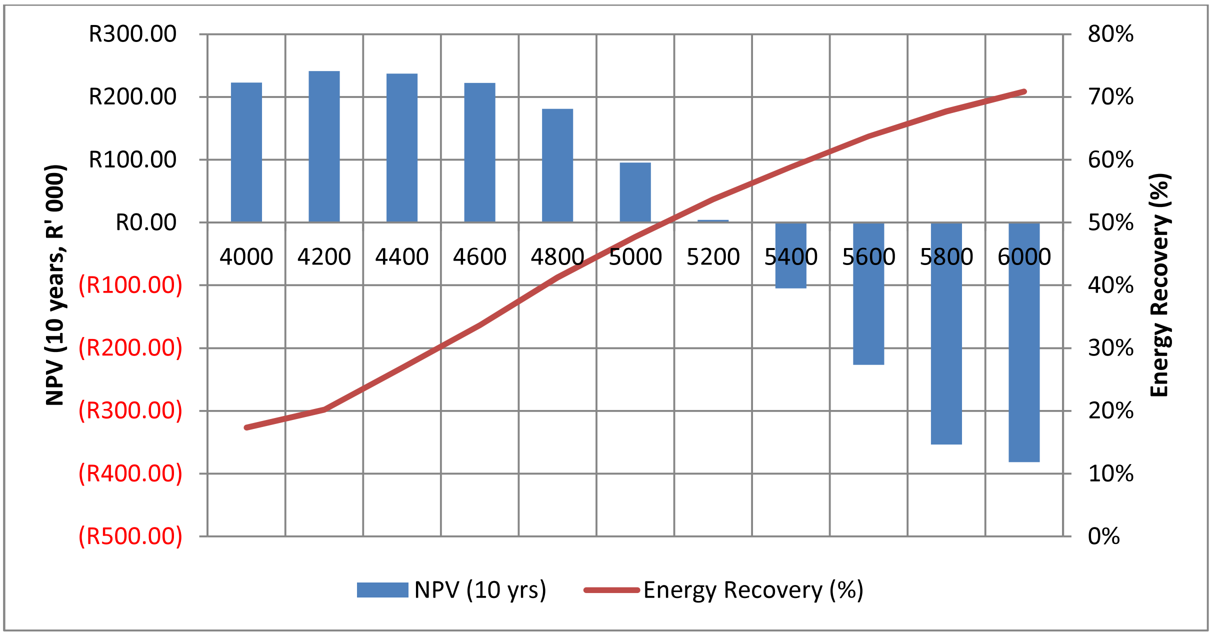

Figure 173: *Waterberg Upper Ecca - Economic Value versus Energy Recovery for FGX & Cyclones for domestic thermal production.*

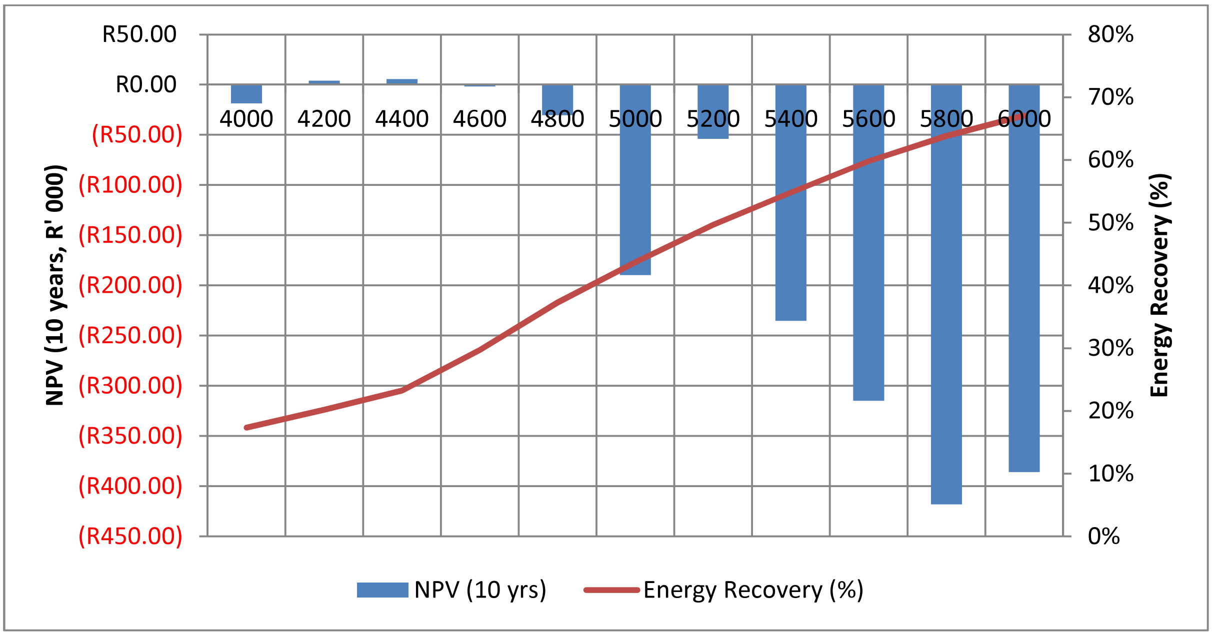

Figure 174: *Waterberg Upper Ecca - Economic Value versus Energy Recovery for XRT Sorter & Cyclones for domestic thermal production*

(D) **Free State (Vereeniging) Coal** – Cost Benefit for different processing scenarios and thermal grade products (low to high)

Note that for the Free State Vereeniging modelling was done at higher quality (lower ash products) than what is currently produced at (Vereeniging) (i.e. 15.00 MJ/kg and CV).

The energy recovery and economic values (NPV) that can be obtained through the processing of the Free State Coalfield with the various coal beneficiation pathways in the case of domestic production are depicted in Figure 175 to 179. The optimal product and beneficiation pathway is shown in Figure 177, where the coarse fraction is processed with Jigs (coarse size fraction) and processing of the medium-to-fines fines fraction is achieved using DSM cyclones. Similar to the Waterberg Upper Ecca domestic production scenarios result, the main product that could potentially deliver the highest economic value (NPV) is a 4000 kcal/kg NAR CV product.

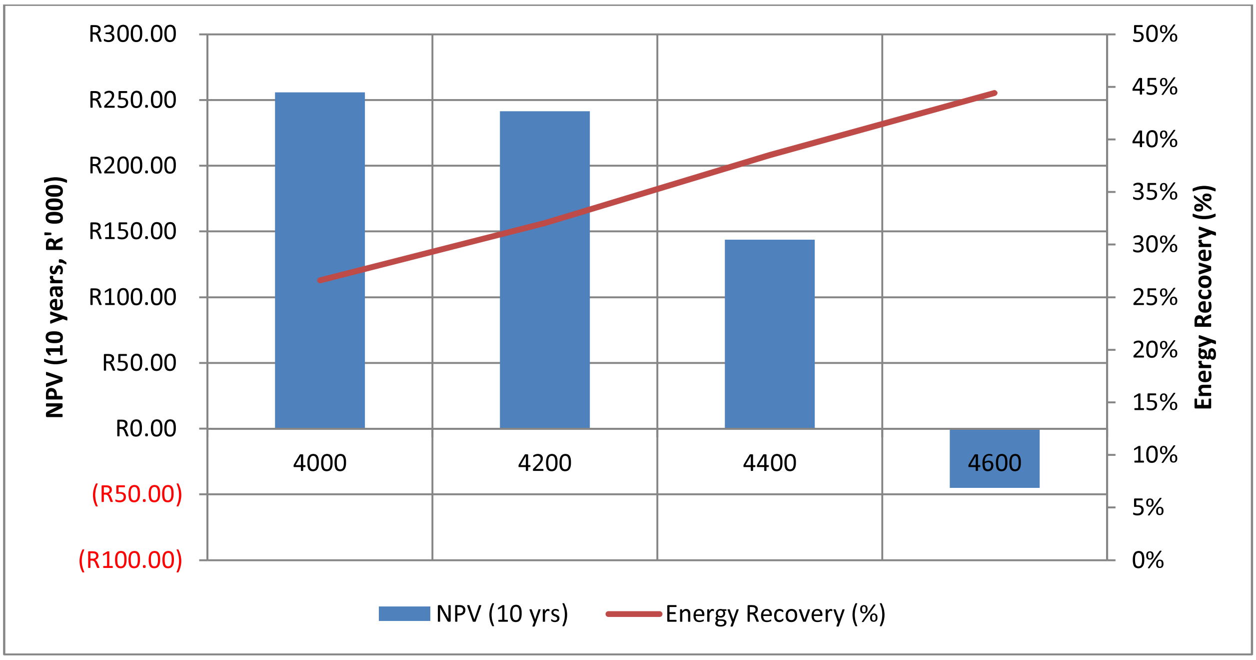

Figure 175: *Free State (Vereeniging) - Economic Value versus Energy Recovery for Conventional Dense Medium Cyclones for domestic thermal production*

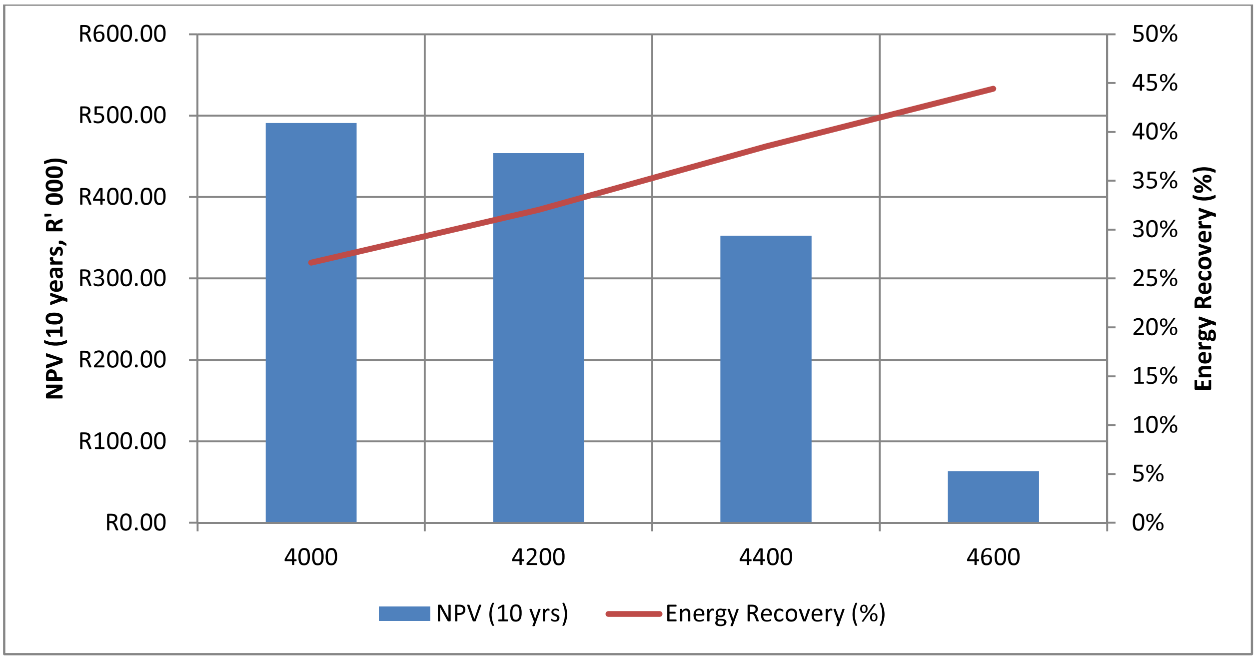

Figure 176: *Free State (Vereeniging) - Economic Value versus Energy Recovery for Conventional Dense Medium Cyclones & Baths for domestic thermal production*

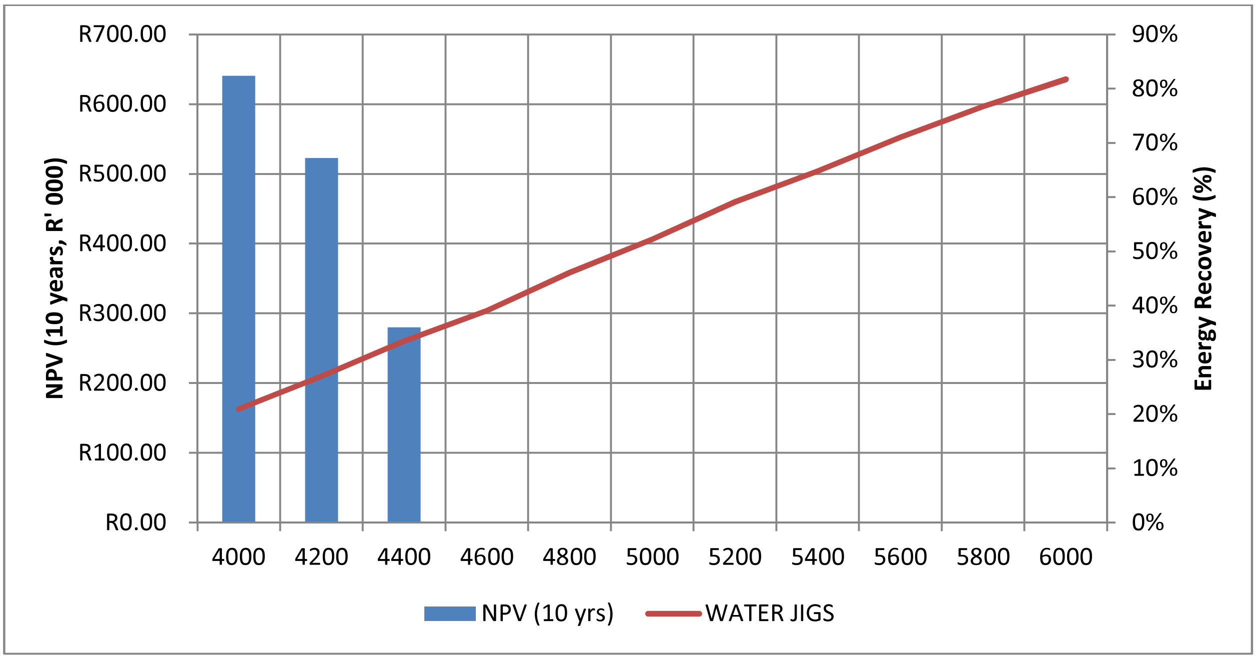

Figure 177: *Free State (Vereeniging) - Economic Value versus Energy Recovery for Water Jigs & Dense Medium for domestic thermal production*

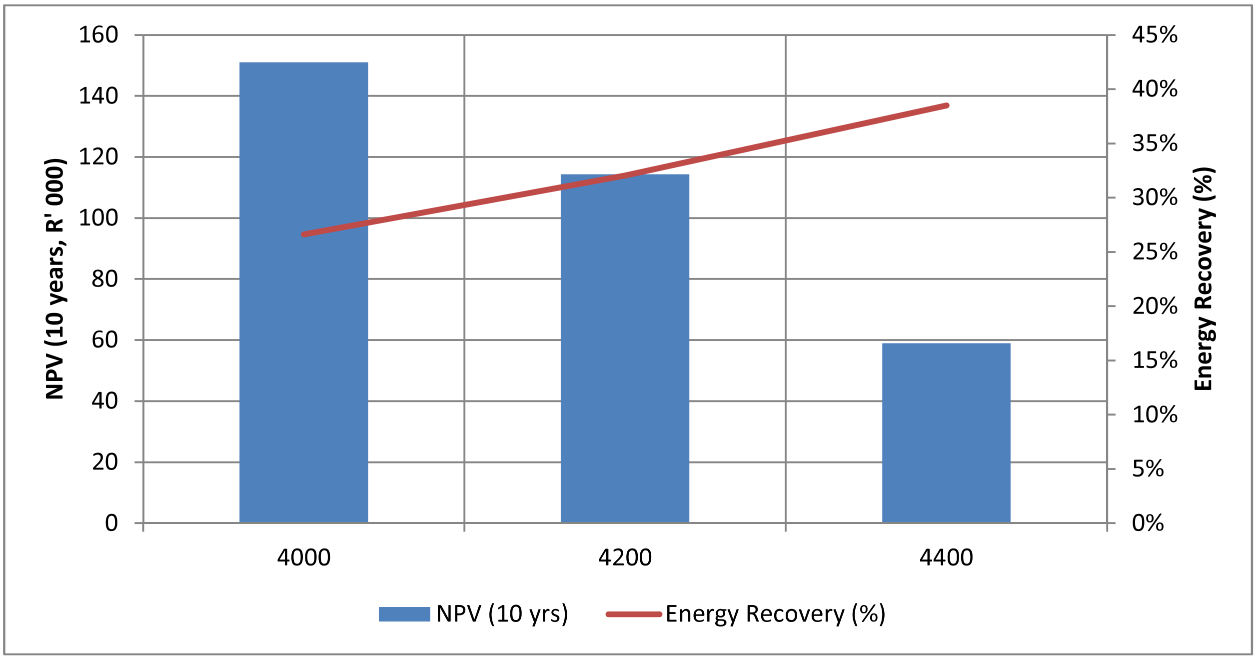

Figure 178: *Free State Vereeniging - Economic Value versus Energy Recovery for Dry FGX Separator & Dense Medium for domestic thermal production*

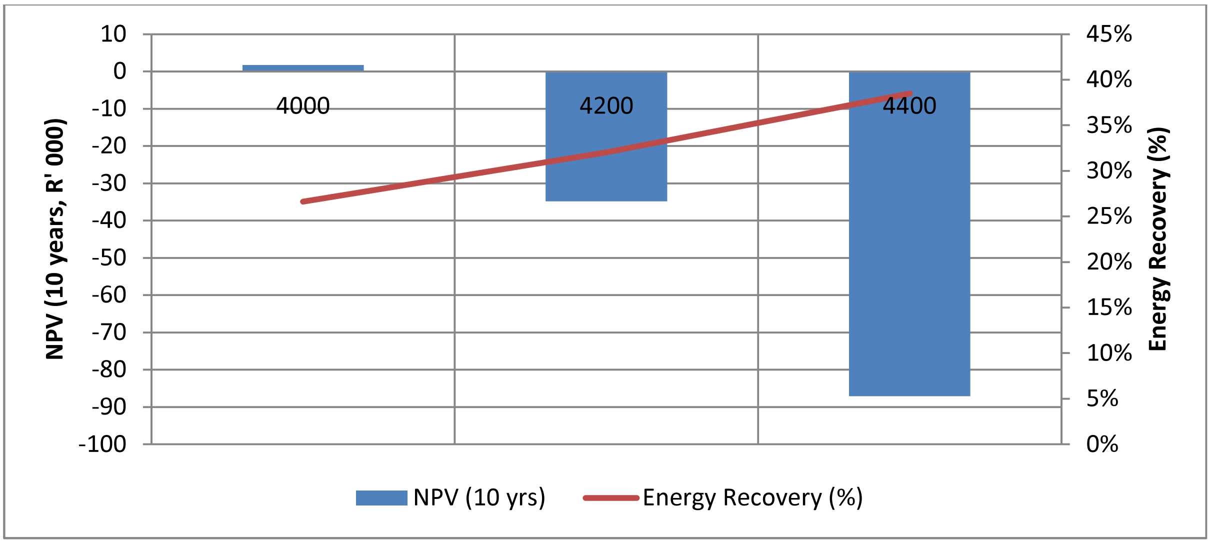

Figure 179: *Free State (Vereeniging) - Economic Value versus Energy Recovery for Dry XRT Sorting & Dense Medium for domestic thermal production*

10.7 Techno-Economic Impact of Low Grade Thermal Coal Export on the South African Coal Utilisation Industry

A summary diagram (Figure 180) explains the advantages and disadvantages of low grade export production in South Africa versus high grade traditional 6000 NAR CV product.

The broader implications to the local coal combustion industries is however vast. Energy security in the form of electricity in South Africa is crucial for the economic growth in South Africa. The energy security could be under threat by the advent of the low grade export market.

The quality of the remaining reserves in South Africa is declining in quality compared to historically. Due to the lower quality, the exploitation of the reserves for the high quality traditional export market is less economically and practically viable.

Figure 180 describes the advantages and disadvantages associated with the production of low versus high grade export thermal coal and the impact on the South African economy and energy security.

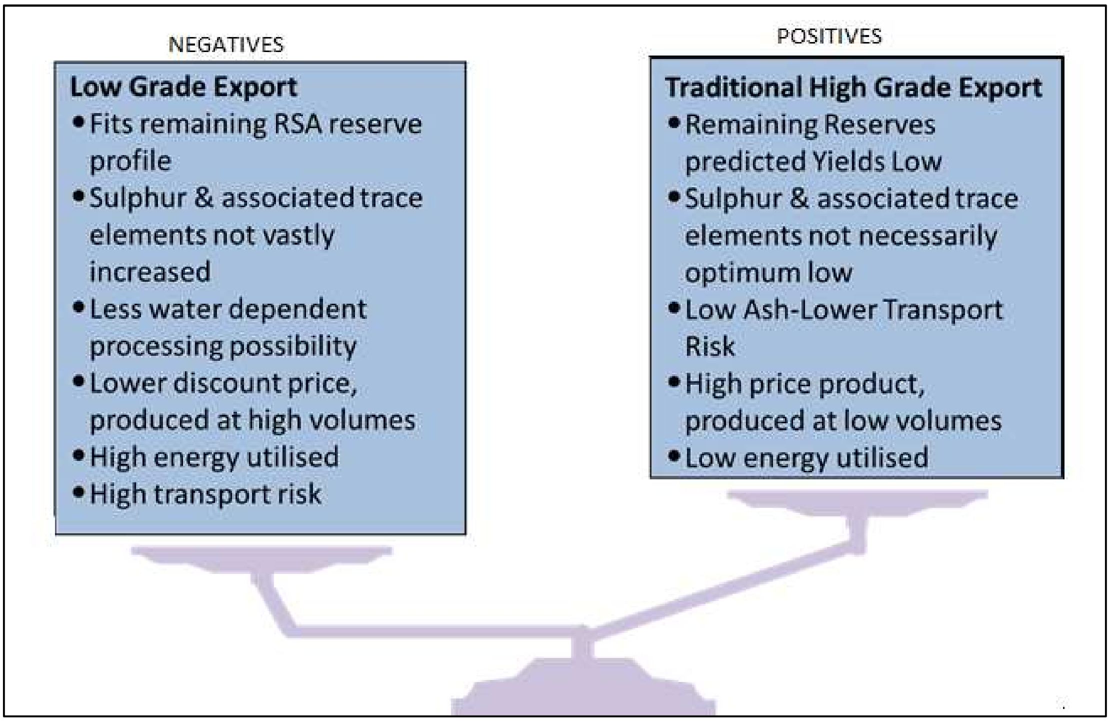

Figure 180: *Low versus High Grade Thermal Coal Export positives and negatives.*

From the study undertaken it was discovered that 'higher' quality reserves like the Witbank Coalfield No. 4 Seam of traditional export value can be exploited for vast benefit in producing low grade exports whilst having limited additional impact on the environment, especially on a pollution quantity per energy utilised basis.

One should also not lose sight of the environmental risks associated with both low and high grade export production as discussed previously. On the Waterberg Upper Ecca it was found that the domestic production of 4000 NAR CV product would be optimal (with the highest NPV), but this would entail local gas cleaning, for which water is required as well. Based on existing experiences in the Waterberg, it would be envisaged that the discards generated from low grade export production would also be more prone to spontaneous combustion due to the higher associated sulphur content in the discards.

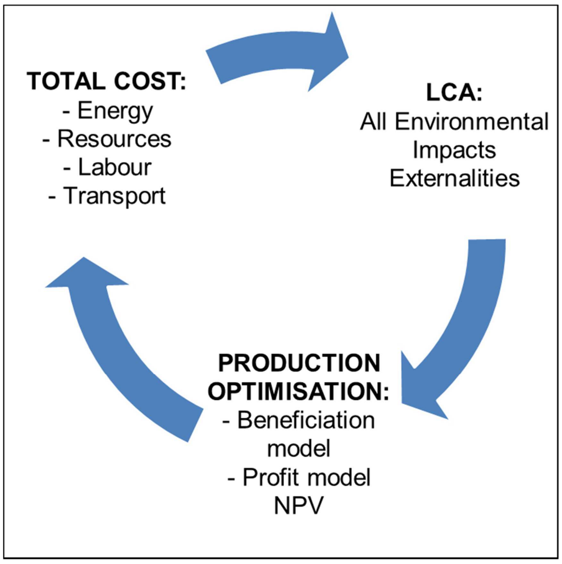

Figure 181: *Illustrating the analysis algorithm required to adequately address the determination of product to be produced.*

Nevertheless, it is the opinion of the author that, unless massive price hikes on thermal coal low grade products is imminent (back to 2008 levels higher than 130 US$/ton for 6000 NAR CV product), that careful evaluation would indicate that in the case of a low quality reserve, it would be more beneficial economically and environmentally to produce a domestic thermal product. To this effect, one could also sacrifice saleable volume within reason and allow for sustainable beneficiation methods to produce the domestic thermal product.