CHAPTER NINE – COAL BENEFICIATION INFLUENCE ON UTILISATION

In Section 9, the influence of coal beneficiation efficiency on subsequent utilisation processes is described with the focus on techno-economic efficiency.

Combustion and thermal efficiency is greatly influenced by the maceral composition and characteristics of the feed coal. The maceral characteristics influences the ignition efficiency and flame control which in turn could have a significant impact on heat transfer and burn-out in the boiler. Higher ash volumes will be produced with associated increases in ash-handling costs and possible environmental impact.

In summary, for successful utilisation potential, it would be beneficial to design the utilisation equipment and processes for which these specific grade products are to be used. For example in the case of combustion in power generation, this would entail matching coal quality to optimal boiler design and downstream process handling. This would ensure improved combustion and ultimately increased thermal efficiency.

In Section 9.1 the possibility of producing specific mineral matter are described. In Section 9.2 the associated pollutants SO_x , NO_x and CO_2 are explored. The resultant utilisation potential and expected utilisation efficiency with increased energy recovery is described in Section 9.3.

In Section 9.4 and 9.5 the associated techno-economic aspects based on the modelling scenarios are discussed with the emphasis on ash utilisation and gas cleaning.

9.1 Effect of Specific Mineral Content

With an increase in recovery of combustible material there is an associated rejection of ash or mineral matter.

In Figure 141 the rejection of mineral matter with combustible recovery is illustrated for the Witbank Coalfield No. 4 Seam. Figure 141 illustrates that the rejection of

mineral matter above a combustible recovery of 77 % (RD >1.60) is lower (30 %) than at combustible recovery levels below 77 % (RD<1.60) where 70 % of the mineral matter is rejected. Based on the liberation analysis, pyrite and dolomite cannot be rejected readily at low combustible recovery levels due to poor liberation at low density fractions.



Figure 141: Witbank Coalfield No. 4 Seam mineral rejection curve

For the Waterberg Upper Ecca greater rejection levels of pyrite and calcite are observed especially at higher combustible recovery levels, compared to quartz and kaolinite. Quartz and kaolinite display higher liberation and hence higher rejection levels. In the Waterberg coals (Figure 142) the rejection of different mineral matter varies with an increase in combustible recovery.



Figure 142: Waterberg Upper Ecca mineral rejection curve

9.2 Emissions Reduction (SO_x, NO_x, CO₂)

SO_x

The greatest source of sulphur in RSA coals can be attributed to the conditions during coal reserve deposition. The distribution of the pyritic and organic sulphur with an association to the ash content is illustrated for both the Witbank Coalfield No. 4 Seam and Waterberg Upper Ecca in Figures 143 and 144 respectively. Based on the distribution of the organic sulphur and higher concentration in the low RD fraction below RD 1.50, it is proven that the organic sulphur is within the vitrinite maceral through association. With an increase in vitrinite content an associated increase in organic sulphur can be expected. In Figure 143 the Waterberg Upper Ecca organic sulphur decreases with an increase in relative density, similar to the Witbank Coalfield No. 4 Seam in Figure 144.



Figure 143: Forms of sulphur washability distribution for the Waterberg Upper Ecca

The pyritic sulphur in the case of the Waterberg Upper Ecca on the other hand increases uniformly to the higher density and sinks fractions. The uniform increase in concentration based on the curve indicates a higher level of liberation as mentioned previously.



Figure 144: Forms of sulphur washability distribution for the Witbank Coalfield No. 4 seam

NO_x

As indicated by Juniper (1995), emissions of NO_x from coal fired plant is affected by several factors including coal properties, specifically rank, volatile content, nitrogen content, and as well as burner design.



Figure 145: Distribution of nitrogen on the washability curve, with volatile content and fuel ratio for the Witbank Coalfield No. 4 Seam.

In Figure 145 it can be seen that there is a negative correlation between nitrogen content and Fuel Ratio for the Witbank Coalfield No. 4 Seam. In contrast a positive correlation exists between the nitrogen and volatile content. In Figure 145 it can be seen that fractions with higher nitrogen content exhibit higher Fuel Ratios. It was found that the nitrogen content in the high vitrinite fractions is generally higher than in the high inertinite rich fractions.

CO_2

Coal beneficiation can play a part in carbon emission reduction. A higher quality product can result in a "cleaner burn" and since less will be burned, this will result in

lower carbon emissions. Lower electricity usage on mines and beneficiation plants would also constitute a net reduction in carbon footprint and value. The graphs discussed below were deducted from the process modelling and cost exercise described in Chapter 10.

The question is on the first initiative if a reduction in carbon loss, hence higher carbon recovered, would justify the net loss in energy, as a higher CV coal would involve a lower energy recovery.

Figure 146 illustrates the carbon emissions per unit energy for combinations of wet and dry processing applications. In Figure 146 it can be seen that a reduction in carbon emissions per unit energy would be expected (in general) with a decrease in product quality produced. This is due to the associate increase in energy recovery.



Figure 146: Witbank Coalfield No. 4 Seam Carbon Emissions per Energy Unit gained - Wet processing and combinations of wet – and dry processing.

In the case of export production through dry processing as seen in Figure 147 a dissimilar trend is observed and a lower grade product incurs higher net emissions.



Figure 147: Witbank Coalfield No. 4 Seam Carbon Emissions per Energy Unit gained – Dry Processing.

For the Waterberg low grade export or ESKOM quality production scenario (Figure 148) in the case of wet processing (dense medium) a reduction in carbon emissions per unit energy is observed with a decrease in quality and increase in corresponding yield. This is due to the increased energy and combustible recovery associated with the production of the higher ash product lower grade product.

In Figure 148 the carbon footprint for various processing options are illustrated. The carbon footprint is based on an energy basis, as CO_2 emitted per GJ produced. The carbon footprint and processing options varies with the production of low to high grade export.



Figure 148: Waterberg Upper Ecca - Carbon Emissions per Energy Unit gained - Wet

9.3 Utilisation Potential and Efficiency

The increase in energy recovery obtained through the production of lower grade export products has to be related to the consequent effect that could be expected on utilisation potential.

The production of lower grade products would entail the following:

- 1. Unit product with lower grade calorific value.
- 2. Unit product with higher ash content and subsequent ash handing costs.
- 3. In the case of some pollutants (CO₂, SO_x and HAP trace elements) a possible increase in pollution volume per unit energy utilised.
- 4. The low grade export products could have lower volatile contents and hence different ignition characteristics
- 5. The maceral characteristics of the product could be significantly different and impact the utilisation potential. The maceral characteristics could have an influence on the ignition efficiency and flame control. In turn the maceral characteristics could have a significant impact on heat transfer and burn out in

the boiler. Combustion and thermal efficiency therefore is greatly influenced by the maceral composition and characteristics of the feed coal.

In summary, for successful utilisation potential, ideally it would be beneficial to also design the utilisation equipment and process to utilise the specific grade products meant for utilisation. For example in the case of combustion this would entail optimal boiler and downstream process design. This would ensure improved combustion and ultimately thermal efficiency.

9.4 Techno-Economic Aspects of Ash Utilisation

Based on Juniper (1995), an indicative increase in ash handling costs is given based on an increase in power station feed ash content. In Figure 149 it is illustrated that an increase in ash content has an expected impact on the pulveriser costs (<5 % increase in cost through increased wear and maintenance requirements) and also an increased effect on ash handling costs (>10 % increase). Ash is considered as the most influential cost parameter on power station costs.



Figure 149: Relative Operating and Maintenance costs in a coal fired power station for different quality coals (Juniper, 1995). O&M = Operating and Maintenance costs given in Australian Dollars.

9.5 Techno-Economic Aspects of Gas Cleaning

For South Africa a dissertation written by Singleton (2010) addressed numerous economic aspects relating to the implementation of FGD at Medupi. Medupi is one of the latest coal fired power stations built to ensure energy security in South Africa. It is anticipated that Medupi will be fed by coal mined in the Waterberg Coalfield. In his dissertation Singleton quantified the cost of operating various FGD (wet and dry) units at Medupi, and calculated a CAPEX of R 160 Million for a 700 MWe Plant and an OPEX of R450 per kW for a wet scrubber. All FGD calculations in this thesis are also based on wet FGD from Singleton (2010) and Juniper (1995).

From the modelling of various grade products (4000-6000 NAR CV) the estimated FGD cleaning costs through utilisation of the products are plotted in Figures 150, 151 and 152. Please note that a lower grade product would entail a higher volume of sulphur requiring abatement. The sulphur content could be lower for lower grade products at higher yields as is the case with the Witbank Coalfield No. 4 Seam, but is only the case for fractions below 1.80 RD. Note that FGD scrubber units are sized on exit air flow rates and not only on estimated sulphur content and SOx emission volumes.



Figure 150: FGD Modelled OPEX at various product sulphur contents - Witbank Coalfield No. 4 Seam Export scenario

In the case of the Waterberg Upper Ecca (see Figure 151) a general increase in FGD OPEX is observed with an increase in power station feed sulphur content, this coincides with an increase in volume feed as well.



Figure 151: FGD Modelled OPEX at various product sulphur contents - Waterberg Upper Ecca Export scenario

In the case of the Free State (Vereeniging) coal (Figure 152) with low sulphur contents, the costs of FGD at lower sulphur contents are marginal.



Figure 152: FGD Modelled OPEX at various product sulphur contents - Free State Domestic Power supply scenario