PAC PARTNERS

EQUITY RESEARCH

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Tungsten Industry

A critical renaissance

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KEY POINTS

- **Australia is poised to emerge as a new critical minerals supplier with two significant tungsten mines ramping up in 2023.** Together Group 6 Metals (G6M) and EQ Resources (EQR) should see Australia go from virtually zero, to supply 15-20% of the ex-China tungsten market in the years ahead.
- This provides the opportunity to invest in a strategically supported critical mineral that exhibits low volatility, double digit demand growth and constrained supply.
- Australia's re-emergence should then be followed by South Korea, as Almonty (All) ramps up the major Sandong Mine.

TUNGSTEN SECTOR CONTINUES TO FACE DEFICITS

- **Significant deficits:** We forecast tungsten market deficits for the coming 3 years driven by growing demand (including defence 20%+ growth), and restricted supply (China, 80% market share, has seen declining and depleting production while the western world struggles to finance new mines). **New mines… few and far between:** The current set of new mines remains only a fraction of the total supply and unlikely to dampen world tungsten prices.

INVESTMENT VIEW

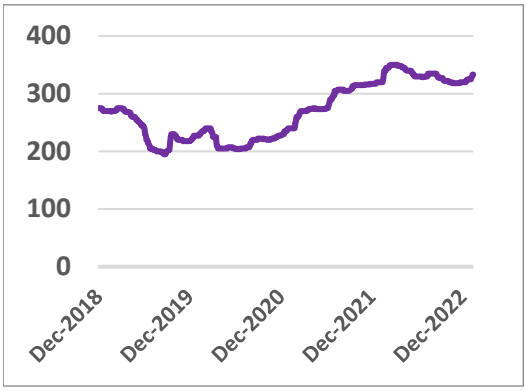
- Group 6 Metals (G6M) **(BUY, target price $0.32, market cap $130m)** – The Dolphin Mine is the highest grade mine outside China. We expect development to be complete by mid-year pathing the way for significant cashflows from FY24 (refer: Tonnes at the right time).
- EQ Resources (EQR) **(BUY, target price $0.12, market cap $95m)** - Already processing ore at Mt Carbine ahead of open pit operations. Recent world class drill results indicate this modestly sized enterprise can grow significantly (Refer: Small start, significant potential).
- **Almonty (All) (not rated, market cap $181m)** – we profile Almonty throughout this report as the most significant western world tungsten producer with operating mines in Europe, and the industry's largest mine development in South Korea. As the most successful western operator of size in recent history, Almonty is also a prominent and consistent proponent of the tungsten industry as a whole.

RISKS

Risks to our positive tungsten thesis include (and not limited to) –

- **Manufacturing downturn:** With automotive and transport accounting for near 30% of demand, plus mining and construction another ~25%, tungsten prices are vulnerable to a general economic slowdown.
- **China excess supply risk**, despite export restrictions, Chinese and European index prices correlate almost exactly. Chinese oversupply or a rebound in marginal European production, may have downward price pressures (but looks unlikely given Chinese mine depletions).
- **Do not forget… critical minerals risk.** Trade restrictions from the world's dominant supplier could cause a physical scarcity and a spike in prices, threatening manufacturing and defence sectors. We sense widespread initiatives to mitigate this risk through supporting the producers we name above.

Tungsten Price (APT Rotterdam 88.5% min) US$/MTU



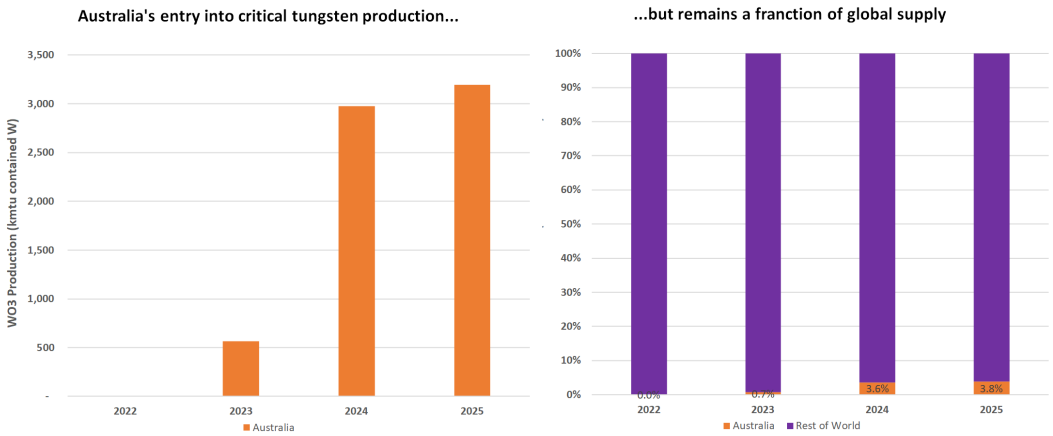
Source: Asian Metals

Group 6 Metals	G6M
Recommendation	Buy
12 Month Price Target	$0.32
Risk Rating	High
Current Share Price	$0.17
Previous Recommendation	Buy
Price target Methodology	DCF
Total Return (Capital + Yield)	88%
Market Capitalisation $m	$130m

EQ Resources	EQR
Recommendation	Buy
12 Month Price Target	$0.12
Risk Rating	High
Current Share Price	$0.065
Previous Recommendation	Buy
Price target Methodology	DCF
Total Return (Capital + Yield)	100%
Market Capitalisation $m	$95m

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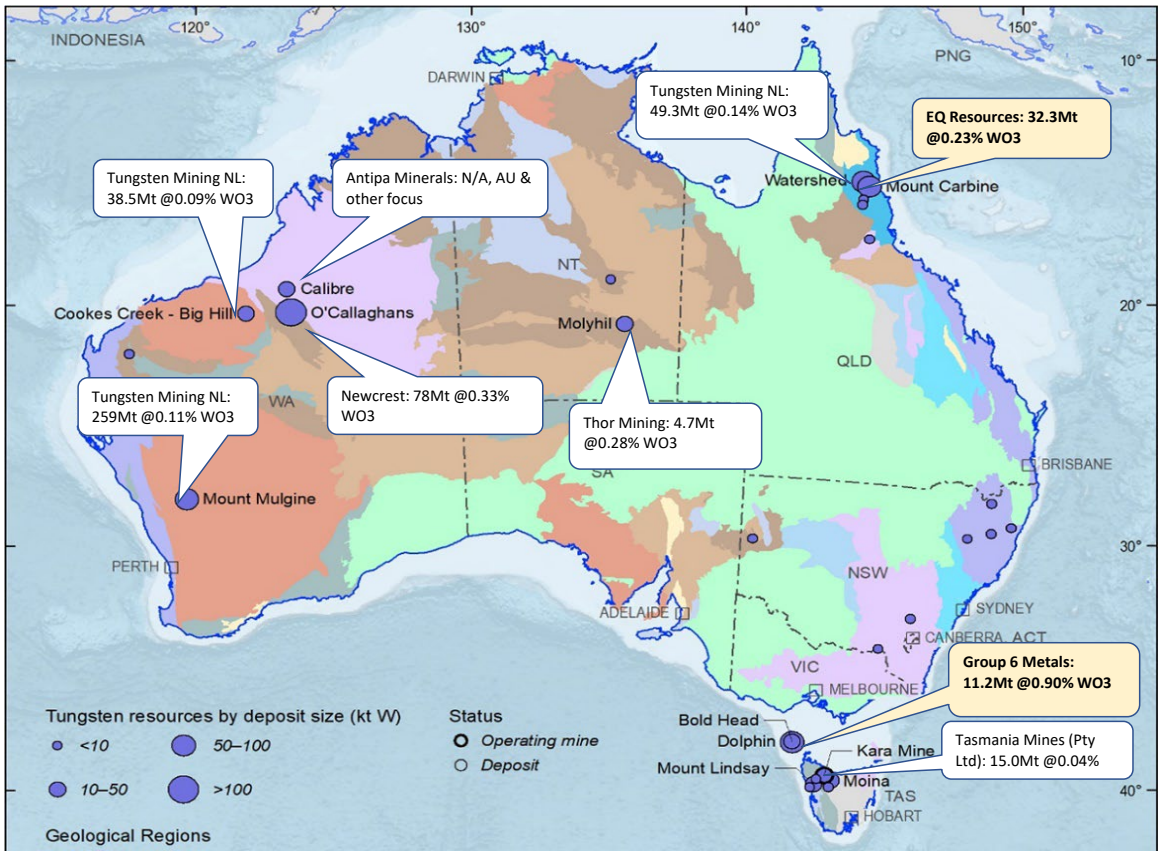
Figure 1: Australia re-enters the tungsten scene …



Australia's ramp up is unlikely to tip the balance in limited global supply.

Sources: Company announcements, PAC Partners analysis

Figure 2: Australian Tungsten Deposits



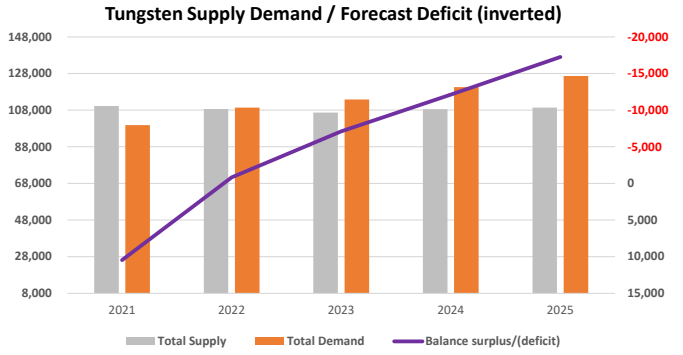
G6M's and EQR's resources, at either end of the country, are notable for grade and size.

Source: Geoscience Australia (Tungsten), 2018, Company announcements, PAC Partners analysis and annotations

Supply-Demand Summary	2021	2022	2023	2024	2025
		Forecast->			
Total Supply	**110,263**	**108,583**	**106,690**	**108,486**	**109,380**
...Growth %	6.9%	-1.5%	-1.7%	1.7%	0.8%
Total Demand	**99,800**	**109,400**	**113,776**	**120,603**	**126,633**
...Growth %	0.0%	9.6%	4.0%	6.0%	5.0%
Balance surplus/(deficit)	**10,463**	**-817**	**-7,086**	**-12,116**	**-17,253**
As % of supply		0.8%	6.6%	11.2%	15.8%
Avg price US$/mtu	294	338	340	345	363

Supply Tungsten W kt	2021	2022	2023	2024	2025
China	**71,000**	**69,000**	**66,930**	**64,922**	**62,974**
...Growth %	*7.6%*	*-10.0%*	*-3.0%*	*-3.0%*	*-3.0%*
...% of total	*85%*	*84%*	*83%*	*79%*	*76%*
Vietnam	**4,500**	**4,900**	**4,900**	**4,900**	**4,900**
...Growth %	*0.0%*	*8.9%*	*0.0%*	*0.0%*	*0.0%*
...% of total	*5.4%*	*5.9%*	*6.0%*	*5.9%*	*5.9%*
Russia	**2,400**	**2,520**	**2,646**	**2,911**	**3,202**
...Growth %	*0.0%*	*5.0%*	*5.0%*	*10.0%*	*10.0%*
...% of total	*2.9%*	*3.1%*	*3.3%*	*3.5%*	*3.9%*
Bolivia	**1,400**	**1,452**	**1,506**	**1,561**	**1,619**
...Growth %	*3.7%*	*3.7%*	*3.7%*	*3.7%*	*3.7%*
Rwanda	**950**	**998**	**1,047**	**1,100**	**1,155**
...Growth %	*10.5%*	*5.0%*	*5.0%*	*5.0%*	*5.0%*
Austria	**900**	**913**	**913**	**913**	**913**
...Growth %	*1.12%*	*1.41%*	*0.00%*	*0.00%*	*0.00%*
Spain	**900**	**937**	**714**	**714**	**714**
...Growth %	*80.0%*	*4.1%*	*-23.7%*	*0.0%*	*0.0%*
Portgual	**620**	**620**	**620**	**620**	**620**
...Growth %	*12.7%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Australia	-	-	**567**	**2,975**	**3,193**
...Growth %				*425%*	*7%*
...% of total	*0.0%*	*0.0%*	*0.5%*	*2.7%*	*2.9%*
North Korea	**40**	**40**	**40**	**40**	**40**
...Growth %	*-22.6%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
South Korea	-	-	-	-	**1,030**
...% of total	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*1.2%*
Canada	-	-	-	-	-
...Sission	-	-	-	-	-
...% of total	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
United Kingdom	-	-	-	**532**	**1,065**
...% of total	*0.0%*	*0.0%*	*0.0%*	*0.6%*	*1.3%*
Kazhakstan	0	0	0	0	378
...*Severniy Katpar*	*0*	*0*	*0*	*0*	*378*
...% of total	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.3%*
Other	**1,090**	**1,145**	**1,202**	**1,262**	**1,325**
...Growth %	*5.0%*	*5.0%*	*5.0%*	*5.0%*	*5.0%*
Total Mine Supply	**83,800**	**82,523**	**81,084**	**82,450**	**83,128**
...Growth %	***6.9%***	***-1.5%***	***-1.7%***	***1.7%***	***0.8%***
Rececyling Tungsten Rate	*24.0%*	*24.0%*	*24.0%*	*24.0%*	*24.0%*
Recycled Tungsten Supply	**26,463**	**26,060**	**25,606**	**26,037**	**26,251**
Total Supply	**110,263**	**108,583**	**106,690**	**108,486**	**109,380**
...Growth %	6.9%	-1.5%	-1.7%	1.7%	0.8%

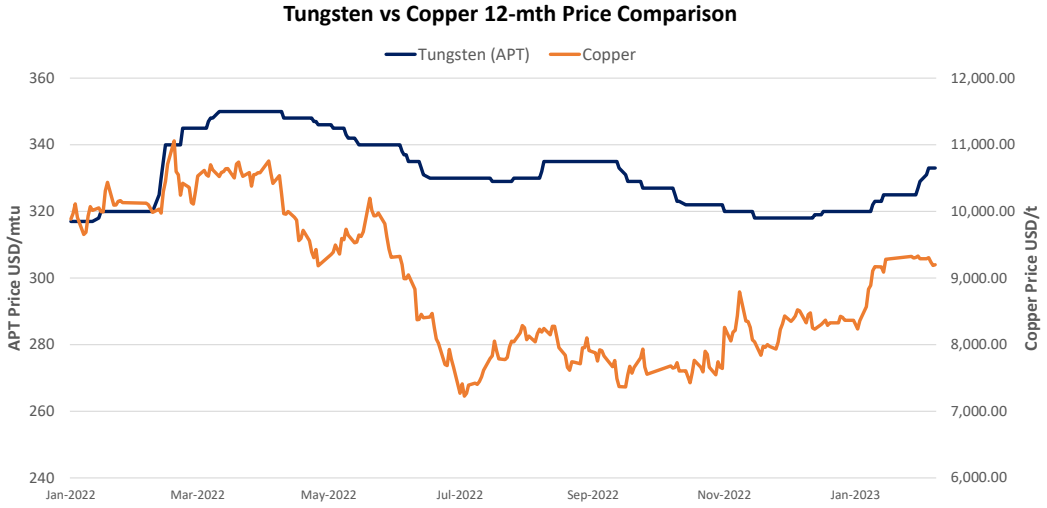
Sources: US Geological Survey (Jan 2023), Asia Metals, Almonty, ITIA, G6M, PAC Partners



Demand Tungsten W kt	2020	2021	2022	2023	2024	2025
Transport	**25,800**	**27,100**	**28,900**	**28,075**	**28,917**	**30,363**
...Growth %			*6.6%*	*-2.9%*	*3.0%*	*5.0%*
...% of total	28%	27%	26%	25%	24%	24%
Mining & Construction	**23,800**	**26,200**	**29,800**	**33,270**	**35,862**	**37,655**
...Growth %			*13.7%*	*11.6%*	*7.8%*	*5.0%*
...% of total	26%	26%	27%	29%	30%	30%
Industrial Use	**12,100**	**13,000**	**13,500**	**13,095**	**13,488**	**14,162**
...Growth %			*3.8%*	*-3.0%*	*3.0%*	*5.0%*
...% of total	13%	13%	12%	12%	11%	11%
Chemical / Petrochem	**9,600**	**10,200**	**10,700**	**10,379**	**10,690**	**11,225**
...Growth %			*4.9%*	*-3.0%*	*3.0%*	*5.0%*
...% of total	10%	10%	10%	9%	9%	9%
Consumer durables	**8,100**	**8,500**	**8,700**	**8,439**	**8,692**	**9,127**
...Growth %			*2.4%*	*-3.0%*	*3.0%*	*5.0%*
...% of total	9%	9%	8%	7%	7%	7%
Energy	**5,400**	**5,700**	**6,800**	**7,505**	**8,228**	**8,639**
...Growth %			*19.3%*	*10.4%*	*9.6%*	*5.0%*
...% of total	6%	6%	6%	7%	7%	7%
Defence	**7,200**	**7,700**	**9,500**	**11,400**	**13,110**	**13,766**
...Growth %			*23.4%*	*20.0%*	*15.0%*	*5.0%*
...% of total	8%	8%	9%	10%	11%	11%
Medical & Pharma	**1,200**	**1,400**	**1,500**	**1,455**	**1,499**	**1,574**
...Growth %		*16.7%*	*7.1%*	*-3.0%*	*3.0%*	*5.0%*
...% of total	1%	1%	1%	1%	1%	1%
Other	-	-	-	**158**	**117**	**123**
...Growth %					-26%	5%
...% of total	0%	0%	0%	0%	0%	0%
Total Demand	**93,200**	**99,800**	**109,400**	**113,776**	**120,603**	**126,633**
...Growth %			9.6%	4.0%	6.0%	5.0%
	2020	**2021**	**2022**	**2023**	**2024**	**2025**
Balance surplus/(deficit)	**9,958**	**10,463**	**-817**	**-7,086**	**-12,116**	**-17,253**
Avg price US$/mtu	270	294	338	340	345	363
Change in price		9%	15%	1%	1%	5%

Sources: US Geological Survey (Jan 2023), Asia Metals, Almonty, ITIA, G6M, PAC Partners

Figure 3: ***Tungsten prices (LHS) are proving to be less volatile than Dr copper (RHS)***



Source: PAC Partners Analysis, Asian Metals, IRESS

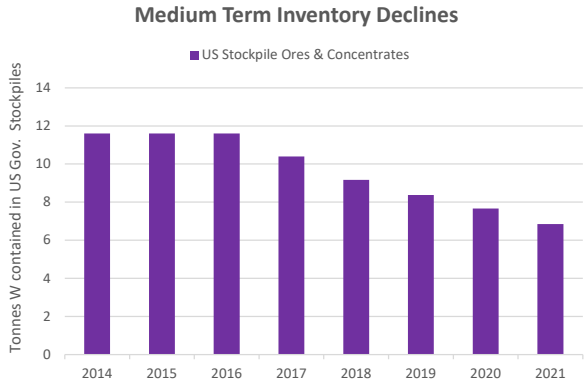
OVERVIEW

Tungsten industry globally is experiencing declining supply and growing demand.

Falling supply and increasing demand drive a positive tungsten outlook. China, the world's dominant tungsten producer, is seeing production fall on the back of restrictions, tougher environmental regulation and a permanent fall in mine grades. Outside China, new tungsten project developments are notoriously difficult to develop due to challenging geology and limited capital funding. On the demand side, defence demand is growing at double digit rates, followed strong growth in oil and gas, mining and construction sectors. We therefore forecast strong tungsten prices for the coming years. We forecast tungsten market deficits for at least 3 years.

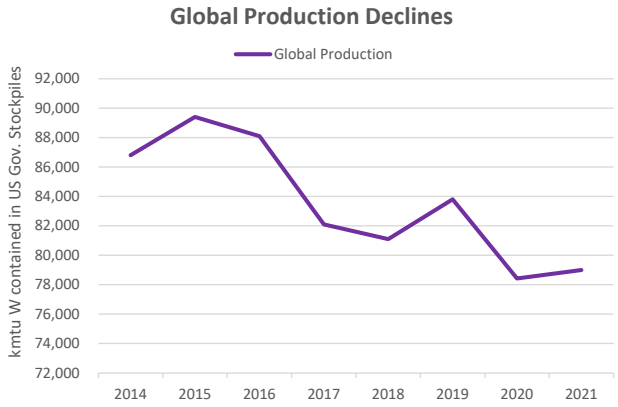
Status as a critical mineral. Tungsten is considered a critical metal due to its strategic and economic importance (defence accounts for ~9% of demand and growing rapidly, tungsten is widespread in manufacturing), coupled with supply risk (China >80% of global production). After China, the next rank of suppliers are also non-OECD countries (e.g. Russia, Vietnam). Tungsten features on critical minerals lists of Australia, US, EU and Japan and is the mineral with the greatest critical status - high economic importance and high supply risk – a world without tungsten may put manufacturing at risk.

Figure 4: US Strategic Stockpile of Tungsten has been in decline since the Cold War and trend continues in the medium-term… ***but political pressure for a reversal is mounting…***



Source: US Geological Survey, Mineral Commodities Summary, January 2022, PAC Partners Analysis

Figure 5: Production has trended lower in recent years.



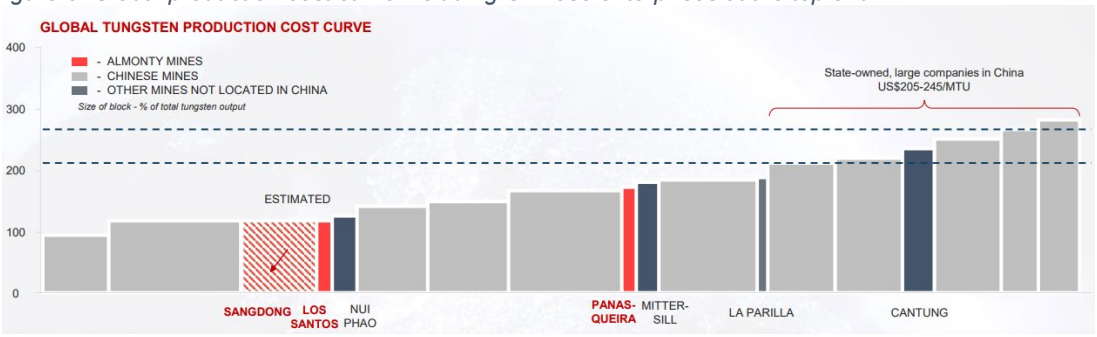
Source: US Geological Survey, Mineral Commodities Summary, PAC Partners Analysis

Strategic support for tungsten mine developments. Critical status is most practically evident in government grants to new tungsten mines, development bank funding and downside price protection in offtake agreements. For example, EQ Resources has received $6m from the Australian Govt Critical Minerals Accelerator Initiative, Almonty and Group 6 Metals both have downside price protection mechanisms.

Dwindling US strategic stockpile… an about turn in 2023 should be anticipated. The US strategic stockpile of tungsten is now at a mere ~10% of its peak post war levels and is expected to be completely exhausted by 2025. Given tungsten's economic importance, role in industrial manufacturing and lack of US domestic supply we expect an "about turn" is being considered, potentially in the next critical minerals update due later this year which could include a rebuild of the strategic stockpile (including raw tungsten concentrate produced by the miners).

Tungsten price has favourable skew with slim margins for miners and buyer tolerance of higher prices. Prices remain on the industry cost curve as supply struggles to keep up with demand. For end users, this hard waring metal remains an essential part of production but only a small portion of unit costs.

Figure 6: Global production cost curve including Chinese enterprises at the top end -



Source: Almonty November 2022 presentation / Argus media

How to play the theme of emerging tungsten

Our preferred equity exposures are Group 6 Metals, and EQ Resources.

Group 6 Metals (BUY, target price $0.32, market cap $130m) – Dolphin is the highest grade tungsten mine outside China and therefore a critically important scarce asset for the ex-China industry. It is in the final stages of development and set to ramp up production so that and at full rates (in 3 years) can potentially supply 12% of the ex-China market. Refer to our note: Tonnes at the right time (Dec-22).

EQ Resources (BUY, target price $0.12, $95m)– Mt Carbine is already in production, generating cash from processing a lower grade stockpile ahead of starting open cut operations in the months ahead. Recent world class drill results indicate this modestly sized enterprise can grow significantly. Refer to our note: Small start, significant potential (Dec-22).

Almonty Industries (not covered, market cap $181m) - is the most significant western world tungsten producer and seen by many as an industry leader. The company has successful tungsten operations in Europe (Panasqueira, Los Santos and Valtreixal), but its flagship asset is the industry's largest mine development underway in South Korea - The Sangdong Project.

Figure 7: Almonty has an extensive portfolio of tungsten assets operating, in development and in feasibility



Source: Almonty Dec-2022 presentation

Almonty is a western world leader in the industry.

Almonty's Sandong Project has the ultimate potential to produce 50% of ex-China tungsten supply. The project is due to begin commissioning late in 2023 and reach initial nameplate production in 2024 or 2025. By end 2022, ~25% of construction has been complete. The industry eagerly awaits updates on Sandong given the significance of the project. Sandong has 8Mt in reserves at 0.5% WO3 and offtake agreements (with Plansee) that include a price floor at US$235/mtu covering ~50% of forecast production (spot price is ~US$330/mtu). This helps underpin the longer-term viability of the project. Sandong capex spend is approximately US$105m comprising US$65.6m of development and US$40m in other pre-production expenses including working capital. An interesting adjunct to the Sandong Tungsten project, is the Almonty Korea Molybdenite Project with the same footprint (and below) the Sandong Mine which has a JORC Resource 21Mt at 0.26%.

Figure 8: Tungsten Peer Group

Company			$	Share Price (local)	Mkt Cap A$m or local	Mkt Cap US$m	Net Debt ($m)	EV (A$m or local)	Resource (MT)	Grade WO_3%	Resource WO_3 Contained (kt)	EV/WO_3 Resource (Mt) (US$)	Project Details
Group 6 Metals	G6M	ASX	AUD	0.17	130	83.2	6.9	137.0	11.2	**0.90%**	101	868.2	King Island Sheetlite/Dolphin Mine in Australia. Production starts in Q1 2023. High grade mine.
EQ Resources	EQR	ASX	AUD	0.065	95.2	60.9	5.0	100.2	32.3	**0.23%**	76	847.8	Mount Carbine Australia, redevelop historical mine, tailings processing then o/c, explore u/g opition. Mining to start Q2 2023. Includes LGS 10Mt @ 0.075% in production.
Almonty Industries	AII	ASX, TSE	CAD	0.70	181	132.1	60.1	241.1	80.4	**0.36%**	289	608.3	Tungsten Asset Portfolio: flagship project: Sandong (Korea), others: Los Santos (Spain, stopped production), Panasqiera (small-scale production), Valtreixal (exploring). Sandong constructionis 25% complete. Production forecasted in 2025
Tungsten Mining NL	TGN	ASX	AUD	0.10	78.6	50.3	-15.3	63.4	354.0	**0.12%**	425	95.4	5 Australian tungsten projects, discovery and development. Watershed acquired from Vital Metals in May 2018 for A$15m.
Tungsten West Plc	LSE:TUN	LSE	GBP	0.25	44.2	47.3	-27.3	16.9	328.0	**0.12%**	394	46.0	Hemerdon Tungsten-Tin Deposit located in South Devon, UK. $30M royalty investment with global (2.375% rate). Planning restart.
Northcliff Resources	TSX:NCF	TSX	CAD	0.06	7.5	5.5	-1.7	5.8	334.4	**0.07%**	221	19.3	Owns 88.5% of Sisson Tungsten-Molybdenum Project in New Brunswick Canada. All permitting in place. Updated BFS underway. Needs funding.
Rafaella Resources	RFR	ASX	AUD	0.05	20.5	13.1	-1.0	19.5	10.3	**0.18%**	19	673.8	Developer and explorer, 2 tungsten deposits in Spain: PFS Dec 2022 for Santa Comba (NPV US$43.5m). 2 Projects in Canada. San Finx acquired Jan 22, produced in 2017.
W Resources	LSE:WRES	LSE	GBP	0.03	3.9	N/A	57.9	61.8	53.5	**0.11%**	61	N/A	La Parilla Project, Western Spain. Delisted in April 2022 due to high LNG prices, poor production, poor recoveries. Production closed.
Fireweed	FWZ	TSX	CAD	0.91	83.0	63.8	-6.0	89.0	44.8	**0.80%**	359	187.7	Owns zinc and tungsten projects including Mactung high grade Tungsten project, Indicated 33Mt @ 0.88% and inferred 118mt at 0.78% W03.
Saloro SLU	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0	**0.26**	7	N/A	Barrauecopardo Spain 260kmtupa, since 2019. Oaktree owned.

Source: PAC Partners Analysis, Company Announcements

Risks

While the industry is receiving strategic critical minerals support, tungsten prices will be vulnerable to a general economic slowdown given its widespread use in manufacturing.

GDP downturn: With automotive and transport accounting for near 30% of demand, plus mining and construction another ~25%, tungsten prices will be vulnerable to a general economic slowdown.

Oversupply – China imbalance. Despite export restrictions on tungsten concentrate, Chinese and European tungsten prices correlate tightly. A China recession would see domestic demand drop and domestic oversupply spill into the global market putting downward pressure on prices.

Oversupply - Too many new ex-China mines. Almonty is developing the Sangdong mine in South Korea with guidance that it is due for commissioning in 2H 2023, and production in 2024. We await updated guidance given the significance of The Sandong mine.

To control for such risks, new mines (such as Group 6 Metals Dolphin, and Almonty's Sandong) have downside offtake pricing protection to ensure through cycle operating viability. Back in the 1950s and 1960s the US guaranteed demand for strategic supplies of tungsten by entering into fixed price contracts with miners including those in Australia.

Pricing History: Wars, recessions and stockpiles

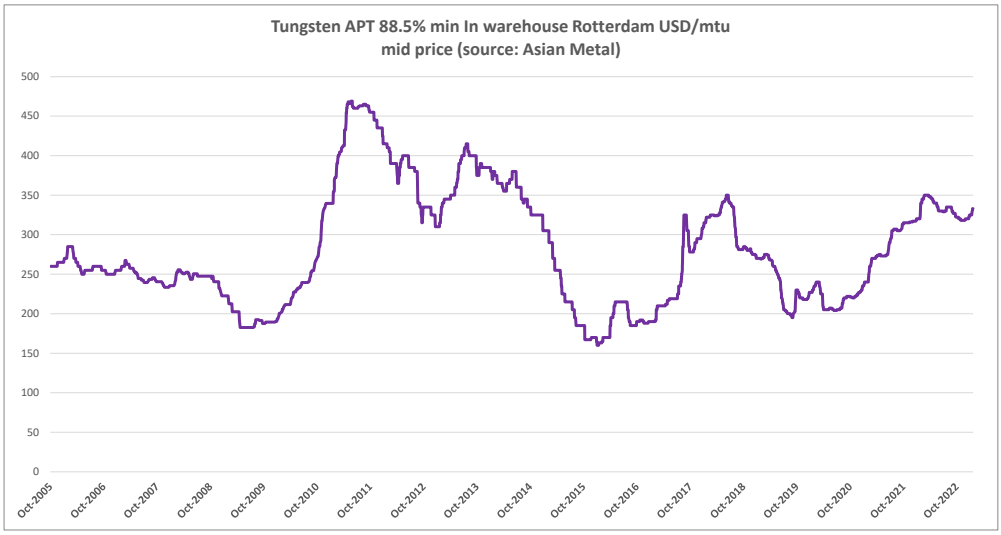
Tungsten prices have been correlated with armament activity, particularly up until the 1980s when manufacturing began to be a key driver. We summarise price developments over the decades:

Prices have trended higher since the start of 2019, largely without interruption.

- 1920s-1960's: The First and Second World **Wars drove the demand for tungsten** in the first half of the 20th century, and the Korean and Vietnam **wars kept demand strong** throughout the 1950s.
- 1950s – 1960's: prices were also supported by the **US government's strategic reserve** buying at **fixed prices**.
- In the late 1980's:, **recession** saw prices decline given tungsten's use in in machining tools.
- In the early 2000's: demand grew steadily and prices recovered from the depths of the 1980's recession.
- 2010: Tungsten prices recovered strongly after the 2009 global financial crisis.
- By mid-2011: prices reached **a high of US$469**/mtu, and again hit this level in mid-2013.
- In 2015: the collapse of the Chinese Fanya Metals Exchange lead to a collapse in prices from US$349/mtu in 2014 to US$217/mtu in 2015.
- 2016: A post Fanya collapse **low of US$182/mtu** was reached in 2016 before a strong recovery.
- 2018-2019: prices dropped during the great financial crisis, but have risen steadily since.
- In April 2022 the APT price reached a recent high of US$360/mtu.

Price falls have been due to market dislocations such as the end of US stockpiling, the collapse of the Fanya Commodity Exchange and of course manufacturing downturns.

Figure 9: Tungsten prices since 2005



Source: Asian Metals, PAC Analysis

End user tolerance of elevated tungsten prices is relatively high as this hard waring metal remains an essential part of production but on average only a small portion of unit costs.

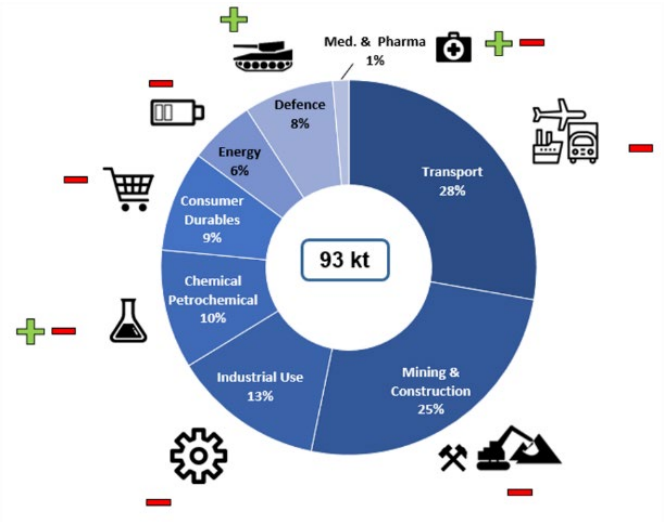
Demand: Growing in defence, mining, and energy

Historically and up until the 1980s, demand for tungsten was closely correlated with wars (armament activity). However since then it has been more correlated with global GDP growth given tungsten's widespread use in manufacturing.

The automotive industry is the largest consumer of tungsten by way of cemented carbides used tools for the manufacturing of car parts. This is followed by the mining and construction industries.

Demand is growing in defence, mining, construction and energy sectors.

Figure 10: Tungsten Demand by Sector:

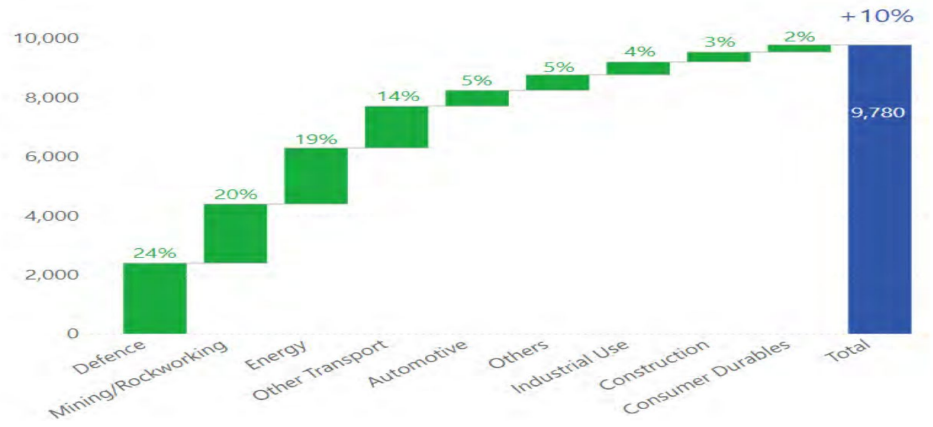


Source: Group 6 Metals / International Tungsten Industry Association (ITIA)

Common Uses of Tungsten:

- Industrial cutting tools (as a wear-resistant alloy),
- Construction and mining equipment,
- Steel hardening,
- Aeronautical (in nickel superalloys for high temperature sections of jet engines / aircraft weights and counterweights) and automobile manufacturing,
- Defence armaments including armour penetrating projectiles and small arms ammunition,
- Defence vehicles including tank and armoured vehicle hardening / reinforcing,
- Semiconductor manufacturing,
- Electronics and lighting, and
- Railways.

Figure 11: 2022 demand growth by sector: Defence, mining and energy are key



Source: Group 6 Metals / International Tungsten Industry Association (ITIA)

Tungsten carbide (WC, equal parts tungsten and carbon) are the most common tungsten product globally in the form of wear-resistant drilling tools and make ~53% of demand.

Common tungsten end products:

- Steel and alloys (24% of total),
- Mill products such as tungsten wire for lamp filaments (14%) and
- Chemicals including as catalysts, in tungsten hexafluoride and other uses (9%).

Figure 12: Common tungsten products



Source: https://wresources.com/projects/tungsten-overview/

New demand growth is occurring in areas such as

- Chemical plating with Nickel-Tungsten,
- Tungsten-hexafluoride gas for the manufacture of semi-conductors,
- In deep drilling and
- Potentially as an anode material in lithium-ion batteries.

In the UK, Nyobolt is using tungsten materials in the battery anode coating. **These tungsten-based Lithium-ion batteries are said to have super-fast charging speeds (90% charged <5 minutes), and 10x higher power density.** They also have less thermal stress relative to graphite-based batteries, reducing risks of battery fire.

Figure 13: nyobolt is promoting a fast charging tungsten battery



Source: https://nyobolt.com/media/

US Stockpile: Now a fraction of former level

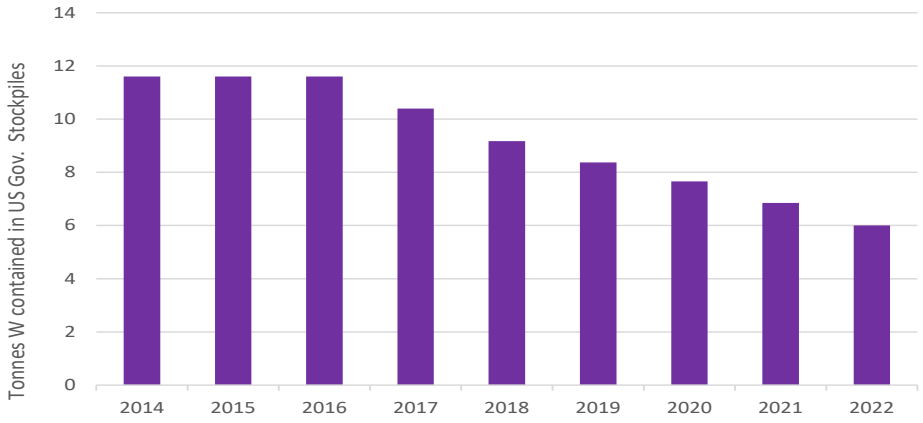
The US strategic stockpile of tungsten has steadily declined.

The US built a strategic stockpile of tungsten by guaranteeing purchases via fixed price contracts with various friendly suppliers (including with Group 6 Metals Dolphin Mine and many others). Tungsten was not the only mineral stockpiled by the US and at the peak of its hoarding in 1952, the value of the stockpile of all minerals was ~US$42bn (defensenews.com). The stockpile of tungsten is expected to deplete by 2025.

The US may re-emerge as a strategic buyer of tungsten concentrates adding a further underpin to current prices and demand.

However since The US Department of Interior labelled tungsten as a critical mineral in May 2018, US lawmakers have pushed to reverse the stockpile sell down and begin initiatives to sponsor new supply and potentially rebuild a stockpile. The Inflation Reduction Act has US$370bn allocated to "greenification" and production of critical minerals including tungsten. While the US does not have any currently operating tungsten mines, significant tungsten deposits occur in Alaska, Arizona, California, Colorado, Texas, Utah, and Washington. These deposits are unlikely to be a timely source of material if required given the typical lengthy period of mine development and approvals in the US.

Figure 14: US Strategic Stockpile of tungsten in concentrate has been steadily declining and is forecast to be depleted by 2025 by some commentators



Source: US Geological Surveys / https://www.usgs.gov/centers/national-minerals-information-center/tungsten-statistics-and-information

Figure 15: Tungsten is on the key critical minerals lists: US, EU and Japan (plus others)

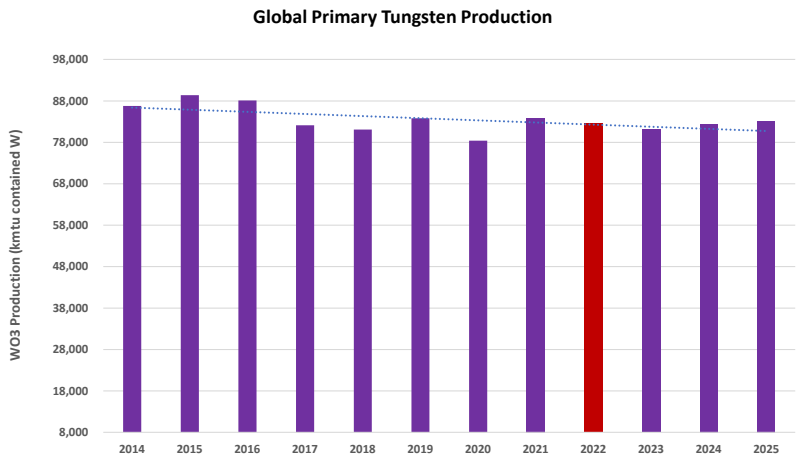
Critical mineral	On US list[6]	On EU list[7]	On Japan list[8]	On India list[9]	Australian geological potential[10]	Australian economic demonstrated resources (2020)[11]	Australian production (2020)	Global production (2020)[12]
Manganese	✓		✓		High	Manganese ore: 276,000 kt	Manganese ore: 4,800 kt	17,200 kt
Niobium	✓	✓	✓	✓	High	216 kt	No data	78 kt
Platinum-group elements	✓	✓	✓	✓	Moderate	107 t	0.522 t	380 t
Rare-earth elements	✓	✓	✓	✓	High	4,200 kt	20 kt	240 kt
Rhenium			✓	✓	Moderate	No data	No data	53 t
Scandium	✓	✓			High	30.34 kt	No data	No data
Silicon		✓[16]	✓	✓	High	No data	No data	8 kt
Tantalum	✓	✓	✓	✓	High	99.4 kt	0.1 kt	1.8 kt
Titanium	✓	✓	✓		High	Ilmenite: 274,000 kt Rutile: 35,300 kt	Ilmenite: 1,100 kt Rutile: 200 kt	Ilmenite: 12,000 kt Rutile: 1000 kt
Tungsten	✓	✓	✓		High	577 kt	<1 kt	84 kt
Vanadium	✓	✓	✓	✓	High	7,408 kt	0	86 kt
Zirconium	✓		✓	✓	High	Zircon: 79,300 kt	Zircon: 400 kt	Zircon: 2,000 kt

Source: Australian Government, 2022 Critical Minerals Strategy (March 2022)

Supply: A declining trend

According to the U.S. Geological Survey global primary tungsten production was estimated at 84,000 tonnes in 2022.

Figure 16: Global primary tungsten production has been declining since 2014-2022

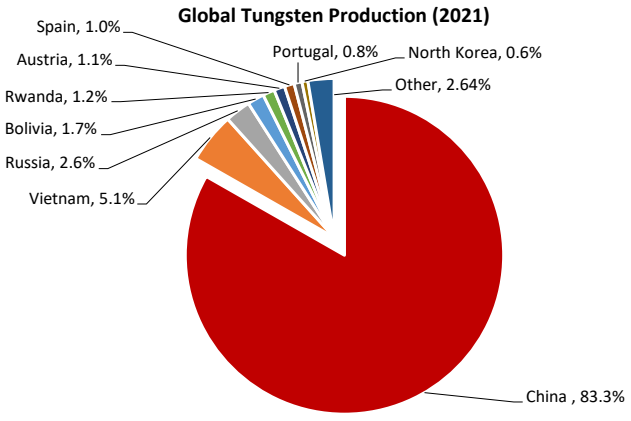


Source: US Geological Survey and PAC Partners forecasts

Of this total production, **China produced ~83%** followed by Vietnam 5.1%, Russia 2.6% and Mongolia 2.3%.

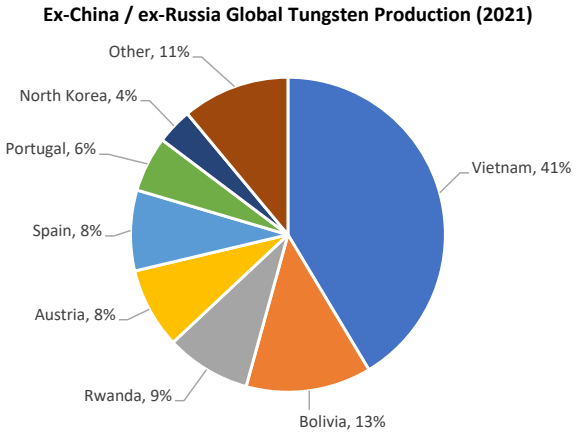
Other producing countries included Bolivia (1.7%), Rwanda (1.2%), Spain (1.0%), Austria (1.1%), Portugal (0.8%) and other countries produced 1.8% of world supply.

Figure 17: Global Tungsten Production (2021), was dominated by China, second-tier of supply if non-OECD located



Source: US Geological Survey 2022, Mineral Commodity Summaries 2021, Almonty Inc

Figure 18: Tungsten market share current, ex-China and ex-Russia



Source: US Geological Survey 2022, Mineral Commodity Summaries 2021, Almonty Inc

Chinese mine production is falling

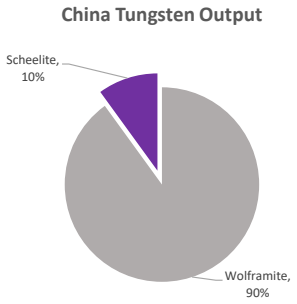
Chinese tungsten mines are located mainly in the southeast of the country with a handful of projects along the northern border with Mongolia/Russia. Four companies MinMetals, CMOC, Jiangxi Tungsten and Xiamen Tungsten are the largest producers in China accounting for ~45% of the country's total production.

China's tungsten production was officially restricted in 2002 to protect its reserves and has been strictly controlled by the Chinese government since. This is because China's Wolframite reserves are being rapidly depleted with an estimated 30 years of tungsten reserves remaining. Although China has substantial Scheelite resources, its Scheelite is more costly to extract and the reserves are of a much lower grade and quality.

"China's government regulated its tungsten industry by limiting the number of mining and export licenses, imposing quotas on concentrate production, and placing constraints on mining and processing," the USGS wrote.

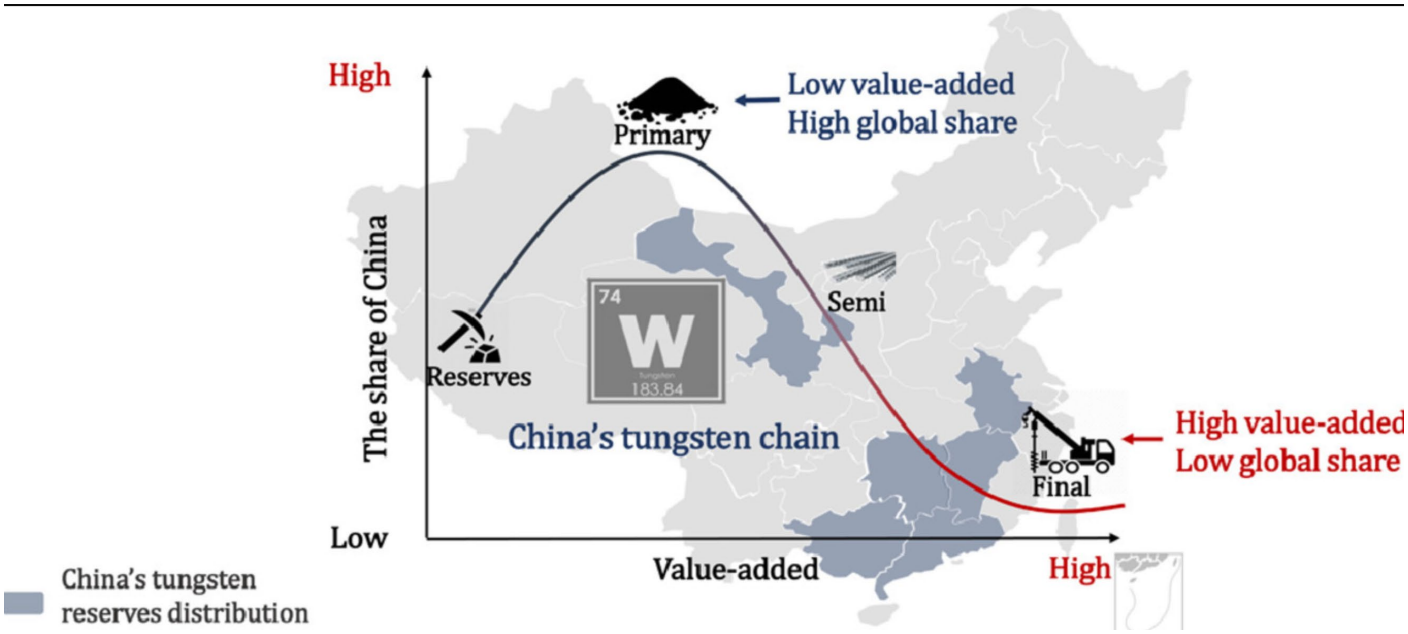
Recent statistics also back this up with Chinese tungsten concentrate falling 12% in the 2022 half year, due to "depleting high grade ore resources; environmental restrictions and stricter mining licence regulations including a longer renewal process" (Ganzhou Tungsten Industry Association).

Figure 19: Only 10% of Chinese tungsten supply comes from scheelite



Source: CTIA: China Tungsten (news.chinatungtsen.com)

Figure 20: Distribution of Chinese tungsten reserves and share of value added supply chain



Source: Refining the understanding of China's tungsten dominance with dynamic material cycle analysis. Linbin Tang July 2020

New supply elsewhere is few and far between

Figure 21: Key supply outside of China and Russia

Tungsten-Supply Analysis Mine	Location	Owner	Resource Deposit (Mt)	Grade WO_3 %	Reserves (Mt)	Grade WO_3%	WO_3 Contained in Reserves kmtu	Stage
Dolphine Mine	Australia	Group 6 Metals (G6M)	11.2	0.90%	4.4	0.92%	4,064	Construction
Mt Carbine	Australia	EQ Resources (EQR)	32.3	0.23%	13.5	0.14%	1,923	Production
Sandong	Korea	Almonty Industries (AII)	69.0	0.45%	7.9	0.47%	3,711	Construction
Panasquiera	Portugal	Almonty Industries (AII)	22.3	0.23%	2.0	0.20%	390	Production
Los Santos	Spain	Almonty Industries (AII)	7.7	0.25%	3.6	0.23%	824	On Hold
Valtreixal	Spain	Almonty Industries (AII)	20.8	0.21%	2.5	0.34%	867	Pre-Feasibility
La Parilla	Spain	W Resources	49.0	0.100%	29.8	0.09%	2,774	On Hold
Regua	Spain	W Resources	4.5	0.27%	N/A	N/A	N/A	Pre-Feasibility
Barruecopardo	Spain	Saloro S.L.U.	27.4	0.26%	8.7	0.30%	2,607	Production
Sisson Project	Canada	Northcliff Resources (TSX)	574.0	0.06%	334.4	0.07%	22,068	Pre development
Santa Comba	Canada	Rafaella Resources	10.0	0.16%	0.3	0.95%	276	Resource & approval
Hemerdon Mine	United Kingdom	Tungsten West (W:LSE)	328.0	0.12%	63.6	0.19%	12,084	Development
Nui Phao	Vietnam	Masan Resources	97.4	0.18%	66.0	0.21%	13,860	Production
Mittersill	Austria	WBH Wolfram Bergbay an(	N/A	N/A	5.0	0.50%	1,600	Production

NB: Excludes China and Russia. Sources: Company announcements, PAC Partners analysis.

Sandong Korea – globally significant and in development

Almonty's Sandong Tungsten Project in Korea has a mining reserve and a **vast resource base**:

- Mining reserve: 8Mt at 0.45% WO3,
- Total resource (MI&I) of ~60Mt at 0.44%-0.49%

Almonty is industry leader and looking to bring the major Sandong project online

Historically it had been **one of the largest tungsten mines in the world** and contributed significantly to Korea's export economy during the 1950s. The mine closed in the 1990s (along with many others across the industry) due to subdued prices.

In September 2015, Almonty acquired a 100% interest in the Sandong Deposit by acquiring Woulfe Mining Corp via a scrip deal.

In August 2021, Almonty listed on the ASX raising A$15.2m in capital to fund the construction & redevelopment of Sandong. This listing added to its existing listings on TSX and Frankfurt.

Key milestones in the development of Sandong include:

- July-2016: 43-101 technical report issued.
  - Ore throughput capacity 900kt/yr to 1.2mt/yr
  - Final end product output of 640kt/yr of tungsten in concentrate (potentially 7-10% of estimated global supply).
- Mid 2021: Construction commenced.
- Target 2H 2023: Mining activities to commence and process plant commissioning.
- Target 2024: Ramp up to steady state production, nameplate capacity targeted 2025.
- **Total capex of US$105m.**
  - US$65.6m of core capex,
  - US$40m in working capital, ancillary and other pre-production expenses.

By end 2022, ~25% of construction has been complete. As with other mining projects in development, we would not be surprised to see some slippage in timing and capex cost of Sandong. Nevertheless Sandong promises to be one of the most significant tungsten mine developments outside of China.

Sandong has offtake agreements in place with a price floor at US$235/mtu, further underpinning its long term viability as a future source of tungsten tonnes.

UK - Hemerdon Mine (in development) (Tungsten West Plc LSE:W)

In April 2022 the re-development of the Hemerdon tungsten open pit mine was paused in the face of high energy prices and economic uncertainty. It last operated between 2015-2018.

On 19 July 22, a detailed re-engineering design program was launched.

In September 2022 a key hurdle was overcome when the company secured finance by entering a royalty agreement for US$30m (£26m) that included:

- Royalty payments 4.75% of revenue until the successful production and sales of 7Mt mtu of WO_3, after which the royalty rate reduces to 2.375%
- The company is able to buy up to 50% of the royalty back within the first 4 years for a single payment of US$30m (the same amount sold for today).

In October 2022 updated capex for the remaining development was £31.5m excluding a 20% contingency.

Orders for long lead time items were placed and commissioning date set for Q2 2023.

In December regulatory approval was received for the mining waste facility and to commence open pit dewatering. Updated resource and reserve was also announced:

- Reserve: 101.2Mt at 0.14% WO3
- Resource (M,I&I): 351.5 at 0.12% WO3

In January 2023, updated feasibility study metrics were announced including:

- 3.5Mt/yr ore throughput
- Average production 2,900t WO3 and 310t Sn (tin)
- C1 cost £135/mtu or ~US$163/mtu
- Capex unchanged at £31.5m for redevelopment, plus £20m of pre-production costs. It was noted that £219m of capital had been spent on the mine and surrounding infrastructure in the previous cycle.

Figure 22: Hemerdon open pit



Source: Company Presentation

Vietnam - Masan High-Tech Materials (Nui Phao Mine)

Masan High-Tech Materials in Vietnam is one of the largest APT producers in the world (up to 30% of ex-China global supply).

The company's flagship asset is the Nui Phao tungsten mine with:

The Nui Phao mine is facing supply challenges.

- Reserves: 66Mt at 0.21% WO3,
- ~20 years of mine life at 410kmtu/yr, and
- Mine production cost US$120/mtu WO3

In 2021 Masan increased ore production by 2-3% but due to technical failures with their fluorspar product, recoveries on tungsten were negatively affected and the treatment of tungsten ore dropped.

In the year to 30 June 2021, Masan produced 20kt of contained tungsten products, containing 2,520kmtu WO3, and we estimate an 80% dependence on 3rd party concentrate.

In September 2019 Masan Resources paid €80m for H.C. Stark's tungsten business, headquartered in Germany with midstream tungsten production facilities in Europe, North America and China and capacity 13.3kt high-value tungsten products.

The company has also invested £45m in Nyobolt UK – a fast-charging Lithium-ion battery technology company. The technology employs H.C. Starck's high-tech Tungsten materials in the battery anode coating. According to Masan, tungsten-based Lithium-ion batteries have super-fast charging speed with 90 percent charged in less than 5 minutes. The batteries would also have up to 10x higher power density, longer durability and lower cost. Having less thermal stress than conventional graphite-based batteries means reduced risk of fire and explosion.

Meanwhile, Western world producers have been facing particularly high (inflated) operating costs…

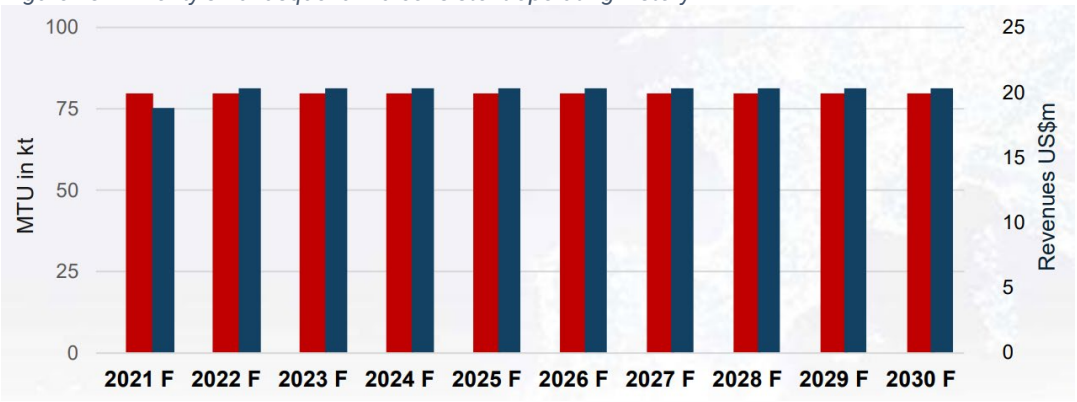
Western producers in Europe have been hampered by high gas prices, with several forced to curtail production.

Portugal – Panasquiera Mine (operating) (Almonty ASX:All)

Almonty's current producing mine was acquired in 2016 and has a consistent operating history throughout the tungsten price cycles, in part due to valuable tin and copper associated with the mine, and in part due to **high tungsten recovery rates (80%) (a key success of the project).** It is a wolframite deposit and started as an open pit mine and has progressed to underground mining in recent decades.

- Reserves are ~2Mt at 0.20% WO3.
- Mine life 20 years.
- Has an operating history of 126 years.
- ~US$150/MTU per cost curve analysis.
- Forecast production 78,100MTU WO3 equivalent (includes 10,500MTU of tin by products).

Figure 23: Almonty's Panasqueira – a consistent operating history



Source: Almonty Nov-2022 presentation

Spain - Los Santos Mine (care and maintenance) (Almonty ASX:All)

In 2011 Almonty (then a PE firm) purchased the Los Santos mine for US$20m (cash component was only US$14m).

The mine operated as an open pit from 2008 through to Q3 2019, and a tailings operation thereafter (45kmtu WO3 p.a, with a recovery of 50%). Operations were paused in Feb 2020 freeing up capital and equipment for Almonty to devote to the Sandong Korea development.

Los Santos has been a valuable project for Almonty. We expect it to be a focus once the Sandong Project is near complete.

As of late 2022, guidance was that operations would resume mid-2023 after plant upgrades and modifications to improve recovery rates, but we would be surprised to see Los Santos in operation before Sandong Korea has achieved steady state operations and generating free cashflow. Underground mining is a long term option and this was modelled in a 2015 technical feasibility.

- 3.6Mt of reserves at an average grade of 0.23%.
- Production: Care and maintenance since 2020.

Almonty also owns the **Valtreixal tin-tungsten (Sn-WO3) project** in North Western Spain located ~250km from its Los Santos. It is a potential open pit operation of complex scheelite mineralisation.
It has:

- Reserve: 2.5Mt at 0.34% grade for 8,667t WO3 (866,660MTU of WO3)
- Resource: 2.8Mt at 0.34% indicated and 15.4Mt at 0.17% inferred.

Spain – Barruecopardo (operating) (Oaktree Capital / strategic review)

Barruecopardo with a financial investor-owner is unique within this niche industry.

This mine was said to be in operation but for sale in 2022.

- 27.4Mt reserves at an average grade of 0.26%.

Previously operational until the 1980s, the mine restarted in August 2018. However shortly after open pit mining started in 2019, owners reported that the mine was facing difficulties with ore grades significantly lower than forecast. This necessitated old backfill was going to have to be removed to access the higher-grade ore.

In October 2019, Oaktree tipped in an additional €10m. This mine was said to be in operation but for sale in 2022 producing significantly less than the 275kmtu pa of WO3-contained promised in feasibility studies.

Austria - Mittersill Mine (operating but fully integrated) (Wolfram Bergbau-und-Hutten)

Being vertically integrated, the mine has remained in production through price cycles since it commenced in 1976 and from 1986 has been an underground mining operation.

The company subsidises feed from its own mine with 3rd party concentrate purchases. It is also the off-take partner of Group 6 Metals, Dolphin mine in Tasmania.

Wolfram Bergbau-und-Hutten produces high-value end-use tungsten products such as tungsten carbide powder, tungsten metal powder, and tungsten oxide.

Spain - La Parilla (care and maintenance) (W Resources) (no longer listed)

- Reserves of 29.8Mt at an average grade of 0.09% WO_3.
- 6 year initial mine life
- 2mt/yr ore throughput for 2,700t/yr WO3
- Open pit

The mine was idled April 2022 and W Resources delisted in May 2022, with few public updates since.

Canada - Sisson Mine Project (pre-development timeline extended) (Northcliffe TSX:NCF)

A large-scale, higher-tonnage but lower-grades tungsten and moly project located in eastern Canada.

- Reserve: 334mt at 0.066% WO3 and 0.021% Mo.
- Resource (measured and indicated only): 387mt at 0.067% WO3 and 0.021% Mo.

It is 88.5% owned by Northcliff Resources, with the remaining interest owned by Todd Corporation (Northcliff's largest shareholder with 56.23%).

Construction to commence by December 2025 to retain environmental licenses.

The most recent Feasibility Study completed in 2013 indicated:

- Average production at 557kmtu of WO3 in APT,
- LOM of 27 years,
- CapEx is $579m and
- OpEx $ 153/mtu.

Canada – Mactung Mine Project (Fireweed Metals TSX:FWZ)

One of the largest and highest-grade tungsten deposits in the world.

A feasibility study was released in 2009 before the project owners subsequently experienced financial distress and the project eventually found its way to Fireweed who are progressing the project alongside the neighbouring Macmillan Pass zinc silver project.

- indicated resources 33.0mt at 0.88% WO3
- Inferred resources 11.8mt at 0.78% WO3.

Vietnam - Tungsten Metals Group (TMG) (tungsten processor)

TMG manages the largest ferrotungsten production plant outside of China and Russia, located in Vinh Bao to the South East of Hanoi, Vietnam.

- production capacity of 4kt/yr FeW

Figure 24: Tungsten Peer Group (ex-China, ex-Russia)

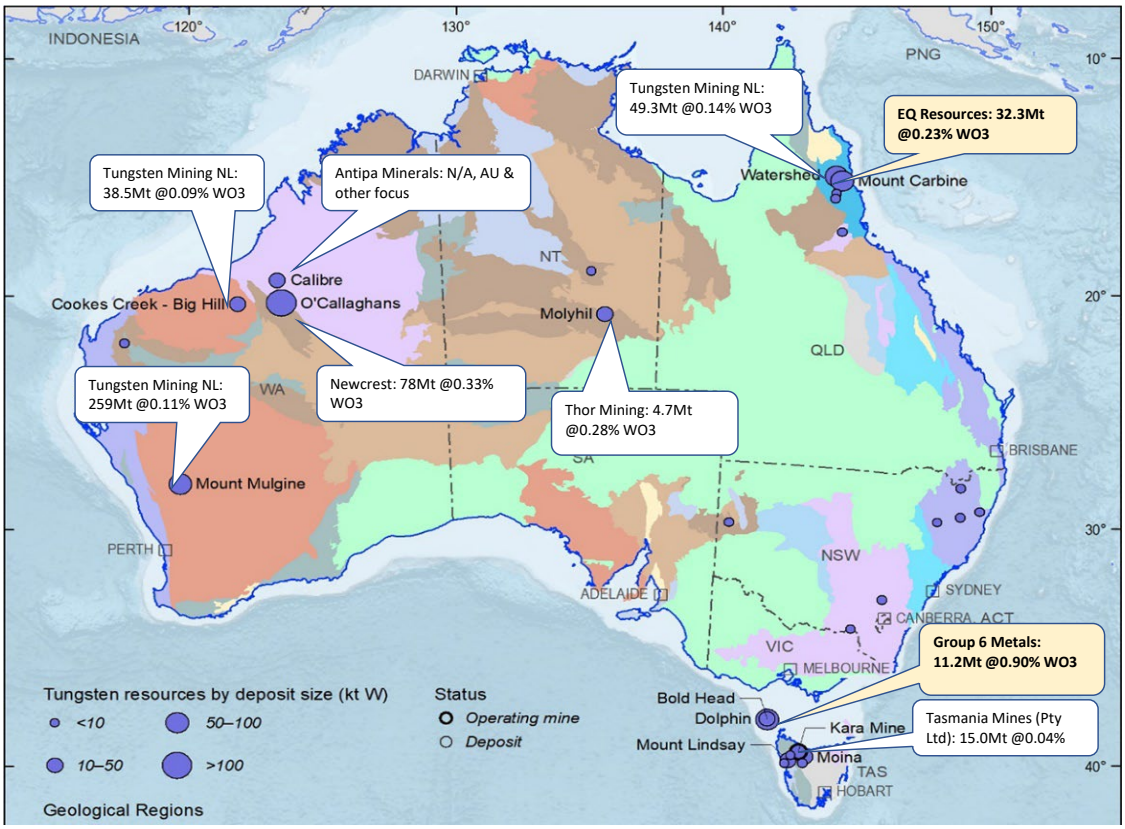
Company			$	Share Price (local)	Mkt Cap A$m or local	Mkt Cap US$m	Net Debt ($m)	EV (A$m or local)	Resource (MT)	Grade WO_3%	Resource WO_3 Contained (kt)	EV/WO_3 Resource (Mt) (US$)	Project Details
Group 6 Metals	G6M	ASX	AUD	0.17	130	83.2	6.9	137.0	11.2	**0.90%**	101	868.2	King Island Sheetlite/Dolphin Mine in Australia. Production starts in Q1 2023. High grade mine.
EQ Resources	EQR	ASX	AUD	0.065	95.2	60.9	5.0	100.2	32.3	**0.23%**	76	847.8	Mount Carbine Australia, redevelop historical mine, tailings processing then o/c, explore u/g opition. Mining to start Q2 2023. Includes LGS 10Mt @ 0.075% in production.
Almonty Industries	AII	ASX, TSE	CAD	0.70	181	132.1	60.1	241.1	80.4	**0.36%**	289	608.3	Tungsten Asset Portfolio: flagship project: Sandong (Korea), others: Los Santos (Spain, stopped production), Panasqiera (small-scale production), Valtreixal (exploring). Sandong constructionis 25% complete. Production forecasted in 2025
Tungsten Mining NL	TGN	ASX	AUD	0.10	78.6	50.3	-15.3	63.4	354.0	**0.12%**	425	95.4	5 Australian tungsten projects, discovery and development. Watershed acquired from Vital Metals in May 2018 for A$15m.
Tungsten West Plc	LSE:TUN	LSE	GBP	0.25	44.2	47.3	-27.3	16.9	328.0	**0.12%**	394	46.0	Hemerdon Tungsten-Tin Deposit located in South Devon, UK. $30M royalty investment with global (2.375% rate). Planning restart.
Northcliff Resources	TSX:NCF	TSX	CAD	0.06	7.5	5.5	-1.7	5.8	334.4	**0.07%**	221	19.3	Owns 88.5% of Sisson Tungsten-Molybdenum Project in New Brunswick Canada. All permitting in place. Updated BFS underway. Needs funding.
Rafaella Resources	RFR	ASX	AUD	0.05	20.5	13.1	-1.0	19.5	10.3	**0.18%**	19	673.8	Developer and explorer, 2 tungsten deposits in Spain: PFS Dec 2022 for Santa Comba (NPV US$43.5m). 2 Projects in Canada. San Finx acquired Jan 22, produced in 2017.
W Resources	LSE:WRES	LSE	GBP	0.03	3.9	N/A	57.9	61.8	53.5	**0.11%**	61	N/A	La Parilla Project, Western Spain. Delisted in April 2022 due to high LNG prices, poor production, poor recoveries. Production closed.
Fireweed	FWZ	TSX	CAD	0.91	83.0	63.8	-6.0	89.0	44.8	**0.80%**	359	187.7	Owns zinc and tungsten projects including Mactung high grade Tungsten project, Indicated 33Mt @ 0.88% and inferred 118mt at 0.78% W03.
Saloro SLU	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0	**0.26**	7	N/A	Barrauecopardo Spain 260kmtupa, since 2019. Oaktree owned.

Source: Company Reports, PAC Partners Analysis

Australian Tungsten Sector

Australia is set to become a major player in tungsten supply over the coming years as the Dolphin and Mt Carbine Mines ramp up operations.

Figure 25: Significant Australian Tungsten (Identified) Resources



Source: Geoscience Australia (Tungsten), 2018, PAC Partners Analysis (updated resource estimates for EQR and G6M)

Australia's tungsten endowment includes only 2 primary producers:

- EQ Resources' and Group 6 Metals, are expected to be **the only primary tungsten mines in operation in 2023.** Small volumes of tungsten are produced as a by-product in Tasmania at the Kara Project (Tasmania Mines Pty Ltd). It produces magnetite powder with tungsten bearing scheelite - a by-product of the magnetite processing.

- Thor Mining (THR) owns, among its portfolio of minerals projects, **the Molyhil tungsten project,** which last issued a feasibility study in 2018. The company is drilling to further define the ore body and "reviewing strategic plans" for the project.

- Tungsten Mining NL (ASX: TGN) owns a number of tungsten projects Watershed, Mount Mulgine and Big Hill. Of these Mount Mulgine has a reserve and pre-feasibility study (259Mt @ 0.11% WO3) featuring valuable moly, gold and silver credits. The company was looking to JV the project as it works towards the next stage of the feasibility.

- **The O'Callaghans deposit is owned by gold major Newcrest** as part of the wider Telfar project area and contains 78Mt at 0.33% WO3 (measured and indicated) along with lead, copper and zinc also.

- **Almonty is listed on the ASX (and TSX) with a market capitalisation of $185m.** Although it does not own any Australian mines, it is a major player within the global industry and its Sandong mine in South Korea is a potential long term significant source of ex-China supply (see below).

Appendix: Tungsten - A Primer

Tungsten, a group 6 a transition metal in the periodic table, is a whitish grey shiny heavy metal of high density that has the highest melting point of any metal.

The word tungsten is derived from "tungsten" a Swedish word for heavy stone. Given its predominant use as a wear resistant material, its main use is industrial manufacturing.

Tungsten is a grey-white metallic element. It has the highest melting temperature of all elements except carbon and is one of the heaviest elements.

Key Points:

- There are 2 minerals that contain economic amounts of tungsten (Wolframite and Scheelite):
  - Scheelite ($CaWO_4$) – is a calcium and tungsten mineral that has fluorescent properties which makes it a popular collectors' item.
  - Wolframite ($FeMnWO_4$) – an iron-manganese-tungstate mineral.
- Scheelite and Wolframite can occur concurrently in ore bodies but one will usually be the dominant form. The presence of other tungsten bearing minerals within an ore body such as hydrotungstite ($H_2WO_4 \cdot H_2O$), anthoinite ($AlWO_3(OH)_3$) and cerotungstite ($CeW_2O_6(OH)_3$), may lead to lower tungsten recoveries and concentrate grades.

Tungsten is produced from the ores minerals scheelite (calcium tungstate) and wolframite (iron-manganese tungstate).

- Unlike most base and precious metals, tungsten is generally not smelted to form metal due to its high melting point (3,422 degrees Celsius) and is instead extracted from concentrate using a series of chemical reactions.

- Therefore given tungsten is not often found in its pure metal form, the most commonly traded form of tungsten is Ammonium Paratungstate (APT).

- Concentrates produced by miners (typically 40-70% WO_3) are purchased by secondary processors that convert the concentrate into APT.

The ore is concentrated and then usually produced into the intermediate product Ammonium Paratungstate (APT) before being processed into metallic applications

- APT is then converted to various powders, which are used in downstream metals and alloys by tertiary manufacturers.

- The miners, as concentrate sellers, receive a playability rate of 70%-80% of the value of the tungsten in the concentrate based on the prevailing APT price.

Properties:

- The second-hardest material, behind diamonds, and often used as a machining metal. .
  - Tungsten is 16x harder than gold
  - …10x harder than titanium
  - …2x harder than cold rolled steel
- Highest melting point of any metal (3422 degrees Celsius) and therefore it is generally not often melted.
- A very ductile metal (able to be drawn out into useful shapes / forms).
- Tungsten also exhibits positive similarities to lead without being toxic.

Strategic Mineral for Western counties, because it is irreplaceable, used widely in manufacturing and defence.

Tungsten: Where does it come from?

A Scarce Metal: The tungsten content of the earth's crust is around 0,0001 g / t or 0,0064 percent by weight (Clarke value). Pure tungsten has not been evidenced in nature.

Tungsten containing minerals scheelite and wolframite generally occur in narrow veins which widen with depth.

- Scheelite (CaWO4) – is a calcium and tungsten mineral that has fluorescent properties which makes it a popular collectors' item.
- Wolframite (FeMnWO4) – an iron-manganese-tungstate mineral.

Figure 26: Black wolframite (LHS), translucent scheelite (middle), Dolphin Mine scheelite ore (RHS).



Source: International Tungsten Industry Association, PAC Partners / Group 6 Metals site visit

Tungsten ores generally contain no more than 1.5% of WO3 (and far more commonly below 1%) and therefore a high amount of gangue material needs to be processed to achieve the standard concentration.

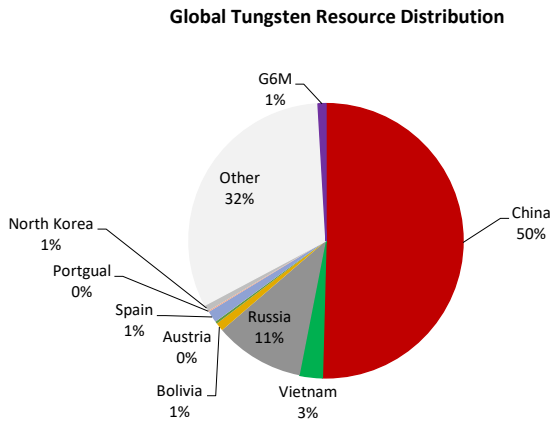
Molybdenum (in the form of molybdenite) and tin are **common by product minerals** found in tungsten mines. Molybdenum concentrations as low as 0.2 – 0.5% Mo can lead to reduced recovery of APT. However cleaning concentrates of the moly is relatively straightforward process due to the flotation properties of molybdenite.

Underground mining is the most common form of extraction but in some cases open cut mines are used where the properties, grade and depth of the ore are appropriate (mostly in Australia and Canada).

China hosts around 60% of the world's known tungsten reserves and over 80% of current world production.

Mine concentrates generally contain around 50-70% WO_3. Benchmark pricing is generally quoted for 88.5% concentrations, but pricing is also common for 50%, 65% and 68% concentrate grades.

Figure 27: The Global Tungsten resource endowment is also dominated by China



Source: US Geological Survey, Mineral Commodity Summaries (Jan 2022)

How do we make it?

The mined ore (consisting of both Wolframite and/or Scheelite) will first be crushed and then milled.

This liberates the Tungsten-mineralised crystals and improves the chemical refining processes. In some production lines (mostly historic), the Wolframite is even hand sorted due to its optical properties.

Figure 28: Hand sorting of tungsten ores (Taoxiken mine, Jiangxi, China)



Source: ITIA Tungsten From Deposit to Concentrate Dec 2012

Downstream products (applications vary significantly)

Both scheelite and wolframite have a high density and are brittle (making ore crushing particularly troublesome).

Only scheelite is readily amenable to flotation (and less so compared to common sulphide minerals).

Wolframite is paramagnetic and can be easier to process, especially for the vastly experienced Chinese producers.

So mine site beneficiation techniques focus on high density and/or flotation (scheelite) or magnetic separation (wolframite).

A Multi-Gravity Separator is used to sperate finer scheelite ores, which are repeatedly refined via gravity separation (commonly includes equipment like jigs, shaking tables and spiral classifiers) until a concentrate of the desired strength has been obtained.

This product is then sold to APT producers.

Refining: A chemical process

The most marketed form of tungsten is its intermediate form Ammonium Paratungstate (APT).

Tungsten's extremely high melting makes smelting a potentially dangerous and expensive exercise and generally not done. Therefore, tungsten is refined chemically.

The ores are acid leached under temperature and pressure, extracting the tungsten into a sodium-bonded precipitate. This is then converted into Ammonium Paratungstate (APT).

APT can be refined further via furnacing, and generally, a powder is the desired form.

For example, Wolfram Bergbau and Hutten sells 3 types of powder products:

- tungsten-carbide,
- tungsten-metal and
- tungsten-oxide.

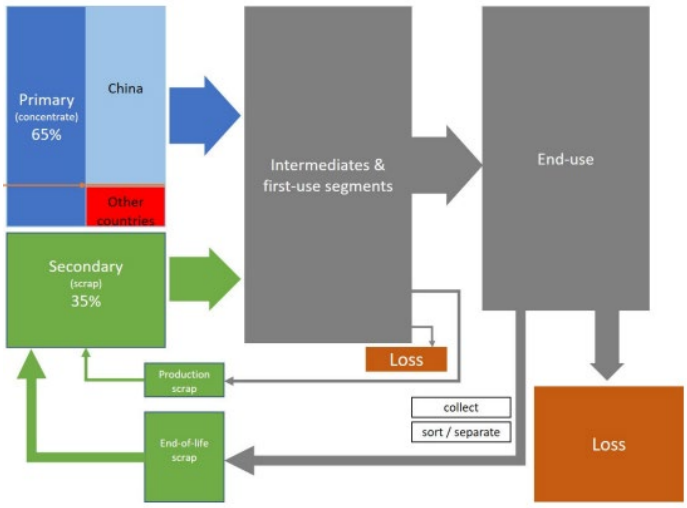
Vietnamese processor Masan Tungsten LLC produces 4 products:

- APT (ammonium paratungstate),
- BTO (blue tungstate oxide),
- YTO (yellow tungstate oxide) and
- ST (sodium tungstate).

From a refinery perspective, China has even more of the world's concentration of tungsten refineries and smelters with 32 compared to 13 outside China according to an OECD study. As a consequence it is a net importer of global tungsten concentrate.

Recycling: A key source of supply

Figure 29: Global Tungsten flow (production to end-use and recycling)



Source: Tungsten Industry Conflict Minerals Council, International Tungsten Industry Association (ITIA), USGS Jan-2021

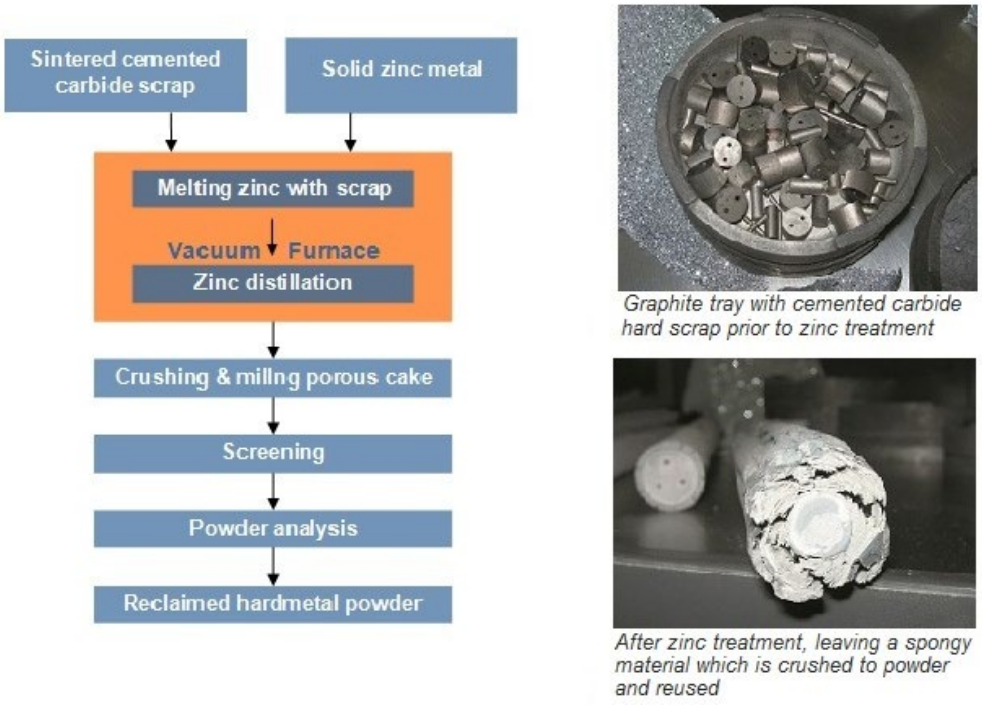
Scrap and recycling of tungsten

Recycling supply approx. 30%

Estimates vary but according to the Tungsten Industry Conflict Minerals Council 35% of tungsten supply is obtained from tungsten-bearing scrap. In the United States and Europe, the current recycling rate is estimated at around 50%, relatively high compared to other metals on average.

Direct recycling: the best-known process is the zinc process, in which molten zinc is provided with sorted and ground hard metal scrap. In a high-temperature process, the scrap first reacts with the Zn, which is then distilled off in the further course. After the product is ground and screened again, a "ready to press" powder is obtained, which corresponds in its composition to the starting material.

Figure 30: Recycling of tungsten in tungsten carbide



Source: International Tungsten Industry Association

Chemical Recycling: chemical recycling is used to produce new high-purity APT powder from tungsten scrap. This involves various leaching or melting and cleaning processes, similar to the process for primary raw materials.

In melting metallurgy, the scrap is added directly to the melting process in the production of steels or superalloys, for example. Depending on the end product, low (steels) to high (superalloys, steelite) requirements are placed on the type and purity of the scrap.

Marketing

The APT price is used as the pricing benchmark for WO_3 concentrate - in Metric Ton Units (MTU) of Ammonium Para Tungstate (APT).

- 1 MTU is equal to 10kgs
- 1 MTU of APT contains approximately 7.93 kgs of tungsten.

APT and concentrate prices are mainly based on quotations published by various trade journals including Argus, Asian Metals and Fastmarkets.

The price received for WO_3 concentrate generally sits at around 70%-80% of the reported APT price for the contained WO_3,.

Figure 31: Pricing of various tungsten products including concentrate, APT, and carbide.

Product	Specification	Unit	Price	Price in USD*
Tungsten Ore	WO3 65%min EXW China	RMB/mt	120000-122000	17608-17901
Tungsten Ore	WO3 50%min FOB Africa	USD/mtu	265-270	265-270
Tungsten APT	88.5%min EXW China	RMB/mt	181500-182500	26632-26779
Tungsten APT	88.5%min FOB China	USD/mtu	328-338	328-338
Tungsten APT	88.5%min In warehouse Rotterdam	USD/mtu	328-338	328-338
Sodium Tungstate	WO3 68%min EXW China	RMB/mt	134000-136000	19662-19956
Tungsten Oxide	WO3 99.95%min EXW China	RMB/mt	207000-210000	30374-30814
Tungsten Oxide	WO3 99.95%min FOB China	USD/mtu	333-343	333-343
Tungsten Powder	99.95%min 2.5-7.0μm EXW China	RMB/kg	273-276	40.1-40.5
Tungsten Bar	W-4 99.9%min EXW China	RMB/kg	293-296	43.0-43.4
Tungsten Bar	W-4 99.9%min FOB China	USD/kg	41.5-42.5	41.5-42.5
Thorium Tungsten Electrode	ThO2 1.7-2.2% EXW China	RMB/kg	380-400	55.8-58.7
Tungsten Carbide	99.8%min 2.5-7.0μm EXW China	RMB/kg	270-273	39.6-40.1
Tungsten Carbide	99.8%min 2.5-7.0μm FOB China	USD/kg	40.5-41.5	40.5-41.5

Source: Asian Metals

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