WOLFRAM – MINING & REFINING
RAW MATERIALS IN CEMENTED CARBIDE

European Hard Materials Group (EuroHM)

SAFETY FIRST

Wolfram’s objective is zero harm to our people, the environment we work in, our customers and our suppliers
WOLFRAM – MINING & REFINING
RAW MATERIALS IN CEMENTED CARBIDE
European Hard Materials Group - EuroHM

<table>
<thead>
<tr>
<th>Property / Metal</th>
<th>Tungsten</th>
<th>Cobalt</th>
<th>Tantalum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedicated mines</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Mining in Europe</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Conflict mineral</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Recycling rate</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>European powder supply</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Predominant importance of powder for final properties</td>
<td>Yes</td>
<td>No</td>
<td>Limited</td>
</tr>
<tr>
<td>Main usage</td>
<td>Cemented carbide</td>
<td>Other (Battery)</td>
<td>Other (Capacitor)</td>
</tr>
</tbody>
</table>

- Focus on **tungsten** as the most important source for cemented carbides
  - Worldwide supply of **primary** raw materials = tungsten concentrates
  - **Dominance** of the Chinese tungsten supply = intermediates
- **Supply situation in Europe**
  - **Responsibility** for supply security and compliance issues
  - Importance of scrap as a **secondary** source
TUNGSTEN SUPPLY SITUATION - PRIMARY
85 kton per year worldwide – estimation for 2016 in kton p.y.
TUNGSTEN RESERVES AND SUPPLY IN CHINA
Share of reserves [%] and concentrate production in kton per year

TEN BIGGEST TUNGSTEN MINES IN CHINA
Total output 2013 = 32 kton WO3 = 26 kton W (equal to 30% of world supply)

<table>
<thead>
<tr>
<th>Tungsten mine</th>
<th>location</th>
<th>Mining company</th>
<th>Annual output (tW)</th>
<th>Proven reserves (tW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banggashan</td>
<td>Koshui</td>
<td>Jiangxi Baoji Tungsten Industry Co</td>
<td>5,750</td>
<td>215,000</td>
</tr>
<tr>
<td>Shiheqian</td>
<td>Chenzhou</td>
<td>Henan Shiyu Tungsten Industry Co</td>
<td>5,468</td>
<td>755,000</td>
</tr>
<tr>
<td>Yangyuanqian</td>
<td>Kishuang</td>
<td>Henan Yangyuan Tungsten Industry Co</td>
<td>4,560</td>
<td>200,000</td>
</tr>
<tr>
<td>Daqian</td>
<td>Quannan</td>
<td>Jiangxi Daqian Tungsten Industry Co</td>
<td>2,800</td>
<td>173,000</td>
</tr>
<tr>
<td>Tossilkeng</td>
<td>Changyi</td>
<td>Guangxi Zangfeng Tungsten Industry Co</td>
<td>2,500</td>
<td>74,000</td>
</tr>
<tr>
<td>Haoqiu</td>
<td>Changyi</td>
<td>Jiangxi Paochang Tungsten Industry Co</td>
<td>2,500</td>
<td>44,000</td>
</tr>
<tr>
<td>Sheshinling</td>
<td>Kudu</td>
<td>Jiangxi Sheshinling Tungsten Industry Co</td>
<td>1,900</td>
<td>------</td>
</tr>
<tr>
<td>Haiqiang</td>
<td>Dayu</td>
<td>Jiangxi Piedang Tungsten Industry Co</td>
<td>1,500</td>
<td>42,575</td>
</tr>
<tr>
<td>Haiqiang</td>
<td>Dayu</td>
<td>Jiangxi Keliang Tungsten Industry Co</td>
<td>1,450</td>
<td>------</td>
</tr>
<tr>
<td>Xhaoshin</td>
<td>Dayu</td>
<td>Jiangxi Xhaoshan Tungsten Industry Co</td>
<td>1,350</td>
<td>88,300</td>
</tr>
</tbody>
</table>
TUNSTEN MINE COST CURVE
High uncertainty – but Chinese mines can be found from low to high end

Drivers of Chinese concentrate supply
State controlled & official mining licences
High prices
Scheelite mine confronted with decreasing ore grades
Pollution issues

10 May 2017 by Metal-Pages

China tungsten concentrate production rises

BEIJING (Metal-Pages) 10-May-17. China’s tungsten concentrate production reached 26,403t tungsten trioxide (WO3) in January-March, up by 12% year on year, national statistics agency NBS data show.

Production growth was driven by higher prices. Average monthly prices for tungsten concentrate rose to Yn75,500/t in March from Yn65,300/t a year earlier.

Production in Jiangxi and Hunan provinces, China’s two largest tungsten concentrate producing regions, reached 9,687t and 7,383t in January-March, respectively, up by 18% and 24% from a year earlier. But production fell by 20% in Henan province to 4,481t in January-March as many scheelite mines in the province halted output because of declining ore grades.

A number of small mines in Jiangxi province are now in maintenance for production restarts in June, encouraged by rising prices. Tungsten concentrate output may continue to rise over the next few months this year, with production restarts at more mines. But production in Hunan province will be curbed by measures to combat pollution, which are likely to remain in place until June.
TUNGSTEN EXPORT FROM CHINA TO EUROPE
Figures 2011 to 2016 in kton tungsten content

TUNGSTEN GUIDE PRICES IN CHINA
Tungsten associations negotiate and publish price policies

05 May 2017 by Metal-Pages
China’s GTA lifts May guide price

BEIJING (Metal-Pages) 05-May-17. China’s Ganzhou Tungsten Association (GTA) has raised its tungsten guide price for May delivery because of tight supply.

GTA raised the price for tungsten concentrate by 5,500 yuan/t to Yn83,500/t ($12,100/t) compared with April. The guide price for intermediate product ammonium paratungstate (APT) has risen by Yn6,000/t to Yn126,000/t. The association also increased the tungsten carbide guide price by Yn0/kg to Yn205/kg.

Anti-pollution measures in Hunan province that have cut production at mines continue to tighten supply of tungsten concentrate and APT — the key raw material for tungsten carbide. Most mines are not expected to restart production until the end of this month.

Spot prices for tungsten concentrate and APT were assessed at Yn81,000-83,000/t and Yn126,000-128,000/t on 4 May, respectively.

-By our staff in Beijing
FORCASTING OF MARKET PRICES IN 2013

Conclusion – the market and price are NOT predictable

US$/mtu
mtu = 10kg

TUNGSTEN APT LMB NOTATION

Chinese export of intermediates = 55-60% of worldwide demand outside China
TUNGSTEN CONSUMPTION IN EUROPE

kton tungsten content (% yoy change)

Source: HCST Market Research

TUNGSTEN CONSUMPTION IN EUROPE

TOTAL 19–20 000 TON PER YEAR

Cemented carbide 66%
Steel & Superalloy 11%
Heavy Metal & Mill Products 8%
Chemical use 5%
Surface applications 10%

TOP CONSUMING COUNTRIES 2015

Austria
Belgium
The Netherlands
France
Sweden
Germany
Switzerland
Italy
UK
BUSINESS WITHOUT CORRUPTION

Wolfram has zero tolerance in respect to corruption. Our commitment to ethical business practices is well-established and absolute.

TUNGSTEN CONCENTRATE SUPPLY

WORLDWIDE SUPPLIES

• Deposits occur world-wide, some remarkable cluster (Iberian Peninsula, China, Bolivia).
• Industrial mining: There is no lack of deposits that could be developed → constraints as for European deposits (financing, size versus market)

GENERAL CONSTRAINTS

• Tungsten is one of the four “conflict minerals” (→ Dodd-Frank Act, EU rule, OECD…) → need to follow strict rules.
• Supplies from “high risk areas”: Central Africa, Myanmar, Columbia…
• Informal mining (artisanal mining): question of compliance, child labour and so on...
• Deleterious elements: Mo, U/Th, As… (Impact on production & legal issues)
TUNGSTEN CONCENTRATE SUPPLY

EUROPEAN SUPPLIES: OPPORTUNITIES

- Europe has good endowment with deposits; could well be self-sufficient
- Four large-scale mines, several advanced projects (relatively speaking, Europe has far more primary mine production for tungsten than for any other metal).

CONSTRAINTS

- Individual projects are big compared to overall market: Delicate balance between shortage and over-supply.
- At current prices, projects are marginally economic at best.
- Financing of new projects difficult - tungsten cannot be hedged. Secure off-take required.
- Off-takers are hesitating to commit – not clear which projects really advance.

EFFICIENCY → REUSE → RECYCLING

- Tool concepts → regrind & recoat
- → chemical recycling and zinc reclaim
SHARE OF USED TOOLS IN TOTAL SCRAP

- Raw material prod.
- Carbide prod.
- Tool prod.
- USE

- Scrap collection

- Scrap market & buy back

-Share of "old" scrap = 80%

SHARE OF RECYCLED MATERIAL IN NEW TOOLS

- Raw Material produc.
- Carbide prod.
- Tools produc.
- USE

- Scrap collection

- Scrap market & buyback

-Share of secondary Raw materials = 45%

Steel
NON FUNCTIONAL RECYCLING

Raw material prod. → Carbide prod. → Tool prod. → USE → Scrap collection

Scrap market & buyback

Total use

Share related to total use
Collected but not used in tungsten applications
10-25%

TOTAL TUNGSTEN LOSSES FROM RECYCLE CHAIN

Raw material prod. → Carbide prod. → TOOL prod. → USE → Scrap collection

Scrap markets and buyback

Total use

Mining & ore dressing → Raw material prod.

losers <5%

Wear & losses 10 - 20%

Non functional recycling
## RECYCLING – COMPARISON OF VARIOUS METALS

<table>
<thead>
<tr>
<th>Refractory metal</th>
<th>Share of used tools in scrap [%]</th>
<th>Recycling content in new products [%]</th>
<th>Non functional recycling rate [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVb Titan</td>
<td>11</td>
<td>52</td>
<td>91</td>
</tr>
<tr>
<td>IVb Zirkonium</td>
<td>-</td>
<td>1-10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>IVb Hafnium</td>
<td>-</td>
<td>-</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Vb Vanadium</td>
<td>-</td>
<td>-</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Vb Niob</td>
<td>50</td>
<td>22</td>
<td>53</td>
</tr>
<tr>
<td>Vb Tantal</td>
<td>10 - 43</td>
<td>21</td>
<td>35</td>
</tr>
<tr>
<td>Vlb Chrom</td>
<td>65</td>
<td>19</td>
<td>90</td>
</tr>
<tr>
<td>Vlb Molybdän</td>
<td>33 - 67</td>
<td>33</td>
<td>30</td>
</tr>
<tr>
<td>Vlb Wolfram</td>
<td>80</td>
<td>46</td>
<td>10 - 25</td>
</tr>
</tbody>
</table>

**United Nations Environmental Program – Report 2011**

## CUTTING TOOLS

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</thead>
<tbody>
<tr>
<td>Cutting tools</td>
<td>45%</td>
<td>26 769</td>
<td>55%</td>
<td>14 723</td>
<td>80%</td>
<td>21 415</td>
</tr>
</tbody>
</table>
### MINING, CONSTRUCTION & ENERGY

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mining construction energy</strong></td>
<td>30%</td>
<td>17,846</td>
<td>40%</td>
<td>7,138</td>
<td>60%</td>
</tr>
</tbody>
</table>

### WEAR PARTS, CHIPLESS FORMING

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wear parts chipless forming</strong></td>
<td>25%</td>
<td>14,872</td>
<td>40%</td>
<td>5,949</td>
<td>70%</td>
</tr>
</tbody>
</table>
RECYCLING RATES IN CEMENTED CARBIDE INDUSTRY

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Hartmetall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<tr>
<td>Mining construction energy</td>
<td>30%</td>
<td>17 846</td>
<td>40%</td>
<td>7 138</td>
<td>60%</td>
<td>10 707</td>
</tr>
<tr>
<td>Wear parts chipless forming</td>
<td>25%</td>
<td>14 872</td>
<td>40%</td>
<td>5 949</td>
<td>70%</td>
<td>10 410</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>59 486</td>
<td>46.8%</td>
<td>27 610</td>
<td>71.5%</td>
<td>42 532</td>
</tr>
</tbody>
</table>

ITIA 2014 – Zeiler & Schubert

KEY DRIVERS FOR RECYCLING

Scrap is not produced – it is generated and to be minimized!
Price is the main driver for scrap flows! FeW – PM Ind.

Only limited importance do have:
- „buy-back“ programs of cemented carbide – and tool producers
- recycling of APT producers
- Offers (price, quantity, flexibility) of specialized recycling companies
- Collection and sorting of international scrap dealers
- Legislation (EU, internat.) related to waste
- Conservation of primary raw materials
- Independence of Chinese raw material supply (intermediates)
- Responsibility for society and environment
Tungsten continues to be an economical & industrial critical metal and by the way the most important raw material in cemented carbide production.

Worldwide supply and tungsten pricing is still dominated by Chinese economic & environmental policies and economic strength.

Supply situation in Europe is governed by Asian imports of intermediates (APT – WC) and by scrap recycling; however the primary concentrate production is moderately increasing and contributing to supply security.

Tungsten carbide may be a commodity in certain areas, but in advanced markets tungsten carbide plays a dominant role for final product properties and enables high yield and efficient cost management throughout cemented carbide processing.
WOLFRAM – MINING & REFINING
THANK YOU FOR YOUR ATTENTION
European Hard Materials Group (EuroHM)