Khanyisa IPP – 450 MW$_e$ CFB project: Practical challenges

Anglo American has embarked on a commercial procurement process for delivery of a 450-MW$_e$ power plant fuelled by discard coal in the Emalahleni area of Mpumalanga, South Africa. The proposed IPP will utilise a circulating fluidized-bed technology and be supplied by Anglo American’s Thermal Coal (AATC) business unit. All electrical power will be purchased by Anglo American’s Platinum (AAP) division through a 25-year PPA and will be delivered to a number of its operations via the Eskom network. This article examines some of these challenges and outlines steps taken to resolving them.

This article describes the option taken to realise value and mitigate risk for Anglo American. It also outlines the particular challenges encountered – challenges that are more commercial than technical and some that are particularly applicable to South Africa.

**Structures**

**Power plant**

The power plant at the heart of Khanyisa IPP comprises three 150 MW$_e$ circulating fluidized bed (CFB) boilers, each with its own turbine-generator set. The choice of boiler rested on the flexibility of CFBs. Appropriately designed, they can burn fuels spanning a range of qualities. At the low-grade end they can handle fuels with low heating values (>6 MJ/kg), high moisture content (<55%), and high ash content (<60%) [3]. High-ash discard coals are generally cheaper than fuels of better quality, so the technology carries a cost benefit. Pollutant emissions from CFB boilers are inherently lower than those from the competing technology, pulversised-fuel (PF) boilers. Because the combustion temperature in CFBs (840 – 900°C) is much lower than that of PF boilers (1 350 – 1 500°C), less NO$_x$ forms (from nitrogen in the fuel and the air); and by injecting limestone (calcium carbonate, a sorbent) into the furnace, one can capture SO$_2$ without resorting to an expensive SO$_2$ removal system [3]. There are further savings in not having to pulverise the coal; CFB boilers can handle a top size of 12 mm.

Two choices for the Khanyisa IPP were constrained by considerations beyond the technology itself. First, there is the primary question of capacity, that of the power plant and the size and number of CFB units. The capacity (which translate to ‘footprint’) was determined by the area of land not undermined—an available area of ±30 ha—and by the base-load consumption of AAP, which is ±430 MW needed 95% of the time.

These factors capped the capacity of the power plant at 450 MW$_e$. The number and the size of units were determined by two requirements, reliability and redundancy. The implications of both requirements were compared in two scenarios. In one of the scenarios the power plant runs two CFB boilers, each of 225 MW$_e$. In the other, the
plant runs three CFB boilers, each of 150 MWe. When one of the units is down for maintenance AAP would need to make up the shortfall from Eskom. It will be easier for Eskom to supply 150 MW (a third of Khanyisa IPP capacity) than 225 MW (half of capacity not generated). The 150 MW unit size is also more widely available, which would enable several potential suppliers and a more competitive bidding process. The other choice sets the design of the plant somewhat apart from some power plants of this kind. Because limestone is more expensive than fuel in the Khanyisa IPP, the coal will be beneficiated in order to use (inject) less sorbent in the furnaces of the boilers to capture \( \text{SO}_2 \). The consequences are that two further plants will be built, a wash plant for beneficiating the discard coal, and potentially an FGD plant for scrubbing \( \text{SO}_2 \) emissions from the off-gas.

The power plant will be built close to sources of fuel, huge dumps of discard coal. AATC manages several collieries in the Witbank area in Mpumalanga Province. Pre-feasibility studies in the project identified six potential sites in an area about 10 km south of Witbank. Three mines operate in the area; on an axis running from north-west to south-east they are Landau Colliery, Greenside Colliery and Kleinkopje Colliery. Four main dumps receive discard coal from these mines (see Table 1). The power plant will be located on a site in the vicinity of Kleinkopje Colliery and its dump, called Klippan. The coal will be transported from the dump to a new modular wash plant, called the Klippan wash plant, and from there to the power plant (~2 km), all of it by conveyor belt. Choosing an appropriate site for the power station presented challenges to the project team. These are discussed in a subsequent section. Challenges aside, however, two overriding considerations informed location; they are the proximity of the plant (1) to sources of fuel and (2) to a source of water [4].

The power plant will lie about 4 km from the eMalahleni Water Reclamation Plant, which treats the mine water from four collieries, three of them run by AATC (Landau, Kleinkopje and Greenside), a fourth owned by BHP Billiton (South Witbank). The plant recovers 99.5% of water treated, producing in a day 30 million litres of potable water (TDS <100 mg/L, the SABS 241 class-0 standard for municipal water) [4, 5]. It discards 240 tonnes of solid waste (CaSO\(_4\) 2H\(_2\)O [gypsum]) and 160 000 L of brine a day [5]. Water serves one purpose at the power plant: from it steam is produced [4]. The only treatment of water at the power plant is ‘demineralisation’—fine particulates and dissolved salts are removed with ion-exchange technology [4].

Compared with a typical South African thermal coal exported to Europe (Bell, personal communication), the discard coal, not surprisingly, is of an inferior quality (see Table 2). It has only half the calorific value; it contains more than 50% ash and up to four times as much sulphur (2,0±1,1% S).

There is half as much carbon, less volatile matter, and five times more chlorine. It contains half as much nitrogen. Ash compositions are comparable. The ash is, by and large, alumina silicate; it contains more iron oxide and less calcium oxide. Ash fusion temperatures of discard coal are about 35 – 65°C higher than those of export thermal coal (see Table 1).

<table>
<thead>
<tr>
<th>Dump</th>
<th>CV* (MJ/kg)</th>
<th>Ash* (%)</th>
<th>Moist.* (%)</th>
<th>Sulphur* (%)</th>
<th>VM* (%)</th>
<th>FC* (%)</th>
<th>Exist 2011 Mt</th>
<th>Arise 2012-2025 Mt</th>
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</thead>
<tbody>
<tr>
<td>Landau 3/Klipfontein</td>
<td>17.5</td>
<td>39.8</td>
<td>3.0</td>
<td>3.2</td>
<td>20.2</td>
<td>41.3</td>
<td>16.0</td>
<td>–</td>
</tr>
<tr>
<td>Kleinkopje</td>
<td>14.3</td>
<td>43.9</td>
<td>2.2</td>
<td>2.2</td>
<td>18.1</td>
<td>35.8</td>
<td>45.0</td>
<td>74.2</td>
</tr>
<tr>
<td>Greenside</td>
<td>15.2</td>
<td>46.4</td>
<td>2.0</td>
<td>3.1</td>
<td>17.9</td>
<td>33.5</td>
<td>42.6</td>
<td>51.8</td>
</tr>
<tr>
<td>Blaauwkrans (co-disposal)</td>
<td>11.5</td>
<td>57.9</td>
<td>2.1</td>
<td>2.4</td>
<td>13.7</td>
<td>26.4</td>
<td>33.4</td>
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</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>136.9</td>
<td>138.6</td>
</tr>
</tbody>
</table>

*Qualities are indicative. CV = calorific value, VM = volatile matter, FC = fixed carbon.

Table 1: The sufficiency of discard coal.
Average values of the AFTs of 37 samples of drill cores through the Klippan dump are plotted; the bars indicate two standard deviations of the statistical sample. AFTs of the thermal coal (Anglo American) are typical values for the period January - May 2011 (Bell, pers. comm.); the bars indicate the ‘ship range’.

Figure 1: Ash-fusion temperatures.

The power plant will receive discard coal from the Klippan wash plant by conveyor and water from the eMalahleni Water Reclamation Plant. The plant will adopt Eskom’s position, that all power stations discharge no waste effluent: all water entering the plant will be contained and used; there will be no discharge. Ash is another matter. There is a great deal of it, and it will need to be discarded in a way that does not harm the environment. The discarded product will be a mix of fly ash, un-reacted limestone and CaSO₄.

It will be transported in a piped conveyor to a disposal site, an old open-cast pit that has been backfilled and rehabilitated south-west of the power station. This site will be permitted as a waste disposal facility and be engineered with a double lining, provision for runoff water, and an appropriate rehabilitation plan.

Electrical connections

The significant connection is an electrical one to the national grid. At full capacity the plant will generate 450 MWₑ. All power generated will be transmitted via the 400 kV transmission network (Eskom). The connection to the grid will include a new sub-station near the power plant and two 400 kV power lines that will extend about 3 km NE of the power station site and into the national grid.

The deal

As Anglo American is a resource company and not a power generation company, it opted for the IPP model. Anglo American has only to supply coal and water and to buy the power. The structure of the deal is such that Anglo American sits on both sides of the transaction (see Figure 2). AATC supplies coal and water to the IPP (the left-hand side of the diagram). The IPP will enter into its own agreements with third parties, one for operation and maintenance (O&M), the other for limestone. In order to connect the power station to the grid the IPP will enter into a transmission agreement with Eskom. AAP will buy power from the IPP (the right hand side of the diagram) through a power purchase agreement (PPA). It will also have an own-generation and use-of-system agreement with Eskom in order to use the network and to be allowed to take electricity off at the various load points.

Challenges

Locating an acceptable site

Besides securing long-term access to fuel and water, the power plant and its location must meet criteria that address geotechnical, social and environmental requirements. One of these is the condition of ground stability upon which the plant will be built. The ground must be geologically stable. If there are mines in the vicinity, they should not pass under the proposed site, nor should the area have been previously undermined. The exclusion applies also to future mining activity in the area. Geotechnical studies have found the ground under the proposed site to be stable, not previously undermined, and the risk of subsidence therefore low. There is sufficient distance between the power plant and underground workings [4].

Another criterion is the road infrastructure in the area. The N12 motorway passes just north of the proposed site. It will allow heavy equipment to be transported to the site. A provincial road currently passes over the site. It will be diverted, as will two distribution power lines, 22 kV each, and a fresh water pipeline that services Kleinkopje colliery. The access road to the site will need to be upgraded. With proper planning, these changes are readily effected.

A more difficult action to undertake would be the moving of graves in the area. A total of 118 graves are located under a 400 kV power line. Rather than move a number of graves and the power line on the southern boundary of the site, developers will fence off this area and respect the graveyard, as well as the servitude to Eskom’s power line. The moving of graves is a specialist matter that requires well-defined statutory procedures to be followed. Nevertheless, in this instance it was possible to avoid disturbing the area by slightly altering the layout of the facility. Judged by these criteria, which by no means complete the set, the viabilities of all of the potential sites considered in the pre-feasibility study were ‘practically the same’ [4]. The proposed site has the advantage of being closest to the mines (arising discards) and priority dumps (existing discards); furthermore, there are no plans to mine under the site.

Who lives longer? Mine vs project

The life of the power station is expected to be 40 years: the term of the Power Purchase Agreement (PPA) is 25 years, with the potential to extend it for another 15 years. The PPA is scheduled to start in 2016. During the life of the PPA the Life of Mine (LOM) of the collieries in
the area would have been reached (within the 2020s). The IPP, therefore, is expected to outlive the mines. More than 60% of the fuel for Khanyisa IPP will come from the Klippan dump (Kleinkopje’s discard dump facility). It will need to secure the access to this fuel. Security will be achieved by Anglo American’s retaining the mining rights over the Klippan dump, thereby securing its access to reclaim the discards.

How to control sulphur emissions

Discard coal from dumps in the area have two properties that disqualify it from conventional PF boilers, but not from CFB boilers. Despite a low calorific value and a high ash content (see Table 1), the coal burns and releases energy, from which power can be generated. A third property is also readily accommodated in CFB boilers. The discard coal contains high levels of sulphur (see Table 1). In CFB boilers sulphur is absorbed by limestone, a sorbent injected into the furnace (Limestone is injected for fuels with more than 0.5% sulphur [3].) Limestone, in this instance, costs ten times as much as discard coal; three quarter of that cost covers transport of the limestone from the quarries to the Witbank area. To reduce the amount of sulphur in the feed to the boilers, the discard coal will be beneficiated (in a wash plant). This will, in turn, reduce operating costs. Beneficiation will also provide a stream of coal of constant quality. Khanyisa will comply with the emission standards of the World Bank IFC (International Finance Corporation).

Tariff structure and capacity charge

The tariff has been set up in order to keep the IPP whole (ie it recovers its costs under most conditions, save its own default). The main component of the tariff is the capacity charge, which will initially make up around 70% of the tariff. The capacity charge arises because the sole purpose of Khanyisa IPP is to provide power to AAP; the developer cannot recover its capital costs from any other user. If AAP cannot take power on a certain day (or days), yet the IPP is available to generate electricity, then AAP will be obligated to pay a capacity charge for the current available energy capacity. This will allow the IPP to continue repaying its debt. Without the capacity charge the IPP would not be able to raise any finance. The other IPP costs in the tariff (ie coal, limestone, water, fixed and variable O&M) are also identified in the tariff and will be passed through to AAP.

Finance lease

As AAP will be the only off-taker of power from Khanyisa IPP, it will be liable to pay for all the electricity generated. By signing the PPA, AAP is committing to buying the power from the IPP and, in particular, the capacity charge for the next 25 years. This condition makes the PPA a liability on AAP’s balance sheet. The liability amounts to the total cost of the IPP (about US $1bn). A finance lease of this magnitude could have an impact on the covenant ratios of AAP. The project team examined the impact of the finance lease on AAP’s balance sheet. The covenant ratios (ie gearing and EBITDA interest cover) are expected to be maintained within the company’s targets.

Carbon footprint

Given that Khanyisa IPP will burn discard coal, its carbon footprint is likely to be slightly higher than that of Eskom’s—because Eskom’s generation mix includes nuclear and hydroelectric besides coal. As less carbon-intensive sources of generation are added to the Eskom generation mix over time, its average carbon footprint per kWh of generation is expected to drop. Purchasing a large portion of its electricity from Khanyisa IPP could therefore ultimately increase AAP’s carbon footprint relative to buying electricity from Eskom. As a mitigating strategy different options are being evaluated to offset carbon emissions partially and to bring Khanyisa IPP’s footprint in line with that of Eskom’s. Some of the options under consideration are CO₂ capture by algae and the use of renewables.

Empowered entity

It is a requirement of AAP’s mineral rights, under the Mining Charter of South Africa, that a minimum of its goods and services are procured from suppliers that are ‘empowered entities’. The electricity to be purchased from Khanyisa IPP through the PPA will meet this procurement requirement. In the absence of an energy charter, AAP will require the IPP to ensure that it meets mining charter procurement criteria. It is a requirement of AAP that the project company meet a minimum empowered-entity ownership of 25.1% at project-company level. Furthermore, AAP has also set transformation requirements for bidders, requirements such as local procurement and employment equity.

Integrated Resource Plan

When the public consultation process for the Integrated Resource Plan (IRP) was held, representation was made to ensure that projects of this nature were included in the proposed future generation mix. This would enable Khanyisa IPP to qualify to apply for a generation license. Including projects such as Khanyisa in the IRP was important in another respect: it linked the IPP to the total future generation mix for South Africa, and, in doing so, included the IPP in the carbon-footprint mitigation plan for the country. South Africa has adopted targets for its future generation mix in order to mitigate its carbon footprint. The capacity allocated for coal-fired power plants in the future generation mix is limited.

Eskom

Electricity generated by Khanyisa IPP will be delivered to AAP’s operations by means of the national grid. As the grid is operated by Eskom, the IPP will need to enter into an agreement with Eskom to connect the power plant to the grid. This, one of two contracts, will cover connection, transmission, and use of the system. A second contract involves AAP. As the platinum producer draws power from an Eskom substation, AAP will need to enter into an agreement with Eskom to use the national grid and take power off at the various designated points of delivery. This agreement with Eskom, one of own generation and use of the system, will credit AAP on the Eskom invoice with the amount of electricity that is being supplied by Khanyisa IPP. AAP will pay Eskom for the use of the network in all the power it receives. The
energy component, however, will be divided in two, (1) the energy supplied by Eskom and (2) the energy supplied by Khanyisa IPP.

Environmental impact assessment
Before it can proceed with construction the project needs the authorisation that follows an environmental impact assessment (EIA). The process can take from 18 to 24 months. In order to deliver the first unit by mid-2015, Anglo American has begun this process on behalf of the IPP. To facilitate it Anglo American provided certain technical specifications to the environmental specialists to help them in their assessment and to secure the authorisation in good time. Some of the specifications include the ash transport system, the design of the ash liner, emissions standards (according to the IFC), a zero-effluent plant, and the air-cooled condensers.

Conclusion
The supply of energy in South Africa is characterised by a shortage of electricity and future increases in the price of the utility. These circumstances give investors good reason to build new power-generating capacity in the country. Anglo American has a competitive advantage over many other potential players in this market in that it has exclusive access to a fuel (discard coal) at very little cost and its operations in South African demand continuously high, stable power [2]. Khanyisa IPP will exploit these advantages. Its location, furthermore, can take advantage of Anglo American’s eMalahleni Water Reclamation Plant for much-needed water. The tender went public in 2011 and seven bidders initially qualified: ACWA/Huadian, AES, China Guodian (GD Power), GDF Suez, JSW Energy, KEPCO and Marubeni had until January 2012 to submit priced and funded bids in accordance with pre-issued draft transaction documents. Once the bids have been evaluated and the final terms agreed upon with the selected developer, the project will need approval from the board of Anglo American. Only then, and on conclusion of the environmental and social impact assessments, the licensing process, and the interconnection arrangement with Eskom, can ground breaking begin. If all goes well the first of three 150 MWe CFB boilers could be commissioned in 2015.

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References