W

REFRAM MSP

Final conference

9-10 March 2017

Brussels

Future value chains and innovation pathways in production of tungsten

Yongxiang Yang (TU Delft)
Pedro Acebes (CARTIF), Jason Yang (GTK)

10/3/2017

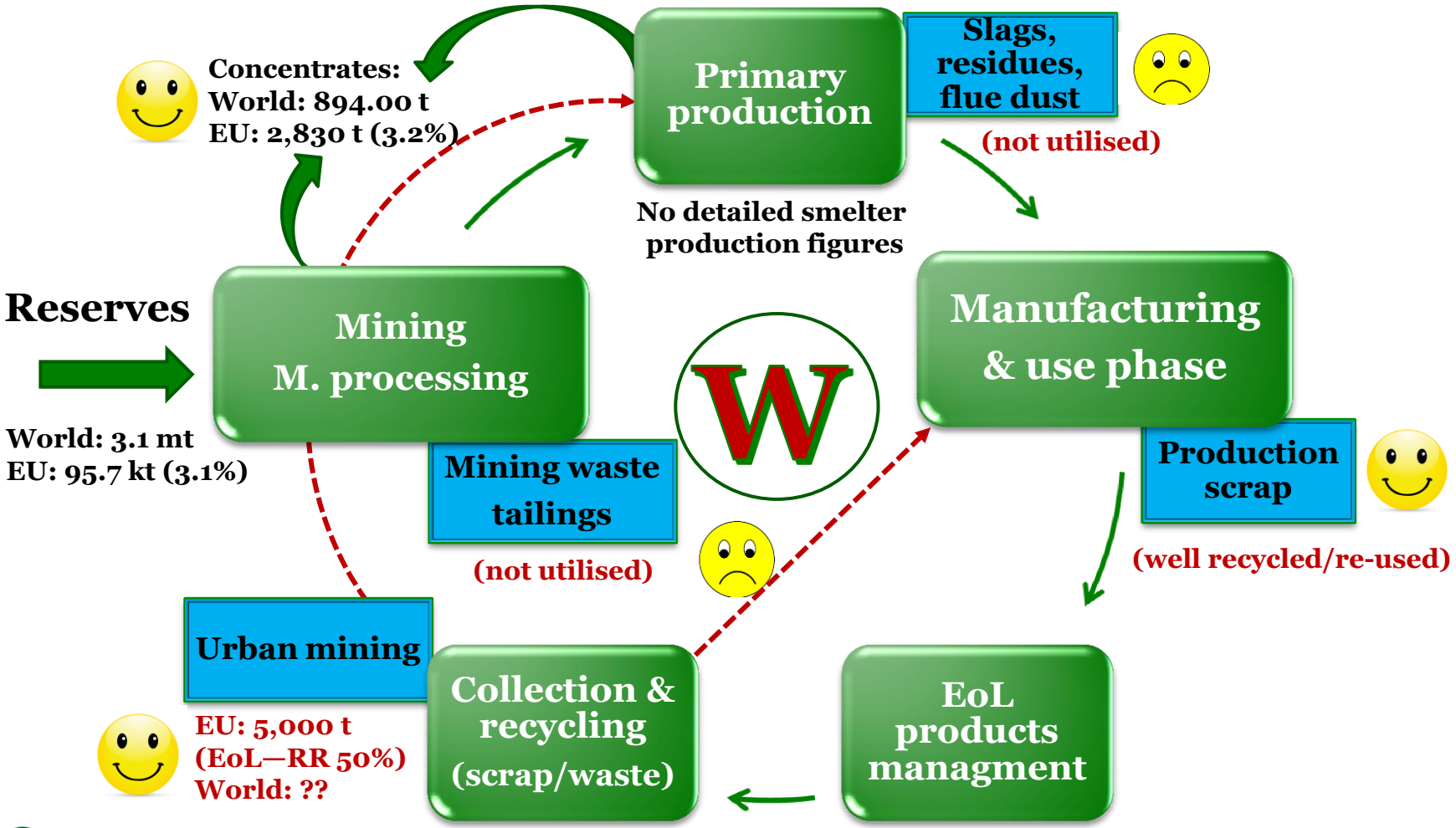
Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Overview

- Current and future W value chains
- Innovation pathways for W. production
- Conclusions and recommendations

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Tungsten value chains



Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Production of Tungsten in Europe

- The reported W mine production in Europe for year 2015: **2830 t (3.2% world)**
  - **Spain**: 730 tonnes (25.8%)
  - **UK**: 600 tonnes (21.2%)
  - **Portugal**: 630 tonnes (22.3%)
  - **Austria**: 870 tonnes (30.7%)

- Global mine production (USGS)
  - 89,400 t (Europe: **2,320t, 2.6%**)

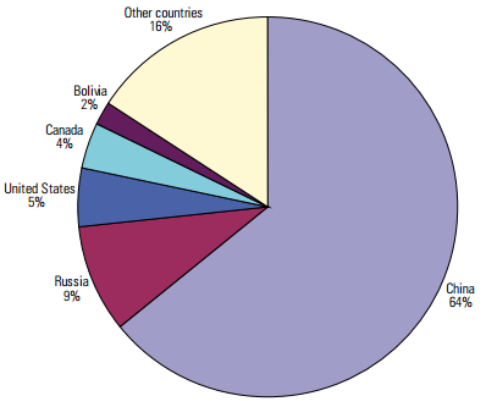
Main European Deposits. Source: SIEMCALSA.

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Current value chain of Tungsten

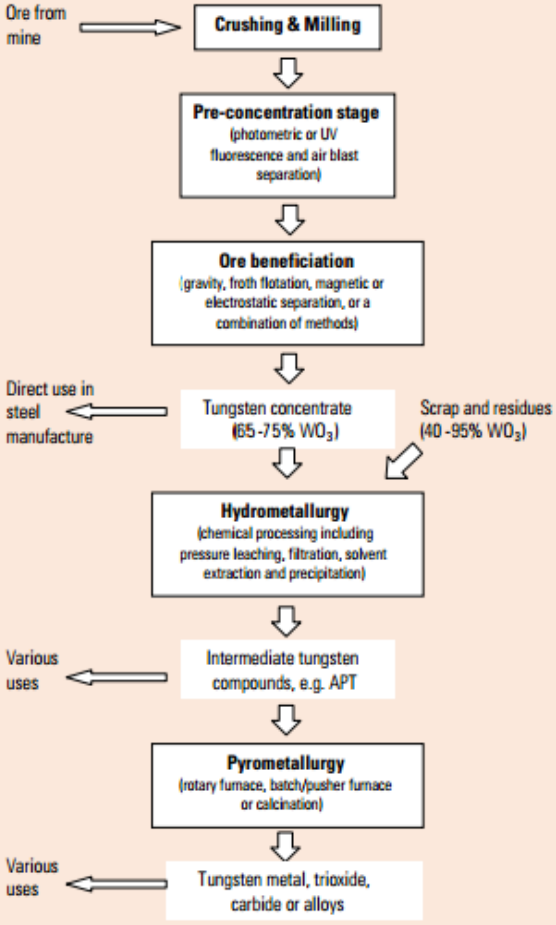
Primary Tungsten Producers – from mines to W concentrates.

Global Distribution of tungsten reserves

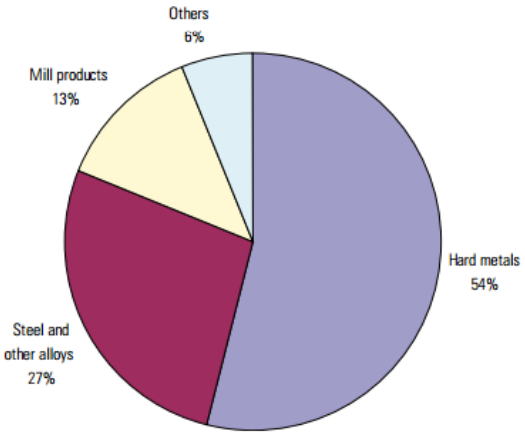


Europe: 3.1%

Primary W production



End – Use Products



The main application are Hard Metals.

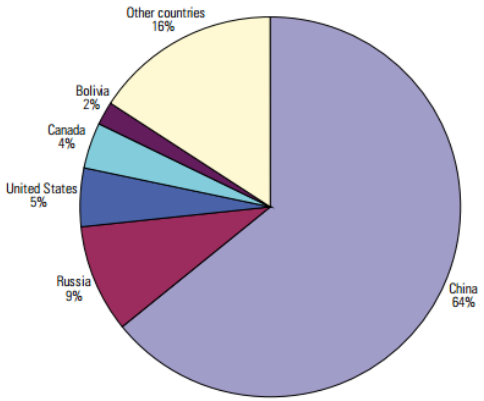
Cemented Carbides: Tungsten Carbide and Cobalt; Machining; etc.
Tungsten in steel: Tool Steel; High Speed Steel; etc.
Special Aplications: Stellites; Superalloys; Diamond Tools; etc.
Lamp Industry.
Electronic & Electrical Industries: X-ray Tubes; etc.
Chemical Applications: Catalysts; Chemical Products; etc.
Other Applications: Jewellery; Biology; etc.
Future Applications: Deep Drilling; Medical Industry; etc.

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

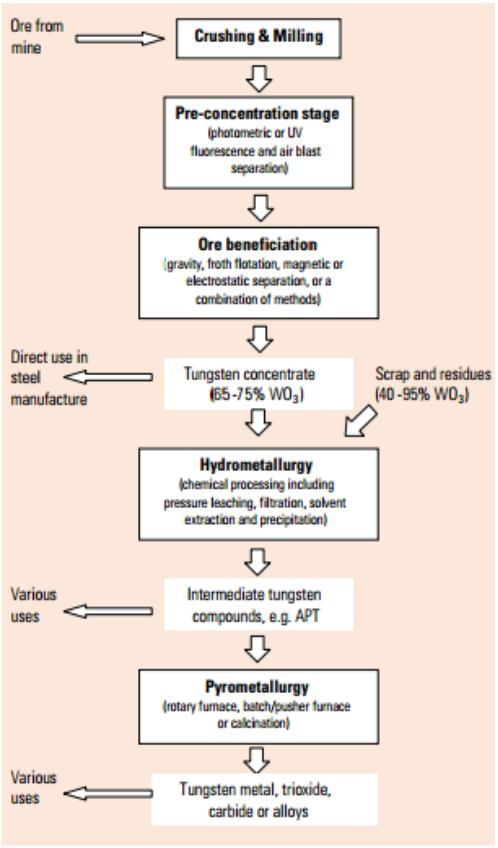
Future value chain of Tungsten

Primary Tungsten Producers – Raw material procurement becomes more difficult, due to lack of investments in new mines .

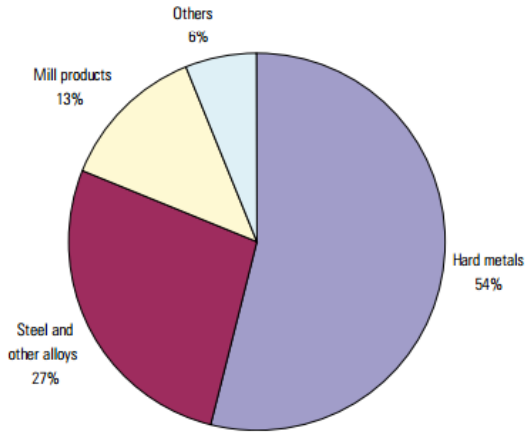
Global Distribution of tungsten reserves



Primary W produciton



End – Use Products



Future actions:

* Update Prospecting Guides.
* Recover Tailings.
* Recycling Tungsten scraps.

The main application are Hard Metals.

Cemented Carbides: Tungsten Carbide and Cobalt; Machining; etc.
Tungsten in steel: Tool Steel; High Speed Steel; etc.
Special Aplications: Stellites; Superalloys; Diamond Tools; etc.
Lamp Industry.
Electronic & Electrical Industries: X-ray Tubes; etc.
Chemical Applications: Catalysts; Chemical Products; etc.
Other Applications: Jewellery; Biology; etc.
Future Applications: Deep Drilling; Medical Industry; etc.

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Technologies need adaption and innovation

Innovation pathways

- **Extending mine production**
  - Possible but depending on market; Wolf Minerals (UK) and Tungsten Resources (Spain) have invested to increase the mine production
- **Increasing W production from mine tailings and metallurgical wastes**
  - Strong challenges faced on technology, economy and environment
- **Increasing W production from Urban mines**
  - Higher recycling rate is expected.
  - Challenges faced: a steady supply (collection), feasibilities (technology, economy), environmental impact

MSP REFRAM

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Innovation pathways

New methods to recycling Tungsten

- **Direct Methods:** tungsten scrap is transformed into powder of the same composition by either chemical or physical treatment, or a combination of both. A typical example is the zinc treatment method.
  - **Advantages:** limited energy consumption, and chemical waste, as well as low production cost.
  - **Disadvantages:** restrictions on the recycled materials.
- **Indirect Methods**: hydrometallurgical treatment are used in the ore refining process.
  - **Advantages:** no restrictions on materials.
  - **Disadvantages:** large quantities of chemicals and energy are needed.

REFRAM MSP

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Innovation pathways

Complete Recycling: three ways

1. **Mechanical Separation**: Whenever possible scraps are first mechanically reprocessed, that means recyclable material contained in secondary raw materials will be separated from unrequested components by milling and subsequent division using varying separation procedures.
2. **Termal Treatment**: When metals and scrap pieces of single origin are provided, they will be also melted first. Finally, through chemical processing the material can be adapted into products.
3. **Chemical Processing**: Oxidic material, but also tungsten capacitor scraps are dissolved after corresponding preparation in acids and caustic solution, chemically cleaned of all impurities and increased.

REFRAM

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Innovation pathways

- The estimated increases in primary mine supply are predicted to be outpaced by the use of secondary recycled tungsten raw materials in the years to 2018.
- Tungsten recycling is expected to keep growing at about **8%** per year over the next five years, increasing global production of recycled tungsten materials from **23%** of total supply in 2012 to **28%** of global supply in 2018.
- The main regions for growth in tungsten recycling are most likely to be Europe and Asia, as collection programs for tungsten products are improved and construction of new tungsten recycling facilities.

REFRAM

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Innovation pathways

Substitutes of Tungsten.

There are no substitutes for tungsten that do not involve a considerable cost increase and compromise in product performance.

- **molybdenum** can replace tungsten in certain mill products;
- **molybdenum** steels can substitute for tungsten steels for some applications;
- **depleted uranium** can be used in weights and counterweights instead of tungsten alloys or unalloyed tungsten;
- **depleted uranium** alloys can also be used in armour piercing projectiles instead of cemented tungsten carbides or tungsten alloys.
- etc.

REFRAM MSP

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Conclusions

- The majority of **Tungsten primary raw material reserves** are located in China (62%). China is the major producer of primary Tungsten (82%).
- **Current primary production** of tungsten in Europe depends mainly on the new mines and their execution.
- The **companies** that execute the projects have their own technologies adapted to the specific mine or project.
- Most of the companies that exploit the Tungsten mines in Europe **exports the mineral**.
- Raw material procurement becomes more difficult, due to **lack of investments in new mines** and reduced secondary raw material availability.

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Conclusions

- The existing **mine tailings** and **metallurgical waste** are huge, but not currently exploited due to low W concentration and high economic costs. These are the future complementary W potentials, and deserve more innovation and R&D!
- The **high melting point** of Tungsten makes its recovery very difficult due to economic reasons (high associated energy cost), but it is reasonably well recycled.
- **Lack** of more efficient and low cost recycling technologies.

REFRAM MSP

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Recommendations

From mining to EoL recycling (common for all refractory metals)

- *Increasing resource efficiency (losses)*
- *Reducing energy consumption and CO2 emission*
- *Approaching more circularity for whole value chain*
- Promoting more "**functional recycling**" by minimizing "**down-cycling**"
- Design for disassembling and material recycling
- Non-technical aspects: new business models and economical incentives →needed!

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)

Thank you for your attention

Yongxiang Yang
TU Delft (y.yang@tudelft.nl)

Funded by the Horizon 2020 Framework programme of the European Union (Grant Agreement Number 688993)