Creating Value in the Coal Delivery Chain via Advanced Beneficiation Approaches

Dr Dave Osborne – Somerset International Australia

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Venue: Convention Centre, New Delhi City Centre
Some focussing questions:

• How long will coal be needed?
• How would optimisation of the supply chain add value?
• Present time, and in the future.....?
• What directions will optimisation need to take?
• When is coal beneficiation optimised?

But first some context...
Coal role as a fuel is facing more scrutiny than it has at any time in the past.

### ENVIRONMENT
- Concerns over emissions and air quality are growing
- Carbon tax and emissions trading policies are being encouraged

### IMAGE PROBLEM
- Coal is being blamed for air pollution and industrial waste disposal concerns
- New coal mining and infrastructure development are facing political hurdles
- Fossil fuels, coal use also viewed as a major impact on climate change

### COAL FINANCING
- Despite being the most affordable fuel for power generation, obtaining finance for a new coal-fired power station is becoming difficult
- MDBs, IFIs, several wealth funds, and even commercial banks are hesitant to finance coal mining and coal-fired power development

### RENEWABLE POWER
- Renewable power generation has increased rapidly in the past few years
- Technology, government incentives and economies of scale are lowering the costs of solar and wind power

### LOW OIL and GAS PRICES
- Low oil prices are reducing gas prices in markets that matter for thermal coal
- Gas supply is rising and the pace of demand growth is slowing in Asia

### DECLINING EXPORT COAL QUALITY
- Coal qualities are falling globally
- Demand for low ash, low sulphur coal is increasing

Source: Wood Mackenzie
Due to growing significance of these emerging markets, coal will remain a dominant source of fuel into electricity (and other industries.
What is the JORC* Code?

- **“Code of Practice”** sets minimum standards for Public Reporting of Exploration Results, Mineral Resources and Ore Reserves.
- **Mandatory classification system** for exploration results, resources and reserves according to the levels of confidence in geological knowledge and technical and economic considerations in Public Reports prepared for the purpose of informing investors or potential investors and their advisors.

*Joint Ore Reserves Committee*
Increasing Resource Scale & Value

Understanding the resource to match market needs

 Suppliers working with users to identify synergies
  – New uses have different functional needs
  – Established specifications and tests may be irrelevant
  – Incremental early analysis can significantly enhance a resource base
  – Simplify/optimise downstream practices

Integrate market needs into resource development strategies
  – Consider relevant performance characteristics and parameters.
  – Examples are mineral matter, reactivity, grinding, petrography, etc.
Value of the Coal Quality database

Quality Control Parameters

- Moisture
- Ash level
- Calorific value
- Sulphur content
- Density

Moisture consistency
- Ash constituents
- Moisture consistency
- Ash value consistency
- Calorific value consistency
- Sulphur consistency

Size distribution
- Free moisture
- Size distribution
- Sulphur variability
- Hardgrove grindability
- Coking properties
- Ash elements

Ash fusion characteristics
- Proximate analysis
- Ultimate analysis
- Ash elements
- Crucible swelling
- Sulphur forms
- Toxic elements

PREPARATION PLANT

STOCKPILE BLENDING

MINE PLANNING/OPERATIONAL

GEOLOGICAL/DATABASE
Whole of Coal Supply Chain

Steelmaking example

Raw materials Value Chain

Supplier's Mining Operations

User's Steelmaking Operations

Market Driven

Sales Led Opportunistic

Traders Opportunistic

Buyers Opportunistic

Opportunistic Buyers

Opportunistic Traders

Opportunistic Sellers
Optimisation - Silo vs. Global

Local Optimisation:
What’s best for an operating silo?

Global Optimisation:
What’s best for the entire supply chain?

Historical
Real Time
0-48 hours
1-7 days
1-13 weeks
3-36 months
LOM

Local Visibility:
What’s best for a time period silo?

Global Visibility:
How does a decision now impact the future horizons?
Tools for Optimisation

Commercial software exists and is in use

**Mine Planning and Coal Cleaning**
- Extraction scheduling and blending from day of operations to Life of Mine
- Multi objective optimiser; throughput, quality, cost and utilisation
- Bespoke coal cleaning models, e.g., LIMN

**Pit to Port***
- From in-pit stockpiles to ship-loading
- Modelling complex supply chains with multiple mines, plants, rail networks and ports
- Complex blending solutions
- Multi-objective optimiser; throughput, quality, cost and utilisation

**Power plant and Blast furnace: Cost-in-use Analysis**
- Raw materials optimiser; throughput, quality, cost and utilisation
- VISTA Coal Quality Impact Model (EPRI)
- Fuel Evaluation tools (Uniper)

* SolveIT Software
## Cost of Coal Beneficiation

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Treatment</th>
<th>Cost $/t* ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No cleaning</td>
<td>Run-of-Mine crushed and screened in two stages to nominated top size &lt;60mm.</td>
<td>2.25</td>
</tr>
<tr>
<td>2</td>
<td>De-stoning.</td>
<td>Dry cleaning using FGX; removal of coarse rock over 75mm</td>
<td>3.50</td>
</tr>
<tr>
<td>3</td>
<td>Coarse coal cleaning</td>
<td>Run-of-mine dry screened @ 10mm Dense Medium bath</td>
<td>4.50</td>
</tr>
<tr>
<td>4</td>
<td>Coarse and small coal cleaning – no fine coal cleaning – fines added opportunistically</td>
<td>Combination down to fine size ~0.5mm DM baths + DM cyclones; drain/dewatering/desliming.</td>
<td>5.50</td>
</tr>
<tr>
<td>5</td>
<td>Coarser and small coal cleaning – no fine coal cleaning – untreated fines added opportunistically</td>
<td>Combination from ~60mm down to fine size ~0.25mm DM cyclones; spirals/TBS with drain/dewatering/desliming.</td>
<td>6.50</td>
</tr>
<tr>
<td>6</td>
<td>Total coal cleaning – combination down to zero</td>
<td>Depending on coal value with 4 or 5 + flotation cells or columns; dewatering essential.</td>
<td>7.50</td>
</tr>
<tr>
<td>7</td>
<td>Deep cleaning – requires more extensive liberation to release coal from “middlings”.</td>
<td>Top size could be 5mm or less. Further liberation via crushing/milling using small and fine coal cleaning options.</td>
<td>9.50</td>
</tr>
</tbody>
</table>

*Based on 7,000 hours/year
Whole of Coal Supply Chain (CSC) Cost Analysis

Coal Supply Value Chain for Electricity Production
(using Uniper’s Fuel Evaluation Tool)

<table>
<thead>
<tr>
<th>Mining</th>
<th>Preparation</th>
<th>Transport</th>
<th>Export Terminal</th>
<th>Sea Freight</th>
<th>Import Terminal</th>
<th>Transport</th>
<th>Power Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-50 $/t</td>
<td>0-10 $/t</td>
<td>2-15 $/t</td>
<td>4-6 $/t</td>
<td>5-15 $/t</td>
<td>4-6 $/t</td>
<td>0-10 $/t</td>
<td>30-60 $/t</td>
</tr>
<tr>
<td>FOB 40-65 $/t</td>
<td>CIF 45-75 $/t</td>
<td>Total Costs = 90-140 $/t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
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</thead>
<tbody>
<tr>
<td>1.0-1.5 c/kWh</td>
<td>0-0.3 c/kWh</td>
<td>0.1-0.5 c/kWh</td>
<td>0.2 c/kWh</td>
<td>0.2-0.5 c/kWh</td>
<td>0.2 c/kWh</td>
<td>0-0.3 c/kWh</td>
<td>1-2 c/kWh</td>
</tr>
<tr>
<td>Total Costs = 3-5 c/kWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Whole of CSC Cost Analysis

Power Plant Cost Analysis

Power Plant

- Stocking + Handling: 0.1 c/kWh
- Auxiliary Power + Unit Efficiency: +/-0.2 c/kWh
- Ash: -0.1-0.3 c/kWh
- Reagents + By-products: 0.0-0.2 c/kWh
- Emissions Permits: 0-1.2 c/kWh
- Maintenance + Availability: 0.5-1.0 c/kWh

Total Costs = 1.0-2.0 c/kWh

Source: Uniper Technologies Limited
Whole of CSC Cost Analysis

Imports - cost of fuel is usually the largest cost

Highlights that coal brands can have very different outcomes

Source: Uniper Technologies Limited
Optimisation opportunities

Case Study 1: Raw coal handling example

Market Drivers to optimization include:

• Potential cost reductions in Capex & Opex
• Environmental benefits
• Technology advancements to improve productivity
• Change in industry trends or paradigms
• Big Question: When will this change occur?

Source: FL Smidth
Cost Comparison Example

Truck & Shovel vs. In-pit Crushing and Conveying system

**Truck and Shovel**

- Operating cost: $2.82 per tonne*
- Capital recovery: $0.80/tonne
- Based on Capital of: $206,680,000
- Cost of funds: 12%
- Amortization period: 20 years

**In-pit crushing & conveying (IPCC)**

- Fully mobile system
- Operating cost: $0.64 per tonne*
- Capital recovery: $0.90/tonne
- Based on Capital of: $294,790,000
- Cost of funds: 12%
- Amortization period: 20 years

* average for life of project

Source: FL Smidth
Performance comparison

Truck & Shovel & IPCC system

Comparisons for annual operating costs for IPCC c/w Truck and Shovel

Source: FL Smidth
Future Coal Supply Chains

Coal-water based systems

• Opportunities include coal-water mixtures:
  • Hydraulic mining - so far; only brave attempts!
  • Coal-water slurries + transportation + dewatering
  • Coal slurries for gasification
  • Coal-water fuels to replace heavy fuel oil (HFO)
  • Coal-water fuels for direct injection carbon engines (DICE)

• These pose the questions
  • Where is the best place(s) to beneficiate?
  • What extent is optimal?

• Economic decision – the technology is in place!
**Coal Water Slurry Fuel options**

Case Study 1: Coal-Slurry Supply chain

An innovative solution is to recover and use all the fines via production of a coal-water slurry fuel

- Recover more coal (higher yield – lower cost/tonne)
- Less tailings to dispose of (lowers producer costs)
- Solves the fines dewatering problem – a growing cost with increased fines.
- Handle and transport as a liquid fuel, not a difficult lumpy coal containing sticky/wet/dusting solids (lowers both the producer and user costs)
- No further grinding needed at the power station (lowers user costs – a major cost component)
- Although thermal efficiency is reduced by about 3%.....offset by cost reductions created via recovering coal that would otherwise be lost!
Coal Water Slurry Fuel

Slurry fuel for Electricity Generation

- Recover fines / ultrafines to produce additional saleable coal product
- Overall, power generation costs can be reduced

No mining costs: fines often discarded, so only recovery cost included.

Additional up-front processing: crushing, milling, froth flotation, stabilisation.

Transportation of CWS analogous to HFO: Pipelines, tankers etc

End-user costs: Fuel handling & delivery system upgrading, Efficiency impact of higher fuel moisture.

End-user benefits: Improved unit availability and maintenance (low ash), lower ash disposal costs.
# Coal Water Slurry Fuel

## Comparison of CSC Costs for Electricity Generation

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<th>Power Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional Coal</strong></td>
<td>40 $/t</td>
<td>5 $/t</td>
<td>10 $/t</td>
<td>5 $/t</td>
<td>10 $/t</td>
<td>5 $/t</td>
<td>5 $/t</td>
<td>44 $/t</td>
</tr>
<tr>
<td><strong>Coal Water Slurry</strong></td>
<td>15 $/t</td>
<td>11 $/t</td>
<td>5 $/t</td>
<td>11 $/t</td>
<td>5 $/t</td>
<td>6 $/t</td>
<td>47 $/t</td>
<td>47 $/t</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FOB 60 $/t</th>
<th>CIF 70 $/t</th>
<th>Total Costs = 124 $/t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 $/t</td>
<td>5 $/t</td>
<td>10 $/t</td>
</tr>
<tr>
<td></td>
<td>5 $/t</td>
<td>10 $/t</td>
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<td>5 $/t</td>
<td>44 $/t</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FOB 31 $/t</th>
<th>CIF 42 $/t</th>
<th>Total Costs = 100 $/t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15 $/t</td>
<td>11 $/t</td>
<td>11 $/t</td>
</tr>
<tr>
<td></td>
<td>5 $/t</td>
<td>5 $/t</td>
<td>6 $/t</td>
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<td></td>
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<td>47 $/t</td>
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</tr>
</tbody>
</table>

**Total Costs = 4.2 c/kWh**

**Total Costs = 3.3 c/kWh**
“Micronized” Coal Water Fuel

Optimization of the fuel cycle (DICE)

- Increased grade recovery
- Recovery of ultra fines
- Minimal dewatering

- Road/rail/ship of cake
- Pipeline coal water fuels
- Higher solids paste for longer distance

- Mine-mouth or centralized
- No penalty for dry cooling
- Distributed generation, support of renewables

Micronised Refined Carbon (MRC)
Summary

• Coal will be in demand in significant amounts for another two decades.
• Supply Chain optimisation can add significant value – front-end design is essential.
• Many coal producers, supplier companies and traders are already using/developing CSC modelling software.
• Fuel is the largest cost component in the power generation part of the chain – highly efficient plants are essential for continued coal use.
• Step-change to an “optimised energy solution” appears commercially viable.
• “Rocks in a bulk carrier” will become outmoded; and “ready-to-use” fuel supply has growing appeal.
• Coal has a poor image - some form of transition will need to occur soon.
Creating Value in the Coal Delivery Chain via Advanced Beneficiation Approaches

Many thanks for your attention

Any Questions??
Brief Advertisement - Somerset International Australia

• Somerset International Australia Pty (SIA) is a beneficiation technology company that provides equipment and technical expertise to Australian coal producers with wet processing plants.

• It is our mission to increase the recovery of fine coal (-50 microns) from waste streams created in wet processing plants.

• We have a global team of coal preparation and engineering experts with collective experience ranging from plant design and construction to strategic planning and business development.

• SIA is a subsidiary of Somerset Coal International which was formed to seamlessly integrate fine coal recovery technology into Australian coal operations, delivering significant economic and environmental value.

Also, please contact us to discuss your ideas and needs dosborne@somersetpty.com, or jeuston@somersetpty.com