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Presentation outline

• Background - steel industry trends

• Critical issues for the global steel industry
  – Future structure of China’s steel industry
  – Consolidation
  – Future Blast furnace trends

• Implications for coke

• Recent studies to understand coke its reactions & performance

• Summary and Conclusions
The world has changed

But the need for coke and hard coking coal remains
Areas where the world has changed……..

- Industry structure – consolidation; the new wave
- Regional consolidation moves global
- Price volatility – industry consensus; potential to be lower
- Increased market “power” re customers (flat products)
- Current high profitability in the steel industry continues
- Raw materials – too early to be definite, but potential move to higher quality seaborne raw materials
Areas where the world has not changed

- New phase of strong demand growth - BRICS
- China driving major uplifts
- Technology trends - BF still king
- Planned new capacity SE Asia, Brazil, India etc
- Drive for higher productivity = high quality RM’s esp coke
- Environmental conditions
- Raw materials – the benefits of high quality esp coke
The global steel industry continues to power on

**Background**

- **The golden age**
  - 1945 – 1973
  - 6.2%pa

- **Oil Shocks**

- **Rise of Japan**

- **The efficiency age**
  - 1974 – 1995
  - 0.2%pa

- **Consolidation**

- **Privatisations**

- **The China Effect**

**The emerging age**

- **Pre 1945**
  - 2.8%pa

- **Rebuilding of Europe**

- **Fall of Berlin Wall**

- **New golden age?**

- **1996 + >4.6%pa**

**Source:** IISI
Global steel growth rates have picked up a gear

<table>
<thead>
<tr>
<th>CAGR (%)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970 – 1975</td>
<td>1.6</td>
</tr>
<tr>
<td>1975 – 1980</td>
<td>2.2</td>
</tr>
<tr>
<td>1980 – 1985</td>
<td>0.1</td>
</tr>
<tr>
<td>1985 – 1990</td>
<td>1.4</td>
</tr>
<tr>
<td>1990 – 1995</td>
<td>-0.5</td>
</tr>
<tr>
<td>1995 – 2000</td>
<td>2.4</td>
</tr>
<tr>
<td>2000 - 2005</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Source: IISI
China remains the main driver of this growth

First steel producer over 300 million tonnes per annum in 2005: >3.5x production in USA

First and only steel producer over 200 million tonnes per annum in 2003: ~double production in Japan

The largest world steel producer since 1996

Source: CISA and other industry sources

1985~2000, CAGR: 7%
2000~2005, CAGR: 22%
Steel 2005; 2 worlds – balanced & uncontrolled growth

- Market sentiment roller coaster – strong, weak and strengthening again
- China responsible for global increase – world ex China –ve growth in 2005
- Demand led by China, contribution from SE Asia: growing +ve signs US, Europe later
- Chinese production remains buoyant strong steel and stronger pig iron growth
The China effect

Source: IISI, BHP Billiton
Changing trends emerged during the year.

Source: IISI
Annualised steel and pig iron production trends

**Background**

**Annualised pig iron production**

- **Totals**
  - 2004: 724Mt
  - 2005: 785Mt

- **Chinese Government actions**
- **Production cuts to lower inventories**
- **Seasonal Trends**

**Annualised crude steel production**

- **Totals**
  - 2004: 1066Mt
  - 2005: 1129Mt

- **Chinese Government actions**
- **Production cuts to lower inventories**
- **Seasonal Trends**

**Source:** IISI
Massive steel de-stocking during 2005

Inventories (Jan ‘99 = 100)

Source: CRU
Successful price stabilisation – current prices turning up

Background

Recent lows substantially higher than historical lows:
- Good demand
- Consolidation (production cuts)
- Raw material prices

Source: CRU, China – Shanghai spot
### Profitability remained very strong

<table>
<thead>
<tr>
<th>PROFITABILITY</th>
<th>EBITDA Margin %</th>
<th>Pre-Tax Margin %</th>
<th>ROIC (EBIT) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>BlueScope*</td>
<td>18.0</td>
<td>18.9</td>
<td>11.5</td>
</tr>
<tr>
<td>OneSteel†</td>
<td>9.7</td>
<td>9.5</td>
<td>10.7</td>
</tr>
<tr>
<td>Australasia (Mkt cap wgtd ave)</td>
<td>15.0</td>
<td>16.2</td>
<td>11.0</td>
</tr>
<tr>
<td>JFE Holdings</td>
<td>17.8</td>
<td>23.1</td>
<td>23.0</td>
</tr>
<tr>
<td>Nippon Steel*</td>
<td>13.9</td>
<td>18.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Sumitomo Met Ind.</td>
<td>15.4</td>
<td>21.2</td>
<td>23.9</td>
</tr>
<tr>
<td>Tokyo Steel</td>
<td>13.0</td>
<td>34.2</td>
<td>30.7</td>
</tr>
<tr>
<td>Japan (Mkt cap wgtd ave)</td>
<td>15.2</td>
<td>20.5</td>
<td>20.7</td>
</tr>
<tr>
<td>Baosteel (G)</td>
<td>38.6</td>
<td>22.2</td>
<td>15.9</td>
</tr>
<tr>
<td>Maanshan I&amp;S</td>
<td>22.7</td>
<td>17.2</td>
<td>13.2</td>
</tr>
<tr>
<td>Wuhan Steel</td>
<td>30.6</td>
<td>25.3</td>
<td>25.0</td>
</tr>
<tr>
<td>China Steel</td>
<td>40.6</td>
<td>36.8</td>
<td>25.5</td>
</tr>
<tr>
<td>POSCO</td>
<td>32.8</td>
<td>34.1</td>
<td>25.8</td>
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<td>Asia (Mkt cap wgtd ave)</td>
<td>34.4</td>
<td>28.9</td>
<td>22.7</td>
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<tr>
<td>CSN*</td>
<td>47.0</td>
<td>46.5</td>
<td>45.7</td>
</tr>
<tr>
<td>Usminas</td>
<td>45.2</td>
<td>42.4</td>
<td>34.4</td>
</tr>
<tr>
<td>Mechel*</td>
<td>24.4</td>
<td>19.3</td>
<td>20.1</td>
</tr>
<tr>
<td>Severstal*</td>
<td>32.3</td>
<td>27.0</td>
<td>21.8</td>
</tr>
<tr>
<td>Novolipetsk*</td>
<td>54.3</td>
<td>46.8</td>
<td>41.1</td>
</tr>
<tr>
<td>Evra*</td>
<td>33.6</td>
<td>28.4</td>
<td>23.6</td>
</tr>
<tr>
<td>Tata Steel</td>
<td>25.6</td>
<td>35.5</td>
<td>35.5</td>
</tr>
<tr>
<td>Emerging markets (Mkt cap wgtd ave)</td>
<td>37.3</td>
<td>35.4</td>
<td>30.7</td>
</tr>
<tr>
<td>Arcelor*</td>
<td>15.2</td>
<td>17.3</td>
<td>13.3</td>
</tr>
<tr>
<td>Corus</td>
<td>10.0</td>
<td>10.1</td>
<td>8.6</td>
</tr>
<tr>
<td>SSAB</td>
<td>20.6</td>
<td>23.7</td>
<td>19.9</td>
</tr>
<tr>
<td>ThyssenKrupp Group*</td>
<td>8.1</td>
<td>8.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Europe (Mkt cap wgtd ave)</td>
<td>12.6</td>
<td>15.8</td>
<td>12.1</td>
</tr>
<tr>
<td>Nucor</td>
<td>19.5</td>
<td>19.7</td>
<td>18.7</td>
</tr>
<tr>
<td>US Steel</td>
<td>14.1</td>
<td>12.8</td>
<td>11.4</td>
</tr>
<tr>
<td>North America (Mkt cap wgtd ave)</td>
<td>19.3</td>
<td>19.5</td>
<td>19.1</td>
</tr>
<tr>
<td>Carbon Steel Sector (Mkt cap wgtd ave)</td>
<td>24.7</td>
<td>24.8</td>
<td>21.5</td>
</tr>
</tbody>
</table>

Source: UBS

*: Company report from full year
Summary – background steel industry trends

• Strong steel growth phase continues led by China

• Industry highly successful, current steel prices maintained at historically high levels

• Industry profitability currently very strong

• Consolidation benefits

• Widening differentials between global and Chinese steel prices
Future critical issues for the steel industry

1. Future structure of China’s steel industry

2. Consolidation

3. Future blast furnace trends
Future structure of China’s steel industry

Demand driven by construction, infrastructure & machinery

China Steel Demand by End Use Sectors

- Construction
- Infrastructure
- Machinery
- Automobile
- Consumer durables
- Shipbuilding
- Container
- Others

Kt, finished steel

2000 2001 2002 2003 2004 2005

Source: CISA

CAGR %

Total 19
Others 40
Container 13
Shipping 21
Cons. Durables 16
Automobile 20
Machinery 19
Infrastructure 16
Construction 14

Total kg/capita 233

00~05

Source: CISA
China per capita steel consumption still below Asian standards

Per Capita Steel Consumption Comparison Between China’s Tier I Cities in 2005 & Global Major Developed Countries

- S. Korea
- Taiwan 2004
- Japan 1990
- USA 1973
- Shanghai
- Beijing
- Canada
- Italy 2004
- Zhejiang
- Spain 2003
- Germany
- Jiangsu
- Tianjin
- France 1976
- Ukraine
- Guangdong
- Liaoning
- Shandong
- Fujian
- Hebei

Source: China Metallurgical Planning and Research Institute, IISI, BHP Billiton
Coastal provinces are the key steel consumers in China.

China's Per Capita Steel Consumption by Provinces in 2005

Tier I
- Shanghai
- Beijing
- Zhejiang
- Jiangsu
- Tianjin
- Guangdong
- Liaoning
- Shandong
- Fujian
- Hebei

Tier II
- Chongqing
- Hubei
- Heilongjiang
- Jilin
- Hunan
- Henan
- Shaanxi
- Anhui
- Sichuan
- Shanxi
- Jiangxi
- Guizhou
- Yunnan
- Guangxi
- Hainan
- Xinjiang
- Qinghai
- Inner Mongolia
- Ningxia
- Gansu
- Tibet

Source: China Metallurgical Industry Planning & Research Institute, BHPBilliton
China steel industry is very fragmented

Top 10 Crude Steel Production Provinces in 2005

<table>
<thead>
<tr>
<th>Province</th>
<th>Crude Steel Production (MT)</th>
<th>Cumulative Share of China Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hebei</td>
<td>73.9</td>
<td>73.9%</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>32.8</td>
<td>30.5%</td>
</tr>
<tr>
<td>Shandong</td>
<td>31.8</td>
<td>39.7%</td>
</tr>
<tr>
<td>Liaoning</td>
<td>30.6</td>
<td>48.4%</td>
</tr>
<tr>
<td>Shanghai</td>
<td>19.3</td>
<td>53.9%</td>
</tr>
<tr>
<td>Shanxi</td>
<td>16.5</td>
<td>58.7%</td>
</tr>
<tr>
<td>Hubei</td>
<td>15.7</td>
<td>63.2%</td>
</tr>
<tr>
<td>Henan</td>
<td>12.3</td>
<td>66.7%</td>
</tr>
<tr>
<td>Anhui</td>
<td>11.1</td>
<td>69.8%</td>
</tr>
<tr>
<td>Sichuan</td>
<td>10.9</td>
<td>73.0%</td>
</tr>
</tbody>
</table>

Source: CISA
Future structure of China’s steel industry

Top 10 steel mills only account for 35.4% of total in 2005

Top 18 Steel Mills With Crude Steel Production of 5+ MT in 2005

Source: CISA
China’s new steel policy 2005

• Objective
  – Competitiveness of China Iron & Steel Industry to be improved significantly
  – Top 10 steel mills should account for > 50% of total by 2010, and 70% by 2020

• Technology & equipment upgrade policy
  – Outdated processes, equipments and techniques; highly pollutant, raw material & energy consumption and low efficiency to be phased out
  – Pollutant discharge and efficiency standards raised

• Foreign investment policy
  – In general, foreign companies are not allowed to acquire a controlling stake in Chinese steel makers, especially medium and large ones
  – No greenfield project is allowed
  – Advanced technology with intellectual property is needed

Source: NDRC
Plans and Implications

• Industry structure optimization policy
  – Steel mills, especially big ones, are supported to grow through M&A

• Industry layout improvement policy
  – Steel mills encouraged to relocate or build greenfield plant in coastal or along Yangtze River areas to take advantage of markets and overseas raw materials
  – Inland steel mills should cap the capacity based on the available ores in line with the local markets and the mineral resources
  – Those steel mills locate in provincial capital and tourism cities are not allowed to expand capacity of iron-making & steel-making

• Raw materials policy
  – International cooperation with the overseas mineral resources should be enhanced

Source: NDRC
Consolidation targets

**The Weight of China's Top 10 Steel Mills**

<table>
<thead>
<tr>
<th>Year</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>47.6</td>
</tr>
<tr>
<td>2001</td>
<td>42.3</td>
</tr>
<tr>
<td>2002</td>
<td>42.2</td>
</tr>
<tr>
<td>2003</td>
<td>37.1</td>
</tr>
<tr>
<td>2004</td>
<td>34.7</td>
</tr>
<tr>
<td>2005</td>
<td>35</td>
</tr>
<tr>
<td>2010F</td>
<td>50</td>
</tr>
<tr>
<td>2020F</td>
<td>70</td>
</tr>
</tbody>
</table>

Source: CISA
Target 100Mt pig iron closed……but will take time

<table>
<thead>
<tr>
<th>Sintering</th>
<th>Iron-Making</th>
<th>Steel-Making</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase Out</td>
<td>BF ≤ 30 M³</td>
<td>BOF ≤ 20 Mt</td>
</tr>
<tr>
<td></td>
<td>BF ≥ 300 M³</td>
<td>EAF ≤ 20 Mt</td>
</tr>
<tr>
<td>Brownfield</td>
<td>BF ≥ 1000 M³</td>
<td>B0F ≥ 120 Mt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EAF ≥ 70 Mt</td>
</tr>
<tr>
<td>Deep Port Greenfield</td>
<td>BF ≥ 3000 M³</td>
<td>B0F ≥ 200 Mt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crude steel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capacity ≥ 8 Mt Mln</td>
</tr>
</tbody>
</table>

Source: NDRC
Consolidation increased in 2005 more underway

- Arcelor-Laiwu (38.41%)
- Tangshan-Xuanhua Chengde
- Jianlong Tonghua (36.19%)
- Fushun
- Anshan take over Benxi
- Capital take over Shuicheng (34.56%)
- Nanjing/Arcelor take over Tieben
- CITIC Pacific: Xingcheng (79%), Daye (58%), Shijiazhuang (65%)
- Hangzhou 44.39% Ningbo Jianlong
- WISCO Echeng (51%)
- Liuzhou (51%)
- Mittal 36.67%
  (2nd largest shareholder)
  Valin

Source: Public Media
Implications of future structure of Chinese steel industry

• Consolidated more profitable industry
• Larger capacity, more efficient BF production
• Rising higher quality flat product production

Overall implications likely to see rising demand for higher quality coke made with increasing quantities of higher quality hard coking coals
Consolidation will improve market conditions and profitability

- Ending “Social/national” business
- Government support/interference
- Shareholder value destruction
- Inability to retain cost reductions
- Inability to raise capital

- SOx, NOx, Dioxins
- CO₂
- Effluent discharge
- Hazardous chemicals
- Waste management
- Poor public perception

Financial Performance

Consolidated Steel Industry

Environmental Concerns

Globalisation of Steel Markets

Fragmentation & Overcapacity

- Worldwide move to privatisation
- Shareholder demand for value creation
- Capital & opex constraints
- Withdrawing of Bank supports
- M&A/Alliances, regional consolidation

- Emerging regions building own capacity
- Technology diffusion
- Capacity creep
- Low entry/high exit barriers
- Economies of scale

- Opening of import/distribution channels
- Global sourcing/rapid information flow
- Global customer sourcing and specifications
- Consolidated supplier and customers
- Convergence of product standards
- Increased JV’s
The steel industry remains fragmented, despite M&A activity

<table>
<thead>
<tr>
<th>Market share (%)</th>
<th>2000</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 5</td>
<td>16%</td>
<td>19%</td>
</tr>
<tr>
<td>Top 10</td>
<td>23%</td>
<td>28%</td>
</tr>
</tbody>
</table>

Consolidation:

- has increased slightly (+3 and +5 percentage points for the top 5 and 10 steel producers respectively from 2000 to 2005)
- favoured by strong cash flows and increasing desire to escape sluggish and expensive home markets (Europe, US)
- ‘hot spots’ in the US, E. Europe, CIS and China
- currently appears to be enabling improved production control - aligning demand with supply

2005 Crude Steel Production (mt)

- Mittal*: 68 5.1%
- Arcelor: 47 3.5%
- POSCO: 36 2.7%
- Nippon: 33 2.5%
- JFE: 33 2.4%
- Baosteel: 28 2.1%
- ThyssenKrupp: 23 1.7%
- US Steel: 21 1.6%
- Nucor: 20 1.5%
- Corus: 19 1.4%

Source: IISI, Metal Bulletin, BHP Billiton

* Mittal data includes ISG (16.1mt) and Kryvorzhstal (7.7 mt)
Further consolidation directions:

**Regional consolidation:**

- **China**, with government support but low foreign involvement (ownership limited to minority stakes)
- **CIS**: further consolidation, especially as focus shifts from raw material acquisitions
- Smaller **acquisitions between second tier producers** in Europe and North America

**Global / Cross-regional consolidation:**

- **Mergers between groups** (competition issues?): catalyst for rapid consolidation
- **Russian mills going global**
- Acquisitions in **Latin America, Middle East, Ukraine** (partly driven by captive raw materials)

**Product consolidation:**

- **Focus on flat products**
- Limited in long products: Ample opportunity but disincentives
Regional consolidation: likely to result in more benefits than global consolidation:
- Operations are strongly linked (both customer and supply side) to regional markets
- Most products sourced regionally with some global support, even though ~20% of steel production is aimed at global customers

Source: Company reports and news coverage; World Steel Dynamics
Fragmented industry now consolidating – regional impact

**Total Crude Steel Production**

- **1996**: 750Mt
- **1997**: 799Mt
- **1998**: 777Mt
- **1999**: 788Mt
- **2000**: 847Mt
- **2001**: 850Mt
- **2002**: 902Mt
- **2003**: 934Mt
- **2004**: 1069Mt
- **2005**: 1129Mt

**Share of top 5 producers**

<table>
<thead>
<tr>
<th>Year</th>
<th>% Share of Total Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>12.5</td>
</tr>
<tr>
<td>1997</td>
<td>13.1</td>
</tr>
<tr>
<td>1998</td>
<td>13.3</td>
</tr>
<tr>
<td>1999</td>
<td>14.7</td>
</tr>
<tr>
<td>2000</td>
<td>15.5</td>
</tr>
<tr>
<td>2001</td>
<td>17</td>
</tr>
<tr>
<td>2002</td>
<td>17.4</td>
</tr>
<tr>
<td>2003</td>
<td>17.7</td>
</tr>
<tr>
<td>2004</td>
<td>17.1</td>
</tr>
<tr>
<td>2005</td>
<td>16.9</td>
</tr>
</tbody>
</table>

**Source**: IISI, Metal Bulletin, BHP Billiton

Note growth in Chinese steel has countered global consolidation impacts – although regional consolidation has occurred.
Even after recent mergers, industry concentration is low

Global market share of top 3 producers, 2005e

Source: CRU Analysis, Deutsche Bank
Steel industry consolidation

Flat products is relatively consolidated, unlike long products

Flat Products

- High regional consolidation in W. Europe, USA, Japan
- Scope for consolidation in:
  - China: flat product consolidation has fallen
  - North America (limited scope)
  - Western European plate capacity

Long Products

- Significant consolidation is unlikely: the rationale is less compelling:
  - local markets,
  - low barriers to entry
  - low economies of scale
- Consolidation isolated:
  - Beams and structural products
  - Gerdau, CELSA, Nucor and Mittal

Source: CRU
Arcelor & Mittal Steel Plant Locations

**Mittal Steel Plants**
- Major player in NAFTA market, Eastern Europe, Africa and Kazakhstan
- Limited in Western Europe in production and distribution, no presence in South America
- Annual production capacity of Steel of 70 Mtpa

**Arcelor Plants**
- Major player in Western Europe, South America
- Minor operations in North America, Eastern Europe, Asia
- Arcelor has decided to turn their external growth efforts to countries such as Brazil, Russia, India, China, Eastern Europe and Turkey.
- Production of 47 Mtpa of steel in 2005

Source: Public sources, BHP Billiton
Mittal is vertically integrated using high levels of domestic coal.

<table>
<thead>
<tr>
<th>Iron Ore</th>
<th>Coking Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mittal</strong></td>
<td><strong>Arcelor</strong></td>
</tr>
<tr>
<td>Brazil (Fines)</td>
<td>20%</td>
</tr>
<tr>
<td>Brazil (Pellets)</td>
<td>10%</td>
</tr>
<tr>
<td>Australia</td>
<td>6%</td>
</tr>
<tr>
<td>CIS</td>
<td>9%</td>
</tr>
<tr>
<td>Canadian</td>
<td>13%</td>
</tr>
<tr>
<td>Mauritania</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td></td>
</tr>
<tr>
<td>Own/ Dom Mines / Strategic LT Contr</td>
<td>54%</td>
</tr>
<tr>
<td>USA</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>4%</td>
</tr>
</tbody>
</table>

Source: Mittal, Public sources, BHP Billiton

About 50% of iron ore and 70% of coking coal consumed by Mittal are supplied by own resources or sources outside the “seaborne” markets generally lower quality than seaborne supplied materials.
Steel industry consolidation

Mittal Mining Operations:

- **USA**
  - Prod.: 8.2 Mt
  - Contr.: 13.0 Mt
  - Res.: 500 Mt

- **Mexico**
  - Prod.: 2.3 Mt
  - Expan.: 3.5 Mt
  - Res.: 250 Mt

- **Congo (Kinshasa)**
  - Prod.: 15 Mt by 2010
  - Res.: 1Bt

- **USA:** captive supply contract
- **S Africa:** cost plus contract

- **Bosnia**
  - Prod.: 1.5 Mt
  - Expan.: 1.0 Mt
  - Res.: 100 Mt

- **Kazakhstan**
  - Prod.: 6.0 Mt
  - Expan.: 2.5 Mt
  - Res.: 2.3Bt

- **Ukraine**
  - Prod.: 9.4 Mt
  - Expan.: 6.0 Mt
  - Res.: 1Bt

- **S Africa**
  - Prod.: 10.2 Mt

- **Algeria**
  - Prod.: 2.0 Mt
  - Res.: 100 Mt

- **Kazakhstan**
  - Coking Coal
    - Prod.: 5.5 Mt
    - Res.: 1.5Bt

- **Bosnia**
  - Coking Coal
    - Prod.: 5.5 Mt
    - Res.: 1.5Bt

**Source:** Mittal

Iron Ore: 50 Mtpa of Curr. Prod. / Add. 28 Mtpa by 2010 / Res.of 5Bt
Coking Coal Curr. Prod. of 5.5 Mtpa / Res. of 1.5 Bt
Summary steel consolidation - implications

• Steel industry will continue to consolidate
• Moving from regional to global industry players
• Flat product will continue to lead consolidation

Overall implications likely to see more profitable steel industry operating more efficiently requiring high quality coke likely to be made with increasing quantities of higher quality hard coking coals
Most modern EU-15 Blast Furnaces operate at less than design productivity of 2.5 t/d/m³, further improvements will be made.

European Survey
2003 Blast Furnace Productivity

Source: European BF committee, Hatch
BF technology changes will be delayed to well after 2013.

Blast Furnace will remain the mainstay of steelmaking processes

This group offers opportunity for new technology implementation
The BF’s domination of virgin iron unit production will remain.

Blast Furnace Hot Metal as a Source of Virgin Iron Trend to 2025

<table>
<thead>
<tr>
<th>Year</th>
<th>Virgin Iron Units (Mt)</th>
<th>Blast Furnace (Mt)</th>
<th>Other (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yr 2000</td>
<td>450</td>
<td>400</td>
<td>50</td>
</tr>
<tr>
<td>Yr 2015</td>
<td>870</td>
<td>800</td>
<td>70</td>
</tr>
<tr>
<td>Yr 2025</td>
<td>1300</td>
<td>1120</td>
<td>180</td>
</tr>
</tbody>
</table>

Source: Hatch
ULCOS (Ultra Low CO₂ Steelmaking) program likely impact after 2025

- Step 1 (2005–10) exploring wide range of steelmaking concepts
  - O₂ blast
  - Biomass/plastics injection
  - Top gas recycling with CO₂ removal
  - CO₂ sequestration
**Future BF trends**

**Blast Furnace - future evolution**

- **Pre-Heated Burden**
- **Fine IO**
- **Scrap/Metallic DRI**
- **Mid-Furnace Injection (Oxy)**
- **Top Gas Recycling**
- **Plastics**

**Outlook for the BF**

- Decline in no = higher productivity
- Expanded campaign life >20 years
- Shorter down periods
- Higher PCI, O₂, lower fuel rates
- More stable operations
- Enhanced computer models and control, value-in-use
- Enlargement during relines
- New hearth designs
Summary future BF trends and implications

• BF will remain the main source of iron for steelmaking
• Longer lived, high productivity & efficiency future for the BF
• Size will increase as MBF’s move to larger >3000m³

Overall implications likely to see more productive, efficient BF operations requiring high quality coke likely to be made with increasing quantities of higher quality hard coking coals
What happens if you use poor quality
Blast Furnaces must be looked after!
Overall implications for coke in the new world

• Current trends:
  – China’s future, growth and structure
  – Industry consolidation
  – Future BF trends

• All lead to the conclusion that
  – Coke will remain vitally important to steelmaking
  – Coke quality trends are likely to be for higher quality
  – Coke ovens are a valuable asset
  – Implications are for continue requirements for HQHCC
Understanding coke reactions and performance

- Are traditional methods for assessing coke still relevant?
- BF operations have changed and will continue.
- Coke characterisation tests developed 20 years ago!!
  - Cold strength probably OK
  - Hot strength (CSR) generally useful

- New techniques/evaluations for the new world???
- Role of coking coals in making coke
Simulating coke conditions in the blast furnace

Does CSR adequately account for high temperature coke properties?

CSR represents one reaction, under one set of conditions.

Conditions vary through (gas, temp) but are also different in various parts of a blast furnace.

European BF

Australia BF conditions
High temperature coke reaction furnace (HTCRF)

Recent studies of coke its reactions & performance

Heating Elements
99.8% alumina worktube
Control TC

Figure 2. High Temperature Coke Reaction Furnace (HTCRF)

1. Up to 200g coke
2. 1600°C Sample temperatures
3. N₂, CO₂, CO, H₂ controlled atmospheres
4. Programmable gas-temperature regimes
More realistic BF Conditions vs CSR and CRI

Key Findings

1. CRI/CSR indices similar, but there is less differentiation between cokes under the blast furnace profile. CSR and CRI overestimate the differences in cokes.

2. Strength indices show different behaviour between CSR and BF profile. The drop at high rank is likely due to thermal damage (as shown in nitrogen data).

3. High rank coals increase fines when 100% of battery feed, but do not appear to generate increased fines when present in blends.

Source: BHP Billiton
Different parts of the blast furnace

Key Findings
1. Coke behaviour depends on where you are in the BF.
2. At the centre, thermal effects predominate.
3. At the walls (and most likely the mid radial locations, chemical attack via CO₂ becomes much more significant).
4. Similar, non-additive behaviour MV/LV blend.

Source: BHP Billiton
New methods for looking at coke structure

X-ray computer tomography (CT) is a non-destructive imaging technique that has been applied extensively in medical and engineering fields to visualise internal features of humans and objects.

X-ray micro-tomography (XRMT) is based on the same essential principles of X-ray absorption as standard X-ray CT but differs in sample transport and in size of the X-ray source.
Use High Temperature Coke Reaction (HTCR) furnace & XRMT to study the change in coke microstructure through the BF.

Coke microstructures showed significant difference between the effects of

- CSR conditions &
- a typical BF gas-temperature profile

- CSR reaction penetrated deep into the coke lump for all cokes studied
- BF profile resulted in reaction confined to lump surface.

Coke made from higher rank coals showed a more limited change in coke microstructure.
Recent studies of coke its reactions & performance

US LV v Aust LV Coals – Effect on coke strength

![Graph showing the comparison of coke strength for different US LV and Aust LV coals. The graph compares CSR, ASTM Stab, ASTM Hard, and M40 grades, with 25% USLV and 25% Aust LV coals. The source is BHP Billiton.](image-url)
Measurement of oven wall pressure (OWP)

• Moveable wall pilot coke ovens provide a direct measurement of OWP
  – Research Coke Oven at Newcastle completed over 750 experiments since 1994

<table>
<thead>
<tr>
<th></th>
<th>Standard Conditions</th>
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<tbody>
<tr>
<td>Moisture</td>
<td>5%</td>
</tr>
<tr>
<td>Bulk density</td>
<td>825kgm^{-3} (db) box charge</td>
</tr>
<tr>
<td>Grind</td>
<td>85% minus 3.35mm</td>
</tr>
<tr>
<td>Heating</td>
<td>Simulation of Australian slot ovens</td>
</tr>
</tbody>
</table>
Recent studies of coke its reactions & performance

Oven wall pressure studies

Base containing 25% US low vol

Aus LV replacing US low vol

Source: BHP Billiton
Oven wall failure
And the end of the road
Summary

• The global steel industry remains firmly in the “new world” led by China

• Future trends in China, industry consolidation and changing BF practices all suggest the need for higher coke quality

• Traditional techniques to characterise coke lack the precision to provide superior BF performance

• OWP remains an important parameter esp. with aging ovens

• High quality Australian hard coking coals esp. low vols will remain a core part of current and future coke blends