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80-20 Industry Primer: Tungsten

A Pareto Approach to Industry Analysis …

Tungsten is the smallest, most opaque commodity market we've covered in our 80-20 Industry Primer series. Global supply is ~106,000 tons, with recent spot prices around $305 to $325/mtu.

Nobody's pitching tungsten on Twitter or Seeking Alpha. Almost every tungsten mining company profiled over the past 3-5 years is either bankrupt or on care and maintenance. And it's too small of a market for the Big Boys (Vale, Glencore, Rio Tinto) to care about.

But the world's hardest metal is at an inflection point. Tungsten's three primary demand drivers (EV/electrification, semiconductors/robotics, and military) are all increasing and competing for the raw material at a time when Resource Nationalism threatens to remove 80%+ of the world's supply from the market.

Tungsten has everything we want in a commodity thesis:

- ➢ **Multiple accelerating demand drivers**
- ➢ **Bombed-out sentiment**
- ➢ **Lack of new supply**
- ➢ **Potential for massive supply/demand imbalance**

Our goal with this 80-20 Industry Primer is to create a simple but robust global supply and demand model. From this, we can answer the most critical questions surrounding the Tungsten Thesis:

1) **Supply:** How much supply is there currently, where will new supply come from, and how much will there be in 1-2 years?
2) **Demand:** Who's currently buying the supply, how much are they buying, and how will their buying habits change over time?
3) **Price:** How do all of these changes affect the price of tungsten?

We develop deep conviction by doing our own work, stress-testing it against industry experts, and continually updating our models in the face of new evidence.

Let's get after it.

The Supply Side: Primary & Secondary Deep Dive

To understand the future of any commodity industry, it is vital to understand its past. Let's look at historical tungsten production and use cases.

History of Tungsten & Use Cases

Tungsten was discovered in 1783 by Spanish chemists and mineralogists Juan Jose and Fausto Elhuyar. But it wasn't until 1855-1857 that Austrian engineer Robert Oxland patented a process for making tungsten steel.

Oxland's patent paved the way for more industrialized use cases. In the early 1920s, German electrical bulb company Osram developed tungsten carbide by heating tungsten (also called "wolfram"), carbon, and hydrogen at 1,400-1,600 degrees Celsius.

The result is the second-hardest metal on earth behind diamonds. Tungsten scores 9 on the Mohs scale and 1600HV on the Vickers Hardness scale. For reference, diamonds score a 10 on the Mohs scale and steel alloy scores a 160HV on the Vickers scale.

Tungsten has many use cases given its hardness, heat/scratch resistance, and relative cheapness to diamonds. Here's a list from the USGS's 2018 Mineral Yearbook (emphasis added):

> *"The leading use for tungsten is as tungsten carbide in cemented carbides, which are wear-resistant materials used by the* ***construction, metalworking, mining, and oil and gas drilling industries.***
>
> *Pure or doped tungsten metal is used for* ***contacts, electrodes****, and wires in electrical, electronic,* ***heating, lighting, and welding*** *applications.*
>
> *Tungsten is also used to make alloys and composites to substitute for lead in* ***ammunition and other products****;* ***heavy-metal alloys for armaments****,* ***heat sinks, radiation shielding, and weights and counterweights****; superalloys for* ***turbine engine parts****;* ***tool steels****; and* ***wear-resistant alloy parts and coatings****.*
>
> *Tungsten chemicals are used to make* ***catalysts****,* ***corrosion-resistant coatings****,* ***dyes and pigments****,* ***fire-resistant compounds****,* ***lubricants****,* ***phosphors****, and* ***semiconductors****."*

I know there's a lot there. But I want you to focus on three overarching use-case themes:

1) **Military**
2) **Semiconductors/Robotics**
3) **EVs**

Here are some examples of tungsten military applications.

The big idea is that multiple industries are hungry for more tungsten in a supply-constrained environment. We don't need to get every use-case demand projection right to be directionally correct on the supply/demand imbalance.

We'll explain each of the three main demand drivers later. Next, let's discuss primary supply.

Primary Production: Global & Country-Specific

Most tungsten supply comes from underground mines. I like how the International Tungsten Industry Association explains the mining/extracting process (emphasis added):

> *"[Tungsten is] frequently located in narrow veins which are slightly inclined and often widen with the depth. Open pit mines exist but are rare.*
>
> *Tungsten mines are relatively small and rarely produce more than 2000t of ore per day.*
>
> *Most tungsten ores contain less than 1.5% WO3 and frequently only a few tenths of a percent.*
>
> *The ore is first crushed and milled to liberate the tungsten mineral crystals. Scheelite ore can be concentrated by gravimetric methods, often combined with froth flotation, whilst wolframite ore can be concentrated by gravity (spirals, cones, tables), sometimes in combination with magnetic separation."*

Three countries comprise ~93% of global primary supply:

- ➢ **China: 84%**
- ➢ **Vietnam: 6%**
- ➢ **Russia: 3%**

In other words, 87% of primary tungsten production comes from every Bond villain's home country.

World Mine Production and Reserves: Reserves for China, Portugal, Spain, and "Other countries" were revised based on company and Government reports.

	Mine production		Reserves[11]
	2021	2022[e]	
United States	—	—	NA
Austria	[e]900	900	10,000
Bolivia	1,563	1,400	NA
China	[e]71,000	71,000	1,800,000
Portugal	502	500	3,100
Russia	[e]2,300	2,300	400,000
Rwanda	[e]1,340	1,100	NA
Spain	[e]400	700	56,000
Vietnam	4,800	4,800	100,000
Other countries	973	1,400	1,400,000
World total (rounded)	83,800	84,000	3,800,000

These countries also pose "Conflict Mineral" risks. Conflict Minerals are any raw material sourced through non-transparent supply chains. It's like getting Ibuprofen from a man in a dark alley versus going to your local CVS.

The United States hasn't reported primary tungsten production since 2015. Maybe due to "national security" reasons. Or maybe there's just no tungsten production market in the US.

According to the USGS, there are only ***six*** US companies *"with the capability to convert tungsten concentrates, ammonium paratungstate (APT), tungsten oxide, and (or) scrap to tungsten metal powder, tungsten carbide powder, and (or) tungsten chemicals."*

It wasn't always like that. In the early 1920s, most of the world's tungsten came from North America, with production split between Canada and Colorado, Nevada, California, and Arizona.

Tungsten is such a small market that we can go country-by-country to examine primary supply. Let's start with Australia (data as of 2018-2020).

Australia

There are two main tungsten projects and mining companies in Australia:

1) Mt. Carbine
2) Kara
3) Group 6 Metals (G6M)
4) EQ Resources (EQR)

Mt. Carbine is currently the only active producing tungsten mine as of June 2023 (via EQ Resources). Group 6 Metals (G6M) restarted its Dolphin Tungsten mine in July/September 2023 but has only shipped 10t of tungsten concentrate.

Kara produced small amounts of tungsten (~40t) until 2016 before being put on care and maintenance.

Almonty Industries also had a tungsten project in Cairns, Queensland, which it put on care and maintenance in 2016.

Australia has the second-largest tungsten resource base globally, yet only one active producing mine. It's a great example of capital starvation and low incentive prices in the industry.

Austria

Austria produced ~900t of tungsten from its Mittersill scheelite mine via Wolfram Bergbau und Hutten AG (or WBH), a subsidiary of mining/heavy equipment manufacturer Sandvik AB (SAND.OM).

Canada

Canada does not have a producing tungsten mine as of the USGS 2018 Mineral Yearbook survey. The only major project of note is the Sisson tungsten-molybdenum mine in east-central New Brunswick.

Northcliff Resources (NCF.TSXV) did a feasibility study on the mine in 2013. It even received federal and provincial approval in 2017; however, there has been no production.

If successful, the mine would produce ~4,420t/yr of contained tungsten over a 27-year mine life.

China

We don't have individual mine production data. However, China has three central tungsten production provinces: Jiangxi, Hunan, and Henan. Together, they account for 84% of China's tungsten production.

The Chinese government increased the country's production quota to 111Kt in 2023, of which 65% will convert to WO3 (sellable tungsten) for 72,150 tons.

Democratic Republic of the Congo (DRC)

Two provinces control all of the DRC's tungsten production:

- Kinshasa: 67%
- Maniema: 33%

Artisinal mining dominates DRC tungsten supply. There are no major "corporate" producers. This means that local kingpins rely on forced/slave and child labor to extract tungsten *by hand*.

The DRC is a listed "Conflict Minerals" country.

Kazakhstan

Kazakhstan does not currently have an active tungsten production industry. However, JSC NMC Tau-Ken Samruk and Chinese company Jiaxin International Resources Investment Limited agreed to establish a JV to kickstart Kazakhstan's domestic tungsten industry.

South Korea

South Korea imports 95% of its tungsten from China and has no current domestic production. However, Almonty Industries (AII) wants to change that. The company is progressing on the Sangdong tungsten project southeast of Seoul. According to the company's latest investor presentation, production should start in H1 2024.

If production goes as planned, Sangdong would generate ~7% of the world's tungsten supply by 2027 and 43% of non-Chinese supply.

Portugal

Portugal produced ~500 tons of tungsten in 2022 from the Almonty Industries (All)-owned Panasqueira mine.

All is in the process of expanding the mine life by another 20 years.

Russia

Russia produced ~2,700 tons in 2022. There are four primary tungsten producers in Russia:

1) Primorsky GOK JSC's Vostok-2 Mine
2) JSC Zakamensk's Barun-Narynskoe
3) CJSC Novoorlovsky GOK's Spokoininskoe Mine
4) LLC Lemontovsky Mining and Processing Plant

As we noted earlier, Russia accounts for ~3% of global production. They want to increase that percentage in 2023-2024. The country wants to start mining its Tyrnyauz tungsten and molybdenum deposit, which it hopes will 3.5x tungsten production by 2035.

Rwanda

Rwanda generated ~1,100 tons of tungsten in 2022. Most of the country's production comes from artisanal/small-scale operations within two main provinces: Nyakabingo and Gifurwe.

In most of the processes, tungsten is the primary metal extracted. In others, it's a byproduct of tin production.

Spain

Spain produced ~700t of tungsten in 2022. However, the country hopes to increase its production in the future. Almonty Industries (All) plans to restart its Los Santos mine, which it put on care and maintenance in 2020.

There's also the Barruecopardo joint venture between Oaktree Capital (yes, *that* Oaktree Capital) and Ormonde Mining PLC.

The mine, which restarted in 2019 after a 40-year hiatus, is expected to produce 140t per month at full capacity.

United Kingdom

The UK hasn't mined tungsten since 2017 due to environmental restrictions, low tungsten prices, and lack of available capital. For a while, Wolf Minerals hoped to turn on its Hemerdon tungsten and tin project in Devon.

The open pit and beneficiation plant would've generated ~2,900t/yr of tungsten and 563t/yr of tin. However, Wolf couldn't maintain positive cash flow during the ramp-up and on October 2018, declared bankruptcy.

Uzbekistan

Uzbekistan only has one operating tungsten deposit, Ingichki, which Ingichki Metals LLC controls.

However, the country ceased production from Ingichki in 2014.

In 2017, IFG Capital Partners signed an agreement with Uzbekistan's state geology department to explore seven other potential tungsten deposits in Samarkand. The $300M deal hopes to establish a new tungsten deposit containing ~130Kt.

Vietnam

Vietnam produced ~4,800t in 2022. 91% of the country's supply (4,350t) comes from one company, Nui Phao Mining Ltd (Masan Resources on the Vietnam stock exchange). Nui Phao is the largest producer outside China and operates one of the lowest-cost tungsten mines globally.

In other words, ~6% of global tungsten supply comes from one mine in Vietnam. That is not antifragile. Due to lower grades and lower throughput from its beneficiation plant, Nui Phao has seen tungsten production decline 15% YoY.

Zimbabwe

Zimbabwe's flagship tungsten mine, RHA Tungsten, is on care and maintenance. I read an article suggesting that the mine would restart in 2022, but I haven't seen anything to confirm that.

Secondary Supply: What It Is & Where It Comes From

Secondary supply is easy to define but impossible to track. There are two kinds of secondary supply: **recycled scrap materials** and **stockpiles.**

Recycled materials account for ~25-30% of global supply or ~21,000 tons annually.

Here's a snapshot of secondary tungsten supply from an April 2021 *MDPI Journal* article.

3.2. Secondary Resources

Currently, the only secondary resource of tungsten used in industry is tungsten scrap. It has already been used as a substitute for tungsten ore concentrates at conversion plants [39]. Tungsten scrap (e.g., metal drill scrap, superalloys, and tungsten carbide products scrap, and powder metallurgical tungsten new scrap) could be divided into three types: new scrap (by-products of tungsten materials or products), old scrap (spent tungsten-bearing materials), and unrecovered scrap (excess reactants) [1]. The W grade of tungsten scrap is in the range of 40–95 wt.% [40]. Since 2000, a wide variety of tungsten scrap recycling methods have been used globally. The methods to process tungsten-bearing scrap for tungsten recovery can be classified into four groups: hydrometallurgy, melting metallurgy, direct recycling, and semidirect recycling [39]. Approximately 30% of world tungsten demand is met through tungsten scrap recycling [41].

Another possible secondary resource of tungsten is tungsten tailings. They are solid waste generated in the process of tungsten ores beneficiation. Because of the relatively low tungsten content in the ore, around 0.4–0.6% on average [42], the production of 1 t of tungsten concentrate (50–65% WO_3) generates 7–10 t of tailings [43]. The major components of tungsten tailings are typically SiO_2, Al_2O_3, CaO, and Fe_2O_3, while W, Cu, S, Sn, Zn, Be, and Bi are the major trace elements [44]. Much of the wolframite in tungsten tailings is below 25 μm [45], and the scheelite is below 74 μm [46]. Essentially, the remaining tungsten minerals in tailings are mainly in the fine and ultrafine fractions, which makes it difficult for reprocessing by conventional methods. Nevertheless, the incomplete statistics of tungsten tailings deposits around the world, presented in **Table 4**, indicates more than 100 Mt of tailings, containing about 96 kt of WO_3. As a result, there may be a great potential for recovering tungsten from these unexploited secondary resources.

The other form of secondary supply is **government stockpiles.** For example, the United States buys, sells, and stores tungsten (along with other critical minerals) under the Defense Logistics Agency (or DLA).

These reserves are a fail-safe if China or Russia remove global supply.

It's impossible to predict how much DLA has tungsten at any given time. However, we can see the trend in stockpile sales since 2018 (see below).

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022e**
Production:					
Mine	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Ores and concentrates	4,050	2,760	2,020	1,590	2,000
Other forms[1]	10,400	11,100	8,660	10,400	12,000
Exports:					
Ores and concentrates	284	583	480	441	600
Other forms[2]	3,210	2,780	2,470	2,970	4,200
Shipments from Government stockpile:[3]					
Concentrate	1,180	663	728	1,030	700
Other forms	—	—	34	93	—

The last two lines show that from 2018 to 2022, the US has sold 4,301 tons of tungsten. The US has spent the past two decades draining its critical mineral stockpiles (easier than raising taxes, right?).

In 1952, the US critical mineral stockpile was worth $42B (inflation-adjusted). Today, it's worth $888M. The US has sold ~76Mlbs of tungsten alone during that timeframe.

I bet the US defense department is structurally short tungsten after decades of zero wars, an oversupplied market, and no incentive to stockpile after WWII. Historically, the US could tap domestic mines for more tungsten; if that didn't work, they'd import some from China.

But both of those options are gone. The US has severely underinvested in tungsten production, so it can't meet incremental stockpile demands at current WO3 spot prices. And China, as we've discussed, will likely ban *more,* not *fewer,* critical minerals.

How do I know that the US is approaching a stockpile problem? Take this *Defense News* article from May 2022 (emphasis added):

> *"Congress has repeatedly authorized multimillion-dollar sell-offs of the U.S. strategic minerals stockpile over the past several decades, but Washington's increased anxiety over Chinese domination of resources critical to the defense industrial base has prompted lawmakers to* ***reverse course and shore up the reserve.***
>
> ***The House Armed Services Committee will seek to bolster the National Defense Stockpile of rare earth minerals in the fiscal 2023 defense authorization bill****, Defense News has learned. And earlier this week, the Defense Department submitted its own legislative proposal to Congress asking the committee to authorize* ***$253.5 million in that legislation to procure additional minerals for the stockpile.***
>
> *The stockpile includes valuable minerals essential to defense supply chains, such as titanium, tungsten and cobalt."*

You don't make those types of decisions if your tap is full. Then, a few months later, in December 2022, Senator Tommy Tuberville of Alabama wrote an op-ed in the *Federal Times,* encouraging the US to build domestic critical mineral supply chains (emphasis mine):

> *Where are we getting our imports? Mostly from Russia, China, and their surrogates around the world. We're importing these materials from one country*

> *waging brutal and unprovoked war on one of our allies and another country with a human rights abuse record that's too long to list — not to mention the other nations they prey upon for financial and military gain.*
>
> *All the while, America boasts these minerals in abundance right here. This is a disgrace — and it's a serious threat to our national security and military preparedness.*
>
> *America's enormous mineral wealth is sitting right under its citizens' feet in vast tracts of federal and state lands. Yet, we import more than 50% of our supply of 31 of the 35 critical minerals as defined by the Department of Interior. We import 100% of our supply of 14 of the same minerals. And our dependence on foreign countries is growing.*

You don't see these stories with full stockpiles and BFF relations with China.

Unfortunately, the US's pending tungsten stockpile issues come when its military inventory approaches new lows.

NATO Military Committee Chair Rob Bauer recently said of US military inventory:

> "*The bottom of the barrel is now visible. We started to give away from half-full or lower warehouses in Europe*"

We're approaching an inflection point in tungsten supply. The US will quickly run out of stockpiled tungsten and flip from net seller to buyer over the next 12-18 months.

Moreover, there is a non-zero probability of China banning tungsten supply from global markets, just like it did germanium and gallium earlier this year.

And if I'm honest, it's a win-win for China if they do. They've spent decades building domestic supply chains from raw material production to smelting and refining. The US hasn't.

We could see 200-400% price increases if China restricts tungsten supply, as Ronald Limbaugh explained in his book *Tungsten in Peace & War* (emphasis added):

> *"The increase in supply from these sources was not enough to balance the loss of tungsten from Communist countries during a period of strong worldwide demand (Grainger, 1965; Engineering and Mining Journal, 1967). As a result,* ***the annual average U.S. price of tungsten concentrate in 1966 was more than four times greater than that of 1963****."*

As Robert Friedland said in a recent Northern Miner convention, *"you would've needed a telescope to see these prices."*

With that said, let's create the supply side of our model.

Making The Supply Side Of Our Model

We made the following assumptions in our supply-side growth model. First, we assumed that global supply would shrink by ~4% annually from 2022 to 2025 due to:

- ➢ Longer lead times for new tungsten mines
- ➢ Increased environmental regulations
- ➢ Lower grades at existing mines
- ➢ Resource nationalism

Here are the results.

Global Production	**2022**	**2023E**	**2024E**	**2025E**	*2022-2025 Growth %*
United States	0	0	0	0	*#DIV/0!*
Austria	900	855	850	850	*-5.56%*
Bolivia	1,400	1,350	1,325	1,300	*-7.14%*
China	71,000	71,000	70,000	69,000	*-2.82%*
Portugal	500	485	475	450	*-10.00%*
Russia	2,300	2,300	2,150	2,000	*-13.04%*
Rwanda	1,100	1,100	1,100	1,050	*-4.55%*
Spain	700	700	700	650	*-7.14%*
Vietnam	4,800	4,800	4,350	4,250	*-11.46%*
Other Countries	1,400	1,400	1,100	1,100	*-21.43%*
Total Primary Production (t)	84,100	83,990	82,050	80,650	*-4.10%*
Secondary Production					
Scrap	21,025	21,000	20,800	20,500	*-2.50%*
Total Production (P+S)	105,125	104,990	102,850	101,150	*-3.78%*

There are a few things to remember about the supply model. Vietnam, for instance, relies on *one mine* for its entire production. Issues with that mine could result in drastic negative changes to our supply estimates.

The same applies to countries relying on artisanal methods, like Rwanda.

I should also mention that starting January 1, 2026, the US Department of Defense will implement a more widespread ban on critical mineral imports from conflict zones like China, Russia, Iran, etc. All of which negatively affect supply.

How To Update Our Supply-Side Model

The USGS Mineral Yearbook/Survey Summary provides some of the best information on global tungsten supply. But that's an annual publication. Between releases, we can set Google alerts for "tungsten mining" or "tungsten production."

We can also create a Koyfin watchlist for every mining company with "tungsten" in its description.

Finally, just follow the news. War outbreaks in Rwanda probably aren't good for Rwanda's artisanal tungsten mining operations. A flood in Vietnam might not be good for Vietnam's only tungsten mine. China restricting half its global supply … you get the idea.

Concluding Supply

Tungsten is a small and highly opaque market, which is both good and bad. It's good in that you can analyze every producing country within a few pages of this report. But bad in the sense that production data is often unreliable, hidden from the public, or just a plain guess.

The best we can do is get supply *directionally* right. We don't need to stick it within 1-2 tons to make a lot of money off the potential deficits.

Onto demand.

The Demand Side: Primary & Secondary Drivers

Tungsten demand is pretty straightforward. As I mentioned, there are three main demand drivers:

1) Military
2) Semiconductors/Robotics
3) EVs

Let's start with Military Demand.

Military Demand

It's easy to slip and write 5,000 words on every global conflict that could/would/might happen in the next 12-24 months. But I won't. If anyone should do it, it should be Alex. So Alex, if you're reading this, get on it!

What we can broadly say is that the world is leaning more towards global war today than it was a few years ago. Israel and Palestine. Russia and Ukraine. China and Taiwan. Three international conflicts with the US caught in the middle.

War is great for tungsten demand. So great that tungsten prices increased by *700%* during World War I. Back to Limbaugh's book (emphasis mine):

> *"In one two-week period of tense diplomacy in the summer of 1915, prices quoted for high-speed steel nearly doubled. As submarine warfare took its toll on Allied shipping, tungsten rose an astonishing 700% above prewar prices, dropping back later in the year after ore imports eased domestic shortages …*
>
> *Lead jumped 250% in the first year of war, and then dropped 28% in the last two week sof July 1915.*
>
> *Ferrotungsten, quoted at $0.60/lb in 1914, was up to $2.50/lb by July 1915. Pig iron rose from $13.75/ton in mid-1915 to $34/ton by the end of the war. Mercury jumped more than 30%."*

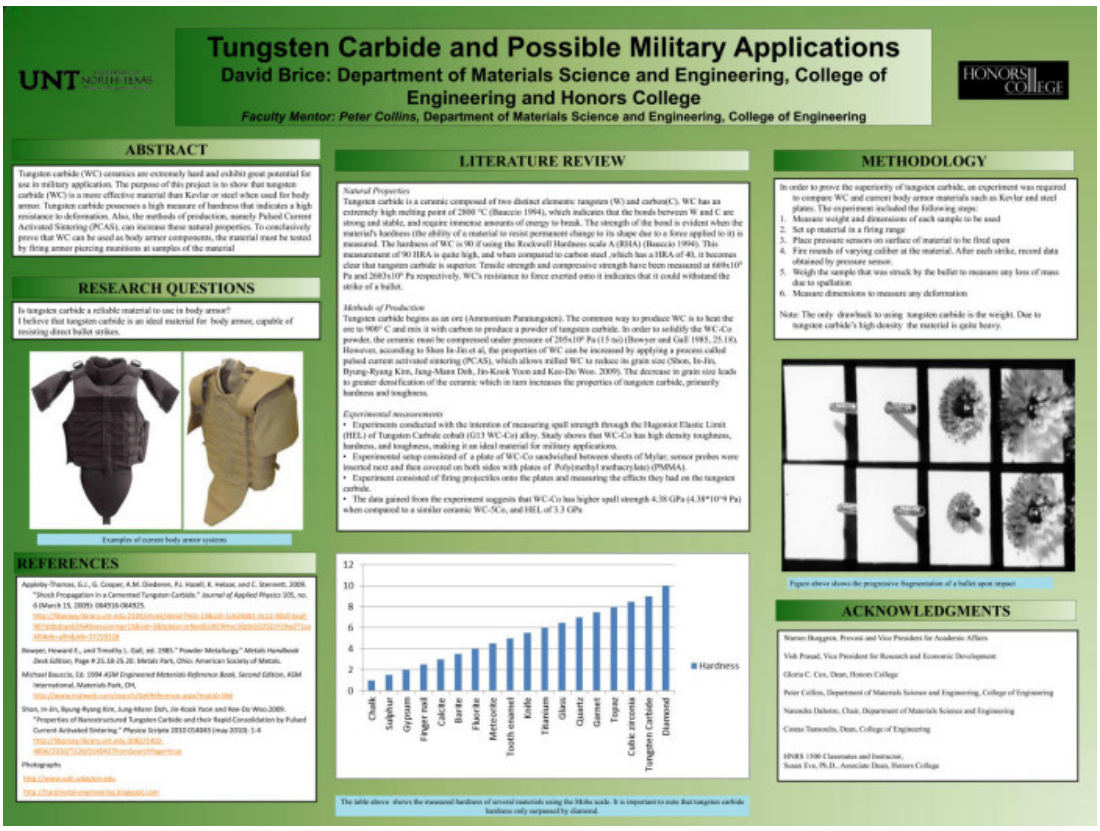
These price movements are possible in tungsten during wartime.

Almonty Industries (All) published a few examples of recent military tungsten applications in its October investor presentation:

- ➢ Poland ordered **116x M1A1 Abrams tanks with tungsten armor** (deliverable end 2024) + further **250 Abrams tanks** (deliverable 2025/2026)
- ➢ Romania and other countries also expressed their interest in Abrams tank
- ➢ France **increased the military budget by 40%** for this decade
- ➢ Australia announced **biggest military budget in decades**
- ➢ Japan has recently unveiled an **ambitious military build-up**, renowned as the most significant since World War II, commonly referred to as "rearmament"
- ➢ China **increased their military budget by 7%** and is working to become the leader in hypersonic projectiles

All of these things point to greater tungsten demand.

If you think about it, tungsten is the perfect military metal. It's nearly as hard as diamond, incredibly heat-resistant, boasts a high melting point, and is non-toxic. Here's a great graphic from the University of North Texas on tungsten's military applications.



Today, military accounts for ~10% of global demand or 8,410 tons.

Let's shift to our second primary demand driver, Semiconductors/Robotics.

Semiconductors & Robotics

Tungsten is an ideal metal for robotic arms in heavy equipment manufacturing due to its high melting point. There's something called an "EDM Process" in manufacturing. Which basically means that you use a spark (i.e., flame) to cut metal. The more heat-resistant and high melting point the metal is doing the EDM process, the better.

Using tungsten as an EDM process is also cheaper than using diamonds, silver, or gold.

Then there's tungsten applications in the semiconductor industry. I had no idea, but semiconductor fabricators use tungsten hexafluoride gas to cover chips in a thin tungsten layer.

Doing this increases the chip's conductivity while insulating it from higher temperature exposure (remember tungsten's high melting point). The gas also allows the chips to interconnect and generate electrical signals.

We've covered semiconductor demand many times over the past year, so I'll copy/paste what I wrote in our Tin Industry Primer (see below).

> *But take something like semiconductors. The world has an insatiable demand for more data centers, advanced AI/ML, autonomous vehicles, and wearable devices. That's not stopping, either.*
>
> *Here's McKinsey's latest AI Hardware report on semiconductor demand (emphasis added):*
>
> > *"AI applications generate vast volumes of data—about 80 exabytes per year, which is expected to increase to 845 exabytes by 2025. In addition, developers are now using more data in AI and DL training, which also increases storage requirements.* ***These shifts could lead to annual growth of 25 to 30 percent from 2017 to 2025 for storage****—the highest rate of all segments we examined."*
>
> *Let's look at Data Center spending from 2017 to 2025E to put that into perspective. In 2017, Data Centers had a market value of ~$5-6B, split between "Inference" and "Training" data storage.*
>
> *By 2025, McKinsey estimates that Data Centers will reach a market value of ~$13-15B, with $9-10B coming from "Inference" data and $4-5B from "Training" data.*
>
> *In fact, we've been pounding the table on semiconductor demand since 2020.*
>
> *Sure, technology and semiconductor demand will decline in a global recession. But the only thing that does is push the long-term thesis back 1-2 years.*
>
> *Companies like Intel are spending $20B+ to build two new semiconductor foundries in the United States.*

Tungsten is a direct beneficiary of the global hunger for more chips.

Finally, there's EV-driven demand. This one's simple. There is currently ~1.5kg of tungsten in every EV. However, that could change.

Battery manufacturers and auto OEMs are testing niobium tungsten oxide as a way to reduce charge times and increase power density within EV batteries. If successful, it would increase the required tungsten by 1kg to 2.5kg *per EV vehicle.*

EVs currently represent ~30% of global tungsten demand at ~25,200 tons. A change from 1.5kg per installed vehicle to 2.5kg would result in an ***additional ~17,000 tons of demand.***

Other Demand Drivers

EVs, Semiconductors/Robotics, and Military represent 50% of global tungsten demand. The other 50% include industries like:

- ➢ Mining: 13%
- ➢ Energy: 10%
- ➢ Construction: 8.5%
- ➢ Aerospace: 8%
- ➢ Consumer: 6%
- ➢ Other 5%

We're bullish on all of those end markets and think demand far outpaces supply over the next 2-3 years.

But let's test that assumption as we build the demand side of our model.

Building The Demand Side Of Our Model

We're making the following assumptions in our demand model:

- ➢ 9% annual growth from military/defense
- ➢ 11% annual growth from semiconductor/robotics
- ➢ 5% annual growth from EVs
- ➢ Increase to 1,000 tons of government stockpile purchases
- ➢ ~4% annual growth in total

Here are the results.

Primary Demand	2022	2023E	2024E	2025E	2022-2025 Growth %	Annualized Growth
Military/Defense	10,513	11,354	12,262	13,243	*25.97%*	*8.66%*
Semi/Robotics	10,513	11,564	12,720	13,992	*33.10%*	*11.03%*
EVs	31,538	33,114	34,770	36,509	*15.76%*	*5.25%*
Mining	13,666	14,076	14,499	14,933	*9.27%*	*3.09%*
Energy	10,513	10,828	11,153	11,487	*9.27%*	*3.09%*
Construction	8,936	8,489	8,064	7,661	*-14.26%*	*-4.75%*
Aerospace	8,410	8,915	9,449	10,016	*19.10%*	*6.37%*
Consumer	6,308	6,371	6,434	6,499	*3.03%*	*1.01%*
Other	5,256	5,256	5,256	5,256	*0.00%*	*0.00%*
Total Primary	**105,651**	**109,966**	**114,608**	**119,597**	*13.20%*	*4.40%*
Secondary Demand	**2022**	**2023E**	**2024E**	**2025E**	*2022-2025 Growth %*	
Govt Stockpiles	0	500	800	1,000	*#DIV/0!*	
Total Secondary	**0**	**500**	**800**	**1,000**	*#DIV/0!*	
Total Demand	**105,651**	**110,466**	**115,408**	**120,597**	*14.15%*	*4.72%*

Our model shows that the demand for tungsten will increase from 105,651 tons in 2022 to 119,597 tons by 2025.

There are a few ways we can be off in our demand model.

First, we could drastically underestimate military demand at ~9% annual growth. Military demand could grow by 20-50% annually if we enter a serious military conflict.

Second, EV demand could collapse as tungsten metal adoption fails to gain traction, reducing our ~5% annualized growth to zero or negative.

Finally, overall tungsten demand could compress if we can't get new supply online in time (i.e. if tungsten prices stay low and mines remain in care and maintenance).

Bringing It Together: Estimating Tungsten Deficits

Alright, we've done the work to create supply and demand side models. Now it's time to estimate future potential deficits and their subsequent magnitudes.

Here are the results from our model.

Year	2022	2023E	2024E	2025E
Supply	105,125	104,990	102,850	101,150
Demand	105,651	110,466	115,408	120,597
(Deficit)/Surplus	**-526**	**-5,476**	**-12,558**	**-19,447**
% Magnitude	-0.50%	-4.96%	-10.88%	-16.13%

According to our model, tungsten is already in a slight deficit, and by 2025, it will be short over 19,000 tons for a 16% supply deficit.

This is a **significant** supply shortfall. To compare, our copper deficit is estimated at ~5%, uranium at ~12%, and tin at ~15%.

The next question is how do we play this deficit in financial markets? Like tin, there aren't many ways to do it. Let's dig in.

How To Play The Deficit In Financial Markets

I ran a Koyfin screener for any company with the word "tungsten" in its business description (plus removing Chinese-listed companies). This gets me 45 results (see below).

Ticker	Name	Flag	Last Price	↓ Market Cap	Trading Region	Description	Industry	Sparkline Graphs (1Y)
• 526371	NMDC Limited		169.70	$ 5.97B	Asia / Pacific	NMDC Limited, to...	Metals and Mining	
• 000426	Inner Mongolia Xingye Silver &Tin Mi...		9.11	$ 2.35B	Asia / Pacific	Inner Mongolia Xi...	Metals and Mining	
• AYA	Aya Gold & Silver Inc.		9.00	$ 804.04M	United Stat...	Aya Gold & Silver ...	Metals and Mining	
• A103140	Poongsan Corporation		36,300.00	$ 765.32M	Asia / Pacific	Poongsan Corpor...	Metals and Mining	
• COPP	Copperstone Resources AB		1.17	$ 200.64M	Europe	Copperstone Res...	Metals and Mining	
• FWZ	Fireweed Metals Corp.		1.15	$ 121.72M	United Stat...	Fireweed Metals ...	Metals and Mining	
• FVL	Freegold Ventures Limited		0.340	$ 104.66M	United Stat...	Freegold Venture...	Metals and Mining	
• AII	Almonty Industries Inc.		0.50	$ 85.37M	United Stat...	Almonty Industrie...	Metals and Mining	
• PREM	Premier African Minerals Limited		0.0026	$ 82.82M	Europe	Premier African M...	Metals and Mining	
• 539151	Arfin India Limited		40.07	$ 76.45M	Asia / Pacific	Arfin India Limite...	Metals and Mining	
• LCY	Legacy Iron Ore Limited		0.0180	$ 75.61M	Asia / Pacific	Legacy Iron Ore L...	Metals and Mining	
• 7610	Lianyou Metals Co., Ltd.		71.60	$ 69.75M	Asia / Pacific	Lianyou Metals C...	Metals and Mining	
• CUSN	Cornish Metals Inc.		0.1750	$ 68.25M	United Stat...	Cornish Metals In...	Metals and Mining	
• EQR	EQ Resources Limited		0.0660	$ 68.15M	Asia / Pacific	EQ Resources Li...	Metals and Mining	
• A081150	Tplex Co., Ltd.		3,290.00	$ 61.63M	Asia / Pacific	Tplex Co., Ltd. op...	Metals and Mining	
• CORAZA	Coraza Integrated Technology Berhad		0.56	$ 59.96M	Asia / Pacific	Coraza Integrate...	Metals and Mining	
• G6M	Group 6 Metals Limited		0.0850	$ 55.92M	Asia / Pacific	Group 6 Metals Li...	Metals and Mining	
• PXC	Phoenix Copper Limited		0.320	$ 50.12M	Europe	Phoenix Copper L...	Metals and Mining	
• ADZN	Adventus Mining Corporation		0.375	$ 49.17M	United Stat...	Adventus Mining ...	Metals and Mining	
• AZM	Azimut Exploration Inc.		0.76	$ 47.27M	United Stat...	Azimut Exploratio...	Metals and Mining	

Ticker	Name	Flag	Last Price	↓ Market Cap	Trading Region	Description	Industry	Sparkline Graphs (1Y)
AZY	Antipa Minerals Limited		0.0170	$ 46.09M	Asia / Pacific	Antipa Minerals Li...	Metals and Mining	
PEX	Peel Mining Limited		0.1200	$ 45.75M	Asia / Pacific	Peel Mining Limit...	Metals and Mining	
TGN	Tungsten Mining NL		0.0750	$ 38.67M	Asia / Pacific	Tungsten Mining ...	Metals and Mining	
5781	Toho Kinzoku Co., Ltd.		1,347.00	$ 36.14M	Asia / Pacific	Toho Kinzoku Co.,...	Metals and Mining	
GENM	Generation Mining Limited		0.2350	$ 31.48M	United Stat...	Generation Minin...	Metals and Mining	
SRT	Strata Investment Holdings Plc		0.1800	$ 20.01M	Asia / Pacific	Strata Investment...	Metals and Mining	-
PAM	Pan Asia Metals Limited		0.1500	$ 17.08M	Asia / Pacific	Pan Asia Metals L...	Metals and Mining	
GWR	GWR Group Limited		0.0780	$ 16.43M	Asia / Pacific	GWR Group Limit...	Metals and Mining	
SMD	Strategic Metals Ltd.		0.1900	$ 15.39M	United Stat...	Strategic Metals ...	Metals and Mining	
ELT	Elementos Limited		0.1150	$ 14.68M	Asia / Pacific	Elementos Limite...	Metals and Mining	
VMS	Venture Minerals Limited		0.0110	$ 14.06M	Asia / Pacific	Venture Minerals ...	Metals and Mining	
SKY	Sky Metals Limited		0.0460	$ 13.83M	Asia / Pacific	Sky Metals Limite...	Metals and Mining	
NCF	Northcliff Resources Ltd.		0.0300	$ 10.51M	United Stat...	Northcliff Resour...	Metals and Mining	-
ATN	Aterian plc		0.0083	$ 10.27M	Europe	Aterian plc engag...	Metals and Mining	
FE	FE Battery Metals Corp.		0.255	$ 8.99M	United Stat...	FE Battery Metals...	Metals and Mining	
GMET	Golden Metal Resources PLC		0.0775	$ 8.32M	Europe	Golden Metal Res...	Metals and Mining	-
MLYCF	Multi-Metal Development Ltd.		0.0310	$ 7.79M	United Stat...	Multi-Metal Devel...	Metals and Mining	
EVR	EV Resources Limited		0.0115	$ 7.20M	Asia / Pacific	EV Resources Li...	Metals and Mining	
PTX	Platinex Inc.		0.0350	$ 6.96M	United Stat...	Platinex Inc., toge...	Metals and Mining	
GCM	Green Critical Minerals Limited		0.0090	$ 6.71M	Asia / Pacific	Green Critical Min...	Metals and Mining	
NPM	NewPeak Metals Limited		0.0010	$ 6.55M	Asia / Pacific	NewPeak Metals ...	Metals and Mining	
CMB	CMC Metals Ltd.		0.0550	$ 5.87M	United Stat...	CMC Metals Ltd. ...	Metals and Mining	
HPY	Happy Creek Minerals Ltd.		0.0600	$ 5.80M	United Stat...	Happy Creek Min...	Metals and Mining	
THR	Thor Energy Plc		0.0158	$ 5.50M	Europe	Thor Energy Plc e...	Metals and Mining	

I notice two things when running this screen. First, the 1YR charts are all terrible. Two of the most tungsten-focused miners are small-to-micro cap stocks trading in Australia or Canada's TSXV.

Only a handful of the 45 names exclusively explore/mine tungsten. Most miners on the list produce tungsten as a byproduct of either silver, gold, copper, or tin.

And when I say bad charts, I mean *awful* charts.

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These are the charts you want to see in bombed-out, capital-starved industries. It means *nobody* cares about these companies. They're left for dead.

But we want a more liquid market cap to express our views. That's why I like Almonty Industries (AII).

Almonty Industries (AII)

Almonty Industries (AII) is a pure-play tungsten miner with an $85M market cap and a $158M EV.

The company has one producing mine (Panasqueira), two current projects, one mine on care and maintenance, and another mine under construction.

There are a few reasons why I like the company. First, the CEO owns 19.50% of the common shares with a history of operating and selling mine assets at an earnings premium.

Second, the company has a 15-year offtake agreement with The Plansee Group at a floor price of $235/mtu with no upside cap. The offtake agreement alone will provide $580M in revenue at run-rate annual production levels.

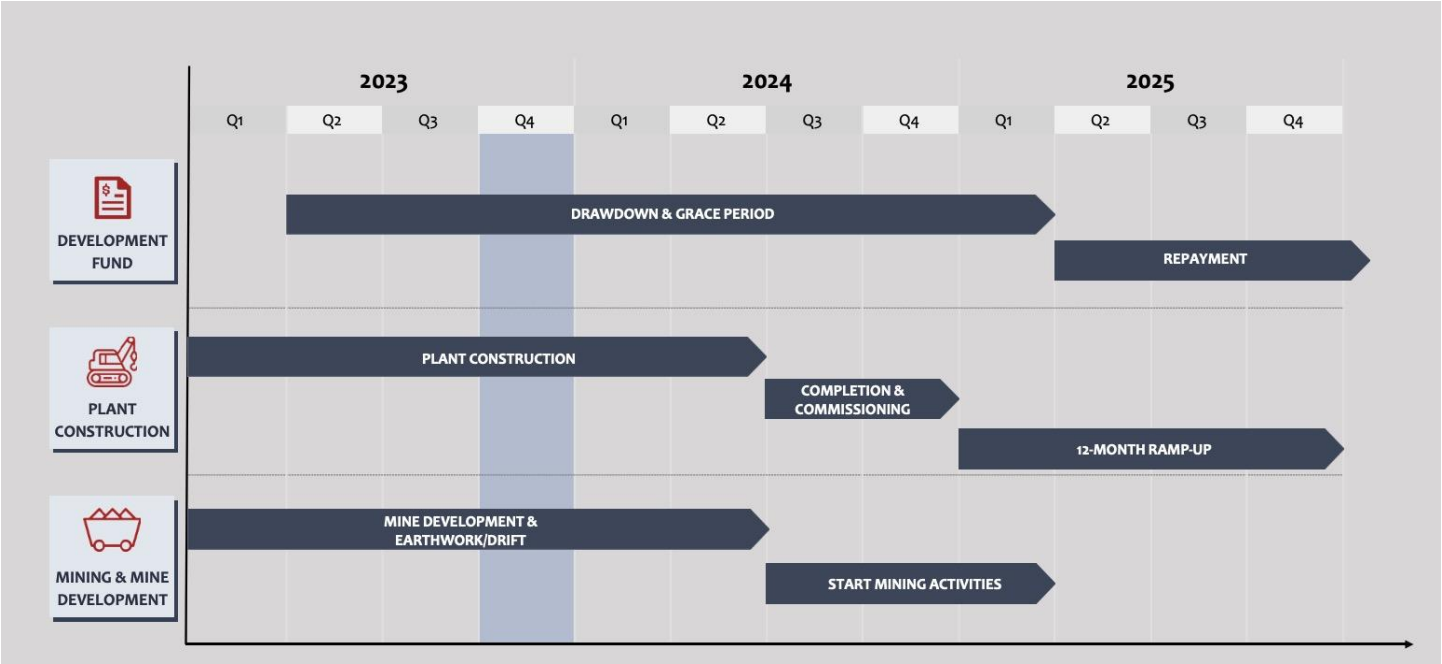
Third, the Sangdong deposit in South Korea is a terrific asset. It's the world's largest tungsten deposit based on Inferred Resources (230,222 tons of contained WO3). It contains 3x higher average grades than Chinese deposits. And it's in the lowest-quartile cash cost, nearly half as low as Chinese SOEs.

The other good thing about Sangdong is that it's a past-producing asset. This means it has all the existing infrastructure and necessary permitting approvals to restart production.

All has funded Sangdong through debt and equity issuance. The company secured project financing from KFW Ipex Bank with attractive terms:

- ➢ $75M credit facility
- ➢ 3M LIBOR/SOFR + 2.3% Interest
- ➢ 2YR Grace Period
- ➢ 6.25YR Repayment Period

Here's the latest Sangdong project timeline (via All's October 2023 presentation).



Phase 1 of plant construction should close by year-end 2023. Actual mining activities should start by Q2 2024. The LOC paydown begins at the end of Q1 2025.

So, the company has ~3-4 quarters to profitably mine and build cash reserves to meet their obligations without further diluting shareholders.

How much cash can the Sangdong mine generate? The current tungsten price is around $300-$325/mtu. All ran its feasibility study at $370/mtu, which is higher than the current price but not unrealistic given the supply/demand imbalance we discussed earlier.

Here's the cash flow model from the study.

Table 22-2. Economic Analysis – Base Case Price $370/MTU WO_3

		Unit	Total	Year								
				-2	-1	1	2	3	4	5	6	7	8
Production	Ore Tonnes	*t*	**4,743,720**		0	451,522	640,308	640,704	640,536	640,499	640,298	640,240	449,613
	WO3	*%*	**0.42**		0	0.44	0.49	0.44	0.48	0.45	0.43	0.29	0.33
	Contained t WO3	*t WO3*	**19,985**			1,985.50	3,126.81	2,840.35	3,076.45	2,890.47	2,762.46	1,830.43	1,472.92
	Plant recovery					81%	81%	81%	81%	81%	81%	81%	81%
	Recovered t WO3	*t WO3*	**16,188**			1,608.25	2,532.72	2,300.68	2,491.93	2,341.28	2,237.60	1,482.65	1,193.06
	Recovered MTUs		**1,618,817**			160,825	253,272	230,068	249,193	234,128	223,760	148,265	119,306
	Concentrate grade	*%*				65%	65%	65%	65%	65%	65%	65%	65%
	T of concentrate / year	*t/year*				2,474.24	3,896.49	3,539.51	3,833.73	3,601.97	3,442.45	2,280.99	1,835.48
	T of concentrate / month	*t/month*				206.19	324.71	294.96	319.48	300.16	286.87	190.08	152.96
	Containers / month					10.31	16.24	14.75	15.97	15.01	14.34	9.50	7.65
Revenue	**Revenue**	*$US M*	**467**			**46.41**	**73.09**	**66.40**	**71.92**	**67.57**	**64.58**	**42.79**	**34.43**
Costs	Mine	*$US M*	**150**			14.24	20.19	20.20	20.20	20.19	20.19	20.19	14.18
	Plant	*$US M*	**51**			4.83	6.84	6.85	6.85	6.85	6.84	6.84	4.81
	G&A	*$US M*	**23**			2.16	3.07	3.07	3.07	3.07	3.07	3.07	2.15
	Total OPEX	*$US M*	**223**			**21.23**	**30.10**	**30.12**	**30.11**	**30.11**	**30.10**	**30.10**	**21.14**
Capital	Mine development and definition drilling	*$US M*	**9.48**	3.68	3.77			1.22	0.41	0.41			
	Mine infrastructure & Services Cap. Exp.	*$US M*	**5.39**	0.91	3.60	0.88							
	Processing plant capex	*$US M*	**32.05**	12.39	19.66								
	Surface infrastructure & mobile equipment	*$US M*	**13.59**	8.30	5.29								
	Owners costs	*$US M*	**6.63**	4.75	1.89								
	Working capital	*$US M*	**1.89**			1.89							
	Mine Closure	*$US M*	-										
	Total capex	*$US M*	**69.04**	**30.03**	**34.21**	**2.77**	-	**1.22**	**0.41**	**0.41**	-	-	-
Cash flow	Project Pre-tax Cash flow	*$US M*	**175.15**	- 30.03	- 34.21	22.42	42.99	35.06	41.40	37.05	34.48	12.69	13.30
	Project Cumulative cash flow	*$US M*		- 30.03	- 64.23	- 41.82	1.18	36.24	77.64	114.69	149.17	161.86	175.15
	Tax **(calculated using 24.2%)**	*$US M*	**42.10**					8.48	10.02	8.97	8.34	3.07	3.22
	Project After-tax Cash flow	*$US M*	**133.05**	- 30.03	- 34.21	22.42	42.99	26.58	31.38	28.09	26.13	9.62	10.08
	Project Cumulative after tax cash flow	*$US M*		- 30.03	- 64.23	- 41.82	1.18	27.75	59.13	87.22	113.35	122.97	**133.05**

All estimates that Sangdong will generate a net cumulative $133M in after-tax cash flow.

Remember, we're not bullish on AII because we think it will stay around $370/mtu. Tungsten prices can rise 25, 50, or even 100% in a severe supply crunch. And when that happens, tungsten producers trade at premium prices. For reference, CEO Lewis Black sold a prior tungsten producer for ***21x earnings*** in 2007 after a supply squeeze from four years of declining production (2004-2007).

However, this is still a mining company with plenty of risks. First, the company has drawn down $50M+ on its $75M credit facility. If it needs more capital above $75M, expect it to come from share dilution.

Second, capex costs could rise as mining companies face labor shortages, cost inflation, and heavy equipment supply chain issues.

Finally, tungsten is a critical mineral with military/defense applications. There is a scenario, albeit somewhat dystopian, that the US government decides, "you know what, I think we'll take Sangdong from here," and nationalizes the mine.

I'm also not rushing to buy here. Yes, the stock is down 60% from its recent highs. But I want lower prices. I'll get excited if AII hits CAD 0.35 or a ~CAD 80M market cap. At

that price, you could buy the company for a ~25% cash flow yield if tungsten prices get (and stay) above $370/mtu.

Conclusion: Stalking A Capital-Starved Industry

Tungsten has all the ingredients for a massive supply/demand imbalance over the next few years. Multiple demand drivers from military/defense, semiconductors/robotics, and EVs are jockeying for more tungsten supply.

At the same time, the industry has been oversupplied for nearly a decade, and there's no incentive to bring new capacity online at the current price. Plus, there's the growing concern that China, the world's largest producer, could turn off its supply at any point in the name of Resource Nationalism.

The result is an industry with a potential 19,000-ton deficit or 16% of total demand. History shows that when that happens, tungsten prices skyrocket, the miners make tons of money, and assets/deposits trade for 20x+ earnings.

Nobody's talking about, looking at, or even thinking about tungsten. Reading this Industry Primer puts you in the top 1% of investors knowledgeable about tungsten. All that's left is to sit and wait for the market to give us our fat pitch price.