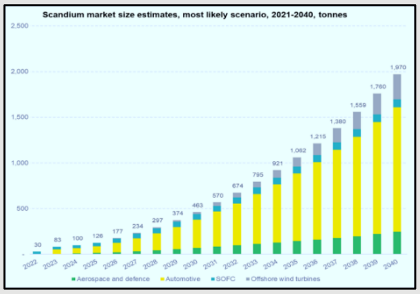
eResearch

Industry Report October 18, 2023



Source: Imperial Mining Corporate Presentation

	Price ($)	Mkt Cap (US$ M)
American Rare Earth	*A$0.13*	*$37*
Ardea Resources	*A$0.51*	*$64*
Australian Mines	*A$0.01*	*$6*
Auxico Resources	*$0.20*	*$14*
Doubleview Gold	*$0.62*	*$84*
Globex Mining	*$0.81*	*$33*
Idaho Strategic Res.	*US$4.86*	*$60*
Imperial Mining Grou	*$0.05*	*$8*
Ionic Rare Earths	*A$0.02*	*$55*
MegaWatt Lithium	*$0.16*	*$1*
NioCorp	*$4.97*	*$120*
Nuinsco Resources	*$0.01*	*$2*
Rio Tinto	*£52.16*	*$107,117*
Scandium Int'l	*$0.03*	*$8*
Sunrise Energy Meta	*A$0.80*	*$42*
Texas Mineral Res.	*US$0.43*	*$32*

Source: S&P Capital IQ

Christopher P. Thompson, CFA, MBA, P.Eng.

Director of Equity Research
eResearch Corp.

Note: All figures are in Canadian dollars unless otherwise noted.

Scandium – A Metal for a Green Future

Your Guide to Understanding and Investing in Scandium Companies

Scandium (Sc) is an important metal with many applications in various industries, particularly in the production of aluminum-scandium (Al-Sc) alloys and solid oxide fuel cells (SOFCs). Scandium is also used in ceramics, electronics, lasers, lighting, and radioactive isotopes.

REPORT HIGHLIGHTS:

- **Scandium Uses**
  - Scandium is a lightweight, soft metal with a high melting point and good electrical and heat conductivity.
  - Combined with aluminum to create stronger, lightweight, and corrosion-resistant (Al-Sc) alloys for aerospace, aviation, defense, automotive, and energy transmission applications.
  - Sc-Al alloy powders offer the potential for 3D printing of complex metal structures that are difficult or expensive to produce using traditional fabrication methods.
- **Scandium in Solid Oxide Fuel Cells**
  - Scandium improves SOFC performance by stabilizing zirconia-based electrolyte materials.
  - Scandium also lowers SOFC operating temperatures, thus reducing thermal stress, improving start-up times, and extending lifespan.
- **Current Supply and Demand**
  - The current scandium market indicates that demand is being met by supply, with approximately 20 to 30 tonnes in demand for 2022.
  - However, if 0.1% of the annual global aluminum production was alloyed with 0.5% scandium, it would result in an annual global scandium demand of 345 tonnes, which is 11x the current demand.
- **Company Spotlight – Imperial Mining Group (TSXV: IPG)**
  - **Imperial Mining's** flagship project is the Crater Lake scandium-rare earths property in Quebec, Canada, with the potential to become a low-cost producer of high-purity scandium oxide.
  - The Preliminary Economic Assessment (PEA) for Crater Lake estimates a post-tax $NPV_{10\%}$ of $1.72 billion and an after-tax IRR of 32.8% over a 25-year mine life.
  - Recent optimization efforts have increased Sc recovery to 96% and rare earths recovery to 94% at the leaching stage, with a mine-to-precipitate recovery of 76% for Sc and 60% for rare earths.
  - A recent NI 43-101 compliant resource update pegged the total resource at 27.7 million tonnes at an average grade of 271 ppm scandium oxide. Work continues on a Feasibility Study (FS), permitting, design and engineering studies, and offtake agreements.

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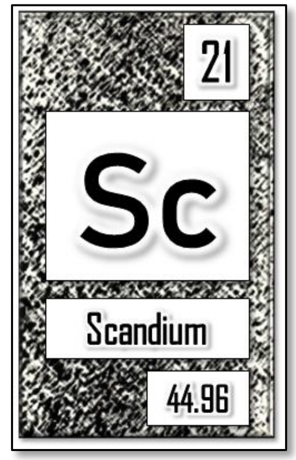
1.0 Scandium Overview

1.1 What is Scandium



Scandium (Sc) is a silvery white metal with the Atomic Number 21 and an atomic weight of 44.955.

On the periodic table, it is the lightest transition metal and has many important industrial applications.

Scandium was discovered in 1879 by Lars Frederik Nilson of Sweden and named after "Scandia", the Latin name for Scandinavia.

According to the US Geological Survey (USGS), the primary applications of scandium are in aluminum-scandium (Al-Sc) alloys and Solid Oxide Fuel Cells (SOFC). Additionally, scandium is also used in ceramics, electronics, lasers, lighting, and the production of radioactive isotopes.

Scandium is on the Critical Minerals list for Australia, Canada, the European Union (EU), and the United States (US), but not the United Kingdom (UK).

1.2 Scandium Uses

Scandium is a relatively soft, lightweight metal that has a high melting point, making it easy to shape. Scandium is also a good conductor of electricity and heat.

Scandium is alloyed with aluminum (Al-Sc) similar to how niobium is alloyed with steel. Scandium increases the strength of aluminum but reduces its weight and provides it with increased flexibility, heat resistance, and corrosion resistance, making it ideal for applications in aerospace, aviation, automotive, defense, and energy transmission.

Scandium is also utilized in SOFCs to enhance the performance and stability of certain components, particularly the electrolyte and interconnect materials. **Bloom Energy** (NYSE: BE) uses scandium in its fuel cell ink coating.

In addition, scandium is also used in ceramics, electronics, EV batteries, green energy solutions, lasers, lighting, and radioactive isotopes.

Al-Sc alloys can also be used in 3-D printing applications. **Relativity Space** (*Private*), a rocket building company, uses Al-Sc alloys for 3-D printing of rockets for commercial orbital launch services. Visit the company's website to see the rocket being 3-D printed (https://www.relativityspace.com/factory).

When scandium is added in small amounts with aluminum, it produces an alloy that is very light and strong. These alloys find applications in various industries, including:

- Aerospace:
  - Al-Sc alloys are employed in aerospace applications, particularly for the construction of lightweight structural components such as aircraft frames, wings, and engine parts. These alloys offer high strength-to-weight ratios, contributing to improved fuel efficiency and overall performance.
- Military Equipment:
  - Al-Sc alloys are utilized in military equipment and armour plating due to their strength and durability.

- These alloys help reduce the weight of military vehicles and equipment while maintaining structural integrity.

- Consumer Electronics:
  - Al-Sc alloys can be found in some high-end consumer electronic devices, like smartphones and laptops.
  - Their lightweight properties contribute to the portability of these devices.
- Automotive Industry:
  - While less common than in other sectors, Al-Sc alloys have been explored for their potential use in automotive manufacturing.
  - Their lightweight nature could aid in improving fuel efficiency and reducing emissions.
  - This application offers one of the largest potential demands for scandium oxide (Sc_2O_3).
- Sporting Goods:
  - The alloys are used in the manufacturing of sporting goods, such as baseball bats, bicycle frames, and golf club shafts.
  - The lightweight and durable nature of Al-Sc alloys enhances the performance of these products.

1.3 Scandium in Solid Oxide Fuel Cells

Scandium plays an important role in enhancing the performance and efficiency of SOFCs, which are devices that convert chemical energy into electrical energy. SOFCs use hydrogen or hydrocarbon fuels and oxygen to produce electricity, making them suitable for various applications, such as power generation and industrial processes.

One of the main uses of scandium in SOFCs is to stabilize the zirconia-based electrolyte materials. The electrolyte is a key component of the SOFC that allows the transport of oxygen ions through the cell. By adding scandium oxide to the zirconia electrolyte, the structure and ionic conductivity of the material are enhanced.

Higher ionic conductivity means faster and more efficient electrochemical reactions within the fuel cell.

Another benefit of adding scandium to the zirconia-based electrolyte is that it lowers the operating temperature of SOFCs compared to conventional high-temperature SOFCs.

Lowering the operating temperature has several advantages, such as reducing thermal stress on cell components, increasing start-up times, and extending cell lifespan.

Moreover, scandium-stabilized zirconia (ScSZ) electrolytes enable SOFCs to achieve a trade-off between high performance and durability, making them more attractive for commercial applications.

Scandium's positive impact extends to the compatibility of SOFCs with hydrocarbon-based fuels. ScSZ allows these fuel cells to operate efficiently with fuels like natural gas or methane, broadening their application scope and offering flexibility in fuel sources.

While scandium is a relatively rare and costly element, its benefits in improving SOFC performance and expanding its operational capabilities justify its use in these energy systems.

Researchers and developers continue to explore ways to optimize scandium utilization in SOFCs and reduce associated costs to further enhance their commercial viability.

2.0 Scandium Sources

Scandium is often grouped with the rare earth metals and is the first of the transition metals. It occurs in low quantities in over 800 mineral species and is relatively difficult to extract from ores.

Scandium is typically found in relatively low concentrations within numerous heavy lanthanide ores, as well as in certain deposits of tin, tungsten, and uranium.

Thortveitite, one of the few minerals recognized for its significant scandium content, is relatively scarce and, consequently, does not constitute a substantial source of scandium.

There are no primary scandium mines currently operating in the world. Scandium is typically obtained as a by-product from other mining operations, such as the extraction of rare earth elements (REE), uranium, nickel-cobalt, titanium, vanadium, or other metals. It is often found in low concentrations in these ores, and its production is a secondary outcome of these mining processes.

Scandium production was historically associated with three mining locations worldwide: Zhovti Vody, Ukraine, where uranium and iron mines yielded scandium; Bayan Obo, China, known for its rare earth mines; and the Kola Peninsula, Russia, where scandium was sourced from apatite mines.

More recently, new projects in Australia and North America have emerged (see Section 4.0). Notable among these initiatives are the Nyngan Scandium Project in New South Wales, the Elk Creek Project in Nebraska, and the Crater Lake Project in Quebec.

Imperial Mining's Crate Lake Project, with its high concentration of scandium, could become a mine with scandium as its primary product. These undertakings share a common goal of optimizing scandium production by improving efficiency and scaling operations. They hold the potential of providing a more economically viable and reliable supply source, aligning with the increasing demand for scandium across various industries.

2.1 Extracting Scandium

Scandium extraction methods are contingent upon the mineralization source, its mineralogy, and economic considerations. Most of the scandium used today is a by-product of the refining of other elements. However, syenite-type deposits with higher scandium grades hold the potential for scandium to be the primary metal extracted.

The section below provides an overview of several mineralization sources for scandium and the techniques employed in its extraction:

1. **Syenite and Alkaline Igneous Rock-Hosted Deposits:**
    - These rocks can be favorable hosts for several rare metals, including REE, niobium, and scandium.
    - **Extraction Method**: After beneficiation (which may involve processes like crushing, grinding, and magnetic separation), scandium can be extracted using a hydrometallurgical process that involves leaching, solvent extraction, precipitation, and calcination. Each step is tailored depending on the source and scandium concentration.
2. **Nickel-Cobalt Lateritic Ores:**
    - These deposit types are one of the primary sources of scandium. When nickel and cobalt are processed from laterite ores, scandium can be extracted as a by-product even though the scandium is in relatively low concentrations.

- **Extraction Method**: After beneficiation, high-pressure acid leaching (HPAL) is the primary method used.
- The ore is subjected to acid under high pressures and temperatures to extract the nickel and cobalt. The remaining solution is further processed to extract scandium, using various chemical methods, such as solvent extraction or precipitation.

3. **Thortveitite:**
   - This is a mineral that can have up to 45% scandium in the form of scandium silicate. However, thortveitite deposits of a significant size are rare.
   - **Extraction Method**: After beneficiation to increase the scandium content, scandium is usually extracted using acid-leaching methods.
4. **Apatite:**
   - A common calcium phosphate mineral that sometimes contains trace amounts of scandium.
   - **Extraction Method**: After concentrating the apatite (often through flotation), scandium can be extracted via acid leaching, usually sulfuric acid or hydrochloric acid leaching.
5. **Bauxite:**
   - Bauxite is the primary ore for aluminum, and it can contain trace amounts of scandium. As with lateritic nickel-cobalt ores, the scandium is typically recovered as a by-product.
   - **Extraction Method**: The Bayer Process, primarily used to extract alumina from bauxite, involves digesting the ore with sodium hydroxide. Scandium, along with other trace elements, ends up in the red mud residue. Various methods, including acid leaching, are then applied to recover scandium from this red mud.
6. **Uranium and Rare Earth Element Ores:**
   - While primarily mined for elements like uranium or REE, these ores can sometimes contain noteworthy concentrations of scandium.
   - **Extraction Method**: For these ores, in-situ leaching, heap leaching, or conventional underground or open-pit mining can be employed to get the ore. Once the ore is accessed, scandium is typically extracted alongside other rare earth elements using a series of acid-leaching and solvent-extraction steps.
7. **Titanium Dioxide Production Waste**:
   - Scientists at a technology centre in Sorel-Tracy, Quebec, Canada, have found a way to isolate and extract scandium from titanium dioxide production waste.

2.2 Comparison of Syenite-Hosted vs Nickel Laterite Scandium Deposits

Syenite-Hosted Scandium Deposits

Syenite-hosted scandium deposits are associated with alkaline igneous rocks such as at **Imperial Mining's** Crater Lake Deposit. Syenite-type deposits have several advantages when compared with nickel laterite deposits.

The Crater Lake Project's higher scandium grades hold the potential for scandium to be the primary metal extracted and ongoing research and development efforts are focused on optimizing the scandium extraction processes to find more cost-effective methods to meet the growing demand for scandium.

At Crater Lake, the NI 43-101 Mineral Resource hosts an Indicated Mineral resource grade of 275.9 ppm (0.028%) Sc_2O_3 and an Inferred Mineral resource grade of 268.4 ppm (0.027%) Sc_2O_3, and additional REE resource with grades in the Indicated Mineral resource category of lanthanum at 605.5 ppm, neodymium at 596.9 ppm, praseodymium at 160.1 ppm, dysprosium at 66.4 ppm, and terbium at 11.75 ppm.

It is one of the few syenite-hosted deposits with demonstrable production potential where scandium is the principal ore metal. The deposit also hosts other REE mineralization as potential valuable by-products further enhancing the economics of the project.

Nickel Laterite Scandium Deposits

Nickel laterite deposits are residual concentrations formed by tropical-style weathering of ultramafic rocks. Scandium in these deposits is often found and can be recovered as a by-product in nickel and/or cobalt production.

Mineral resources of scandium in nickel laterite deposits report lower resource grades ranging between 40 ppm (0.004%) and 300 ppm (0.030%) Sc2O3.

Scandium extraction from nickel laterite ore is a complex and resource-intensive process. The relatively low scandium concentrations in these ores require extensive processing, which can impact the overall economic feasibility of scandium production.

However, recent studies indicate that scandium can be found in high concentrations in limonite nickel laterite ores, with concentrations reaching up to almost 900 ppm (0.09%) Sc2O3. An example of this type of project is the Nyngan Laterite Project in New South Wales, in eastern Australia which plans to extract scandium as its main product from limonitic laterite ores, targeting a scandium reserve grade of 409 ppm (0.4%) Sc or 627 ppm (0.62%) Sc_2O_3 but at a low tonnage of only 1.43 Mt.

Comparison

The main difference between these two types of deposits lies in their host rocks and the minerals that contain scandium. In syenite-hosted deposits, scandium is primarily found in hedenbergite and hastingsite within alkaline igneous rocks.

In contrast, nickel laterite deposits host scandium within ultramafic rocks, and it can be concentrated to exploitable levels through weathering processes.

Another key difference is the economic viability of these deposits. While the Crater Lake deposit has demonstrated production potential, making syenite-hosted deposits an attractive source for scandium extraction, nickel laterite deposits offer the advantage of recovering scandium as a by-product during nickel and cobalt production.

2.3 Metallurgical Process at Crater Lake to Extract Scandium and REE

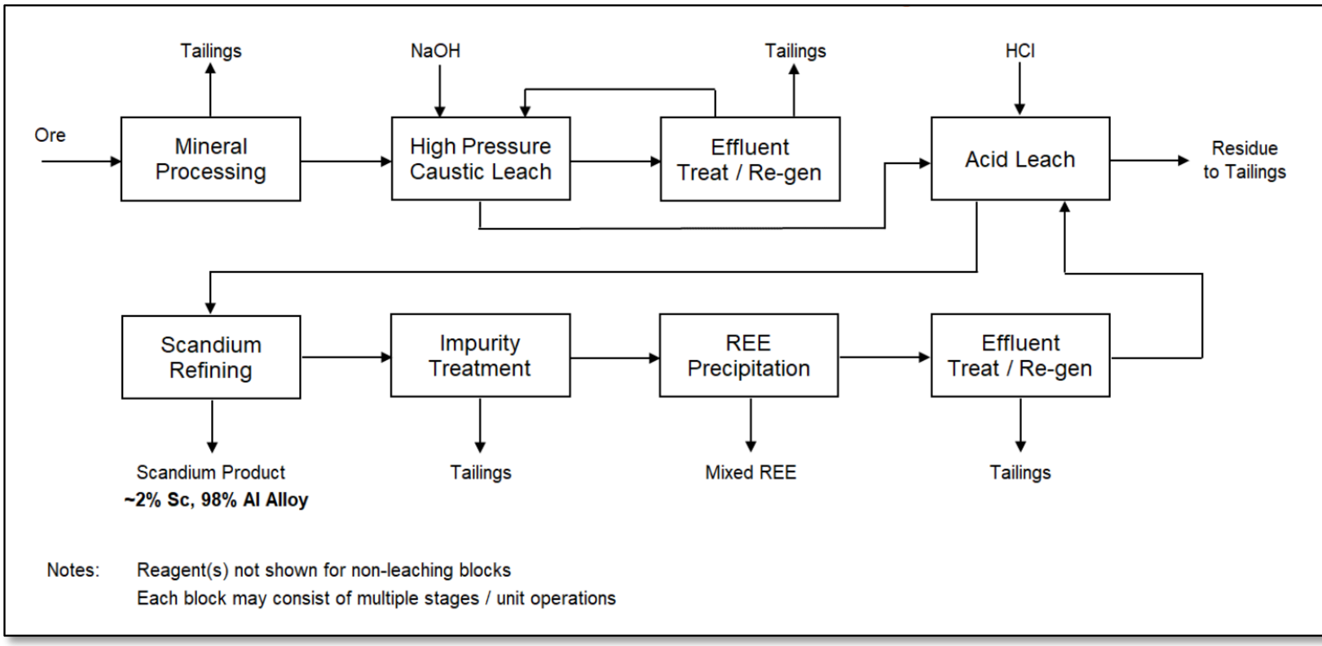
Imperial Mining has been working on methods and processes for the extraction of scandium and REE from the Crater Lake project mineralization.

Central to this endeavor is the hydrometallurgical flowsheet development program. This program, which began in early 2019, is anchored on a patent-pending, two-stage hydrometallurgical process. At the end of the process, the primary leach solution would yield a Sc_2O_3 product and a mixed REE carbonate.

In February 2023, **Imperial Mining** announced the filing of patent applications with the **USPTO** and the **CIPO** for its two-stage hydrometallurgical methods and processes.

Results from the hydrometallurgy flowsheet development program will help in the engineering design of **Imperial Mining's** Pilot Plant program for Crater Lake, set to begin in the latter part of 2023.

Figure 1: Crater Lake – Simplified Conceptual Process Flowchart



Source: Imperial Mining / SGS Presentation (2023)

3.0 Scandium and REE Demand

In the current market, it appears that demand is being met by supply, in the range of 20 to 30 tonnes in 2022.

However, it may also be a "supply and demand conundrum", as it is unclear if the supply of scandium and the demand for scandium are interdependent, and which should be addressed first to stimulate the other.

Growth in Aluminum Scandium (Al-Sc) Alloy

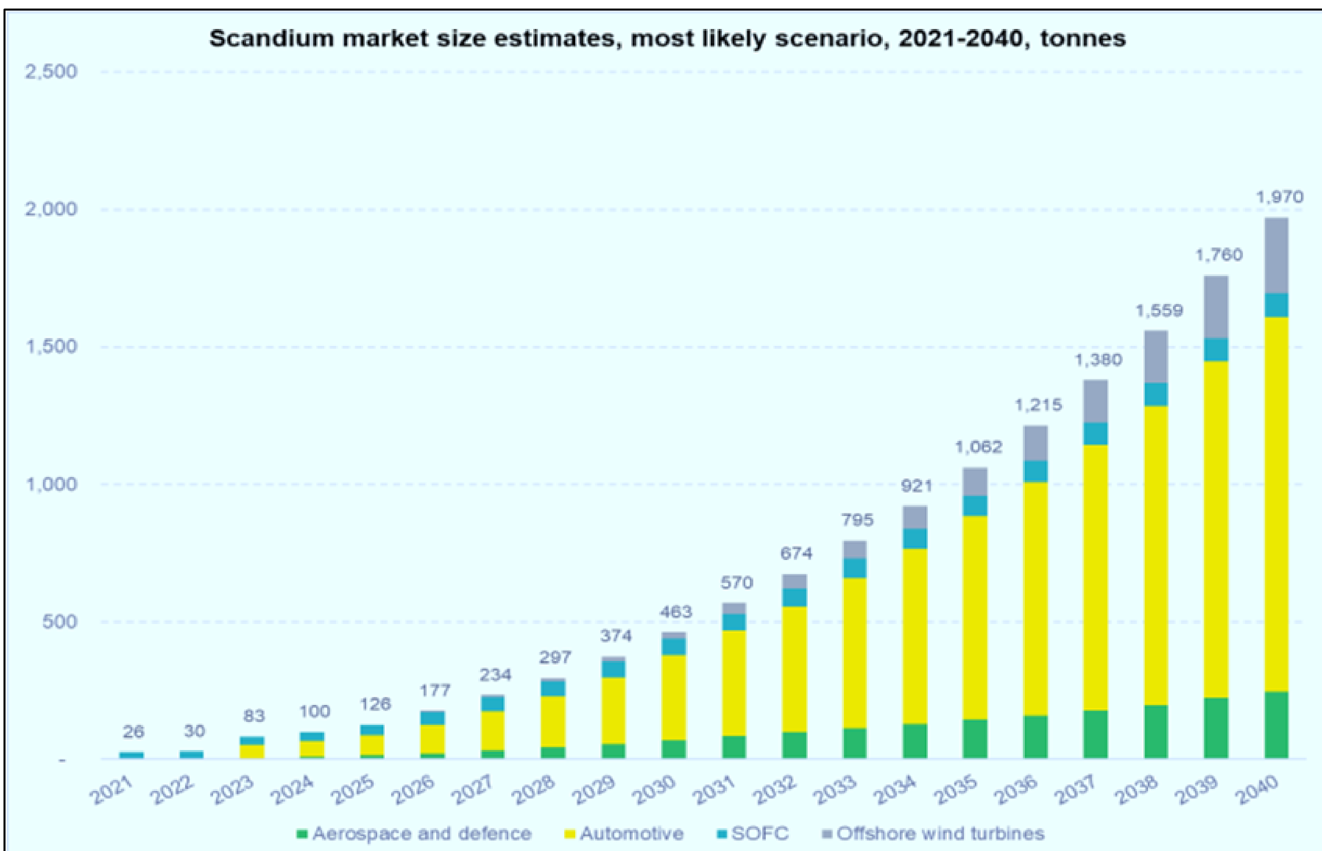
In the context of scandium demand, aluminum alloys represent a significant potential. According to the USGS, the total world production of aluminum was 69 million tonnes in 2022.

If the aluminum industry alloyed just 0.1% of the annual production with a scandium concentration of 0.5%, it would translate to an annual global scandium demand of 345 tonnes, or 11 times the current demand.

Market forecasts suggest that global demand might approach this amount in the near term if reliable production of scandium comes on-stream.

Other scenarios are more aggressive estimating that scandium demand for the car industry could reach 5,300 tonnes by 2030 with total scandium demand reaching 5,560 tonnes. This amount would lead to a scandium deficit of 3,760 tonnes based on the projected supply growth.

Figure 2: Scandium Demand Scenarios



Source: Imperial Mining Corporate Presentation (2023) Citing Internal EY Market Study (2022)

Potential Demand Growth from Additional Uses

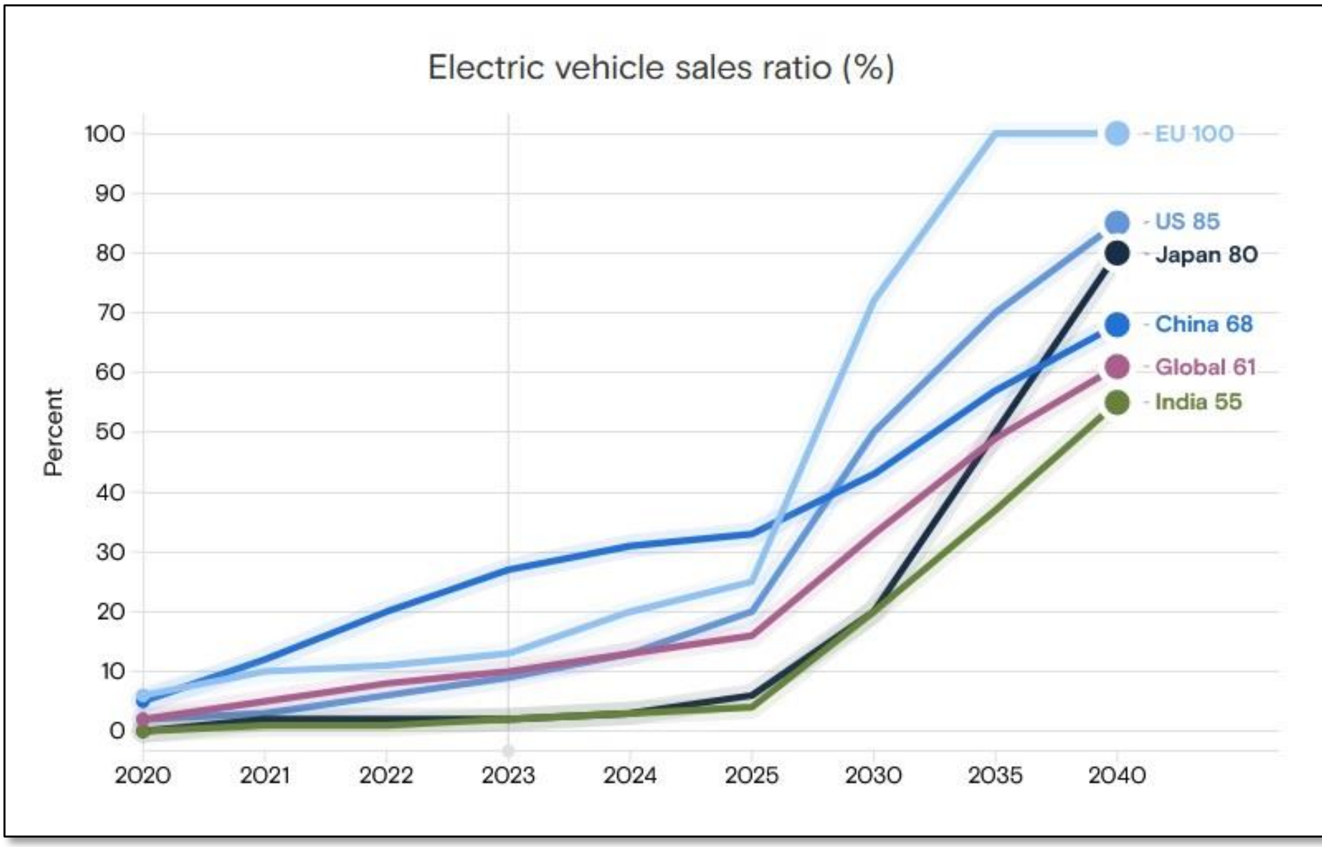
In addition to being a key component in Al-Sc alloys, scandium finds extensive applications across diverse industries, including electric and hybrid vehicles, high-efficiency motors, lightweight transportation systems, and renewable energy systems. Figure 2 illustrates the expanding demand for scandium, encompassing growth in aerospace, automotive, defense, offshore wind turbines, and SOFCs.

This collective demand trajectory has the potential to reach approximately 1,970 tonnes by 2040 (66 times the current demand) from areas including:

- Reducing Weight in Vehicles:
  - Scandium enhances the properties of aluminum alloys and makes the metal lighter, which is particularly useful in the production of lightweight vehicles including aircraft and electric vehicles where light weight is extremely important.
  - Analysts estimate that the EV industry's demand for lighter-weight metals could increase the demand for scandium as the percentage of EVs sold increases to reach government-mandated zero-emission goals (see Figure 3).
  - Other applications include lightweight personal vehicles, including bikes, e-bikes, and scooters.
- Offshore Wind Projects:
  - The **Global Wind Energy Council** reported that the global offshore wind industry delivered 8.8 GW of new wind energy connected to the grid in 2022 and forecasts that 380 GW of new offshore wind projects will be built by 2032.
  - Scandium is employed in offshore wind projects primarily for its role in enhancing the properties of aluminum alloys used in the construction of turbine components.
- Solid Oxide Fuel Cells (SOFCs):
  - Scandium's excellent electrical properties and heat resistance make it valuable in the development of SOFCs since it improves the performance and durability of these energy conversion devices.
  - The growth in SOFCs is being driven by several factors and applications, primarily clean energy production, backup power systems, decentralized energy generation (e.g. remote power generation and portable power packs), and integration with renewable energy.
  - According to a report by S&P Global Market Intelligence, **Bloom Energy** has been one of the biggest scandium purchasers for its SOFCs used as a power source. **Bloom Energy** utilizes scandium and other REE in its fuel cell ink coating.

In addition, various governments, including Canada, the US, the UK, and the EU are pushing for supply chain security for critical minerals, including scandium, and are locking down domestic supplies and supplies from trading partners.

Figure 3: The Shift to EVs as a Percentage of Vehicle Sales



Source: IHS Global Insight; Goldman Sachs Research

4.0 Scandium Supply

Scandium is abundant in nature, even more so than lead. However, unlike many metals, scandium does not occur naturally in its pure, metallic state. As a result, it is spread out in the earth's crust and found in low concentrations in over 100 different minerals.

Scandium is primarily produced as a by-product or co-product during the processing of other ores or tailings, with China, the Philippines, and Russia as the leading producers.

In China, scandium is obtained during the production of iron, REE, titanium, and zirconium. These processes use feedstocks containing scandium and extract it from the final waste streams using solvent extraction techniques.

In the Philippines, scandium is a by-product of nickel mining. Countries such as Russia, Ukraine, and Kazakhstan extract scandium during uranium processing.

However, Australia and Canada have identified scandium resources that could be primarily scandium mines, with mining companies such as **Imperial Mining** in Canada and **Scandium International** (TSX: SCY) in Australia advancing these projects in production.

According to the USGS, the global production of scandium oxide (Sc_2O_3) was estimated to range from 20 to 30 tonnes in 2022, even though the potential production capacity is around 80 tonnes.

In 2020, **Sumitomo Metal Mining's** Taganito facility in the Philippines, which focuses on nickel and cobalt, began commercial production of a new scandium by-product recovery plant. It was designed to recover 7.5 tonnes of scandium oxide per year. Previously, **Sumitomo** had entered into a long-term sales agreement with a major US-based fuel cell manufacturer for the scandium oxide.

Rio Tinto (LSE: RIO | NYSE: RIO | ASX: RIO) announced in June 2021 that it opened a new, $6 million, scandium pilot facility at its Rio Tinto Fer et Titane (RTFT) metallurgical complex in Sorel-Tracy, Quebec. The facility utilizes a new method, pioneered by RTFT, to derive high-grade Sc_2O_3 as a by-product from titanium dioxide manufacturing. The facility can produce up to three tonnes of Sc_2O_3 per year and **Rio Tinto** is contemplating further capital ventures to augment its production potential.

In 2022, **Rio Tinto** announced that it aimed to boost its production from three tonnes to 12 tonnes of Sc_2O_3 annually. This expansion will incorporate new modules in their current plant and cost between $30 and $35 million (US$22 to US$26 million) with production set to begin in 2024.

4.1 Mining Companies Focussed on Scandium

Investors interested in the scandium industry can gain exposure to the market through mining companies focusing on scandium exploration, development, or mining. In Figure 4, we list some mining companies with scandium projects and provide additional details on each company in the sections below.

Figure 4: Select Companies Producing, Developing, and Exploring for Scandium

COMPANY NAME	TICKER	PRICE 2023-10-17	MKT CAP (US$ M)	CASH (US$ M)	EV (US$ M)	EBITDA (M)	EV/ EBITDA
Producers							
Rio Tinto	LSE: RIO	£52.16	$107,117	$10,506	$112,204	$18,743	6.0x
Average					***$112,204***		***6.0x***
Median					***$112,204***		***6.0x***
Feasibility / Pre-Feasibility Stage							
Ardea Resources	ASX: ARL	A$0.51	$64.4	$7.1	$57.7	-$2.0	
Australian Mines	ASX: AUZ	A$0.01	$6.1	$3.1	$4.9	-$1.8	
NioCorp	TSX: NB	$4.97	$120.0	$2.3	$130.2	-$37.4	
Scandium Int'l	TSX: SCY	$0.03	$7.8	$1.4	$6.5	-$0.7	
Sunrise Energy Metals	ASX: SRL	A$0.80	$42.5	$11.2	$31.8	-$6.4	
Average					***$46.2***		
Median					***$31.8***		
PEA / Scoping Study Stage							
Imperial Mining Group	TSXV: IPG	$0.05	$8.1	$0.5	$7.6	-$0.9	
Ionic Rare Earths	ASX: IXR	A$0.02	$55.4	$7.4	$48.3	-$5.5	
Texas Mineral Res.	OTCPK: TMRC	US$0.4	$32.0	$1.4	$30.6	-$3.0	
Average					***$28.8***		
Median					***$30.6***		
Resource Stage (NI 43-101 / JORC)							
American Rare Earths	ASX: ARR	A$0.13	$36.9	$8.3	$29.1	-$2.3	
Nuinsco Resources	CSE: NWI	$0.01	$2.1	$0.1	$2.0	-$0.5	
Average					***$15.5***		
Median					***$15.5***		
Resource Definition Stage							
Auxico Resources	CSE: AUAG	$0.20	$13.7	$0.0	$18.9	-$3.6	
Doubleview Gold	TSXV: DBG	$0.62	$84.0	$2.6	$81.4	-$2.0	
Idaho Strategic Res.	NYSEAM: IDR	US$4.9	$59.6	$2.2	$62.9	$0.3	219.4x
Average					***$54.4***		***219.4x***
Median					***$62.9***		***219.4x***
Early Stage Exploration							
MegaWatt Lithium	CSE: MEGA	$0.16	$1.1	$0.0	$0.9	-$2.5	
Average					***$0.9***		
Median					***$0.9***		
Project Generator							
Globex Mining	TSX: GMX	$0.81	$32.9	$18.1	$15.2	-$1.0	

Source: S&P Capital IQ; eResearch Corp.

4.1.1 American Rare Earths Limited (ASX: ARR | OTC: ARRNF | FSE: 1BHA)

Summary:

- **American Rare Earths** is an Australian-based exploration and development company focused on REE.
- The company's mission is to provide critical materials for green tech, renewable energy, EV, national security, and future low-carbon industries.
- **ARR** focuses on the US market and holds mineral assets in the country, including 100% ownership of the Halleck Creek Project in Wyoming and La Paz Project in Arizona.
- The La Paz Project hosts a 170.6 Mt Total Rare Earth Oxide (TREO) resource that includes Sc_2O_3 at grades of 26 ppm.

Website:

- https://americanrareearths.com.au/

Stage of Scandium Project:

- Resource Stage

Scandium Project Resource Estimate:

- La Paz Project, Arizona, US

JORC: Estimated Resources at La Paz (2021)			
Resource Class	**Tonnage (Mt)**	**TREO (ppm)**	**TREO (kt)**
Indicated	35.2	459	16.14
Inferred	135.4	472	63.87
Total	**170.6**	**469**	**80.01**
Note: A cut-off grade of 300 ppm TREO was used for reporting mineral resources.			

Source: La Paz JORC MRE (2021)

JORC: Select REO at La Paz (2021)		
Element	**Oxide (ppm)**	**Total Oxide (kt)**
Scandium (Sc)	**Sc**: 17 **Sc_2O_3**: 26	4.41
Neodymium (Nd)	79.76	13.61
Praseodymium (Pr)	20.97	3.58
Dysprosium (Dy)	10.35	1.77
Terbium (Tb)	4.59	0.78
Samarium (Sm)	15.31	2.61

Source: La Paz JORC MRE (2021)

4.1.2 Ardea Resources Limited (ASX: ARL | OTC: ARRRF | FSE: A91)

Summary:

- **Ardea Resources** is an Australian-based exploration and development company focused on metals such as nickel, cobalt, scandium, gold, and PGM.
- The company's main projects include the wholly owned Kalgoorlie Nickel Project (KNP) in Kalgoorlie, Western Australia, and the Kalpini Project in Kalgoorlie-Boulder City, Western Australia.
- It also owns several smaller-scale nickel and gold prospects in that region. The company's mission is to create an ethical and sustainable nickel-cobalt resource to cater to the battery minerals supply chain.
- The KNP Project's Pre-Feasibility Study (PFS) was published in July 2023.
- The PFS projected a post-tax $NPV_{7\%}$ of A$4.98 billion and a post-tax IRR of 23% over 35 years of operations. CAPEX was estimated at A$3.12 billion with a 3.1-year payback period. Annual production is 30.0 kt of nickel and 2.0 kt of cobalt.
- The nickel laterite mineralization primarily hosts nickel and cobalt with scandium as a by-product of production. The current PFS does not include processing the scandium.

Website:

- https://ardearesources.com.au/

Stage of Scandium Project:

- Pre-Feasibility Study, working on a Feasibility Study.

Scandium Project Resource/Reserve Estimate:

- KNP, Kalgoorlie, Western Australia

JORC: Estimated Resources at KNP (2023)									
Resource Class	**Tonnage (Mt)**	**Nickel (%)**	**Cobalt (%)**	**Nickel (kt)**	**Cobalt (kt)**	**Sc Tonnage (Mt)**	**Sc (ppm)**	**Sc_2O_3 (ppm)**	**Sc (kt)**
Measured	22	0.94	0.079	207	17	18	40	61	0.7
Indicated	361	0.73	0.047	2,622	168	126	23	35	2.9
Inferred	471	0.70	0.043	3,272	199	14	23	35	0.3
Total	**854**	**0.71**	**0.045**	**6,101**	**384**	**158**	**25**	**38**	**3.9**

Notes:

- *KNP Goongarrie Hub PFS subset nickel, cobalt, and scandium mineral resource estimate (MRE) using a greater than 0.5% nickel cut-off grade.*
- *Scandium is expected to be produced as a by-product from the nickel and cobalt mining and processing at Goongarrie.*

Source: KNP JORC MRE (2023)

4.1.3 Australian Mines Limited (ASX: AUZ | OTC: AMSLF | FSE: MJH)

Summary:

- **Australian Mines** is an Australian mineral exploration and development company focusing on nickel, cobalt, and scandium deposits.
- Its flagship project is the wholly-owned Sconi Project in northern Queensland, Australia.
- **Australian Mines** also has two early-stage projects: Flemington, a cobalt-scandium-nickel-copper-gold project in New South Wales; and Lennard, a nickel sulphide project in Western Australia.
- The Sconi Project's Definitive Feasibility Study (DFS) was published in 2018 and a Mine Plan with an updated resource was issued in 2019.
- The Sconi Project has a post-tax $NPV_{8\%}$ of US$0.82 billion and a post-tax IRR of 15% over a 30-year mine life. CAPEX was estimated at US$0.97 billion with a 5.8-year payback period. Annual production is 46.8 kt of nickel sulphate and 7.0 kt of cobalt sulphate, with scandium sales of 7 t/y but average production capabilities of 48 t/y.
- **Australian Mines** used a long-term Sc_2O_3 price assumption of US$1,000/kg.

Website:

- https://australianmines.com.au/projects

Stage of Scandium Project:

- Feasibility Study

Scandium Project Reserve Estimate:

- Sconi Project, Queensland, Australia

JORC: Estimated Reserves at Sconi (2019)						
Resource Class	**Pit**	**Tonnage (Mt)**	**Nickel (%)**	**Cobalt (%)**	**Sc (ppm)**	**Sc_2O_3 (ppm)**
Proved	Greenvale	4.49	0.83	0.07	36	55
	Kokomo	1.52	0.72	0.15	58	89
	Lucknow	2.07	0.47	0.09	51	78
	Sub-total	**8.08**	**0.72**	**0.09**	**44**	**67**
Probable	Greenvale	13.08	0.73	0.05	29	44
	Kokomo	17.43	0.57	0.09	31	48
	Lucknow	18.71	0.42	0.08	38	58
	Sub-total	**49.22**	**0.55**	**0.08**	**33**	**51**
Total	**Greenvale**	**17.57**	**0.76**	**0.06**	**31**	**48**
	Kokomo	**18.96**	**0.58**	**0.10**	**33**	**51**
	Lucknow	**20.77**	**0.42**	**0.08**	**39**	**60**
	Total	**57.30**	**0.58**	**0.08**	**35**	**54**
Note: Sconi Project Ore Reserve summary based on variable nickel equivalent cut-off between 0.40% and 0.45%.						

Source: Sconi JORC MRE (2019)

4.1.4 Auxico Resources Canada Inc. (CSE: AUAG | OTC: AUXIF | DB: A0H)

Summary:

- **Auxico Resources** is a Canadian mineral exploration firm with a focus on REE, platinum group metals, niobium, tantalum, and other high-value metals.
- It primarily operates in Mexico, the Democratic Republic of the Congo (DRC), Colombia, Brazil, and Bolivia. It is currently the only North American company to commercially produce and sell monazite (phosphate mineral containing rare earth metals) sourced from the DRC.

Website:

- https://www.auxicoresources.com/

Stage of Scandium Project:

- Resource Definition Stage

Scandium Project:

- Minastyc Property, Colombia:
    - The project's focus is on REE and sampling of the various pits and trenches in 2021, which showed TREO grades of 65.57%.
    - However, test results on a sample from a pit on the property resulted in 47% tin content, plus tantalum, niobium, scandium, and rare earth metals.

4.1.5 Doubleview Gold Corp. (TSXV: DBG | OTC: DBLVF | FSE: 1D4)

Summary

- **Doubleview Gold** is a Canada-based mineral exploration and development company that specializes in the acquisition and exploration of precious metal properties.
- The company focuses on identifying, acquiring, and financing high-quality precious and base metal prospects in North America, with a specific emphasis on British Columbia, Canada.
- **Doubleview** is actively exploring the area surrounding its Hat Project following the discovery of gold-rich porphyry in that area.

Website:

- https://www.doubleview.ca/

Stage of Scandium Project:

- Resource Definition Stage

Scandium Project:

- Hat Copper-Gold Project, British Columbia, Canada
    - The Hat Project is a copper-gold porphyry-type deposit located in northwestern British Columbia, Canada.
    - Exploration and drilling have been focused on the Lisle copper-gold-cobalt-scandium mineral zone.

4.1.6 Globex Mining Enterprises Inc. (TSX: GMX | OTC: GLBXF | FSE: G1MN)

Summary

- **Globex Mining Enterprises Inc.** is a Canadian mineral exploration and development company. The company has been engaged in the acquisition and exploration of mineral properties in the US, Canada, and Germany.
- Currently, the company holds a mineral portfolio of 219 early to mid-stage exploration, development, and royalty properties containing a diverse range of minerals such as base metals, precious metals, specialty metals and minerals, rare earths and associated elements, and industrial minerals.
- The company's main objective is to purchase mineral properties, improve them through exploration, optioning, or joint ventures, and develop them to production, or in some circumstances sell the projects outright.

Website:

- https://www.globexmining.com/

Stage of Scandium Project:

- Project Generator

Scandium Project:

- Crater Lake South East (SE) property, Quebec, Canada
    - **Globex** owns the Crater Lake SE property, which consists of 38 contiguous claims totalling 1,863.45 hectares (over 4,600 acres) and is southeast of **Imperial Mining's** Crater Lake Scandium Project.
    - On the project, the main mineral occurrences were determined from the 30 grab samples that were collected in 2010.
    - Scandium mineralization was observed on **Globex's** property as 5 of the 30 samples returned values greater than 100 g/t Sc, including 228 g/t Sc, 180 g/t Sc, 161 g/t Sc, 133 g/t Sc, and 117 g/t Sc.

4.1.7 Idaho Strategic Resources, Inc. (NYSEAM: IDR)

Summary:

- **Idaho Strategic Resources** engages in the exploration and development of REE and REE-thorium projects, and gold production in Idaho, US.
- It produces gold from the Golden Chest Mine in the Coeur d'Alene Mining District.
- It owns the largest thorium resource in the US, which is known as the Lemhi Pass, and is the second-largest REE landholder in the US from its Lemhi Pass, Diamond Creek, and Roberts properties.

Website:

- https://idahostrategic.com

Stage of Scandium Project:

- Resource Definition Stage

Scandium Project:

- Diamond Creek Rare Earth Project, Idaho, US
  - The Diamond Creek Project hosts a historical resource of 70,000 tons of Rare Earth Oxides (REO) at an average grade of 1.22%.
  - Recent drilling results at Diamond Creek returned values of scandium ranging from 8 ppm to 16 ppm.
- Lemhi Pass REE-Thorium Project, Idaho, US
  - Lemhi Pass Project hosts a historical resource of 133,400 tons of thorium oxide (ThO_2).
  - Recent drilling results at Lemhi Pass returned values of scandium ranging from 8 ppm to 43 ppm.

4.1.8 Imperial Mining Group Ltd. (TSXV: IPG | OTC: IMPNF)

Summary:

- **Imperial Mining** is a Canadian mining exploration and development company engaged in exploring, acquiring, and developing technology and precious metal projects in Canada.
- Its current focus is to advance the Crater Lake Scandium-REE Project in Quebec, Canada. The Crater Lake Project contains scandium, dysprosium, lanthanum, neodymium, praseodymium, and terbium.
- The company also has two gold projects in Quebec.
- Crater Lake's PEA was published in 2022 with an estimated post-tax $NPV_{10\%}$ of $1.72 billion and an after-tax IRR of 32.8% over 25 years of operations. Total CAPEX was estimated at $870.1 million with a three-year payback period.
- Total mined metal production over the mining life was estimated at 110 t Sc_2O_3, 57,298 t of Sc-Al Master Alloy, and 23,578 t of REE hydroxide concentrate.
- **Imperial Mining** used a long-term Sc_2O_3 price assumption of US$1,500/kg.
- See Section 4.2 for more details on Imperial Mining and the Crater Lake Scandium-REE Project.

Website:

- https://imperialmgp.com/

Stage of Scandium Project:

- PEA

Scandium Project Resource Estimate:

- Crater Lake, Quebec, Canada

NI 43-101: Estimated Resources at Crater Lake (2023)								
Category	**Tonnage (Mt)**	**Sc (ppm)**	**Sc_2O_3 (ppm)**	**Dy_2O_3 (ppm)**	**La_2O_3 (ppm)**	**Nd_2O_3 (ppm)**	**Pr_2O_3 (ppm)**	**Tb_4O_7 (ppm)**
Indicated	11.8	179.9	275.9	66.4	605.5	596.9	160.1	11.7
Inferred	15.9	175.0	268.4	66.1	606.9	595.6	159.8	11.6
Note: The Crater Lake MRE has a cut-off Net Smelter Return (NSR) of $110.10/t.								

Source: Crater Lake NI 43-101 MRE (2023)

4.1.9 Ionic Rare Earths Limited (ASX: IXR | OTC: IXRRF | FSE: 6UH)

Summary:

- **Ionic Rare Earths** is a mineral exploration and development company specializing in finding and developing REE deposits and recycling REE.
- Its current focus is to develop its flagship Makuutu Rare Earths project towards the production stage. A Scoping Study was released in 2021 and outlines an open-pit mine with an initial 11-year mine life.
- The study estimates an $NPV_{8\%}$ of A$428 million (US$280 million), an IRR (post-tax) of 38%, and a post-tax payback of five years. Year 1 and 2 CAPEX are estimated at US$89 million and US$40 million, respectively.
- The operation has the potential to produce 740 t Sc_2O_3 over the 11-year mine period, using a 30% scandium recovery rate and a long-term Sc_2O_3 price assumption of a minimum of US$700/kg.

Website:

- https://ionicre.com.au/

Stage of Scandium Project:

- Scoping Study Stage

Scandium Project Resource Estimate:

- Makuutu Rare Earths Project, Uganda

JORC: Estimated Resources at Makuutu (2022)								
Category	**Tonnage (Mt)**	**TREO (ppm)**	**TREO no Ce_2O_3 (ppm)**	**LREO (ppm)**	**HREO (ppm)**	**CREO (ppm)**	**Sc (ppm)**	**Sc_2O_3 (ppm)**
Indicated Resource	404	670	450	500	170	230	20	30
Inferred Resource	127	540	360	400	140	180	20	30
Total Resource	**532**	**640**	**430**	**480**	**160**	**220**	**20**	**30**

Notes:

- *The Makuutu MRE has a cut-off of 200 ppm TREO with no cerium oxide (Ce_2O_3).*
- *Definitions: LREO: Light Rare Earth Oxides; HREO: Heavy Rare Earth Oxides; CREO: Critical Rare Earth Oxides (as defined by the US Department of Energy).*

Source: Makuutu JORC MRE (2022)

4.1.10 Megawatt Lithium and Battery Metals Corp. (CSE: MEGA | OTC: WALRD | FSE: WR2)

Summary:

- **Megawatt Lithium** is a Canadian exploration company focused on growing mineral resources for lithium and other battery metals such as cobalt, nickel, and copper in North America and Australia.
- The company holds a 100% interest in the Cobalt Hill Property in B.C., Canada, an 80% interest in two silver-zinc projects in Australia, and a 100% interest in the Route 381 Lithium Property in the James Bay area of Quebec, Canada.
- Its current priority is to ramp up lithium exploration activities in the James Bay area following its recent acquisition of the Mitsumis Lithium Project.

Website:

- https://megawattmetals.com/

Stage of Scandium Project:

- Early-Stage Exploration

Scandium Project:

- The Caribou and Kodiak projects in Australia contain nickel, cobalt, scandium, and high-purity alumina (HPA).

4.1.11 NioCorp Developments Ltd. (TSX: NB | NASDAQ: NB | FSE: BR30)

Summary:

- **NioCorp Developments** is a mineral development company based in the US, specializing in the production of critical minerals such as niobium, scandium, and titanium.
- The company's focus is developing the Elk Creek Project in Nebraska, US, which will produce niobium, scandium, and titanium, with an underground mine and an associated manufacturing facility. It is reported to be one of the highest-grade niobium projects in North America.
- **NioCorp** completed an FS in 2022 and obtained all required Federal permits, with the project slated to launch after a three-year construction period.
- With an estimated 36-year mine life, the project has an after-tax NPV of US$2.35 billion, an IRR of 27.6%, and an after-tax payback period of 2.7 years.
- The total upfront CAPEX was estimated at US$1.14 billion.
- The FS uses a 93.14% scandium process recovery, with a Sc_2O_3 price of US$3,675/kg, and total scandium production of 11,337 t.

Website:

- https://www.niocorp.com/

Stage of Scandium Project:

- Feasibility Study

Scandium Project Resource/Reserve Estimate:

- Elk Creek Project, Nebraska, US
    - Mineral Resource and Reserve Estimate

NI 43-101: Estimated Reserves & Resources at Elk Creek (2022)									
Category	**Tonnage (Mt)**	**Nb_2O_5 (%)**	**TiO_2 (%)**	**Sc (ppm)**	**Sc_2O_3 (ppm)**	**Nb_2O_5 (Mt)**	**TiO_2 (Mt)**	**Sc (kt)**	**TREO (ppm)**
Probable	36.7	0.81	2.92	70.2	107.7	0.30	1.07	2.5	*n/a*
Indicated	151.7	0.43	2.02	56.42	86.5	0.65	3.07	8.6	3,265
Inferred	108.3	0.39	1.92	52.28	80.2	0.43	2.08	5.7	3,769
Note: The Elk Creek MRE has a cut-off NSR of US$180/t.									

Source: Elk Creek NI 43-101 MRE (2022)

NI 43-101: Estimated REE Resources at Elk Creek (2022)				
Category	**Indicated**		**Inferred**	
Tonnage (Mt)	**151.7**		**108.3**	
REE	**Grade (ppm)**	**Tonnage (kt)**	**Grade (ppm)**	**Tonnage (kt)**
La_2O_3	766	116.2	943	102.1
Ce_2O_3	1,320	200.2	1,576	170.6
Pr_2O_3	140	21.3	163	17.7
Nd_2O_3	511	77.5	575	62.2
Sm_2O_3	116	17.6	116	12.6
Eu_2O_3	40	6.0	38	4.1
Gd_2O_3	96	14.6	90	9.8
Tb_2O_3	11	2.2	10	1.1
Dy_2O_3	44	6.7	42	4.6
Ho_2O_3	6	1.0	6	0.7
Er_2O_3	15	2.2	14	1.5
Tm_2O_3	2	0.3	2	0.2
Yb_2O_3	10	1.5	10	1.1
Lu_2O_3	1	0.2	1	0.1
Y_2O_3	187	28.4	182	19.7
LREO	2,737	415.2	3,257	352.6
HREO	528	80.0	512	55.5
TREO	3,265	495.2	3,769	408.1
Note: The Elk Creek MRE has a cut-off NSR of US$180/t.				

Source: Elk Creek NI 43-101 MRE (2022)

4.1.12 Nuinsco Resources Limited (CSE: NWI | OTC: NWIFF | FSE: NJX)

Summary:

- **Nuinsco Resources** is a Canadian, multi-commodity mineral exploration and development company focused on projects in Canada and Egypt.
- The company's current project portfolio includes the Prairie Lake multi-mineral (phosphate, REE, niobium, scandium, and tantalum) project in northwestern Ontario, Canada, and El Sid gold project in Egypt.

Website:

- https://nuinsco.ca/

Stage of Scandium Project:

- Resource Stage

Scandium Project Resource Estimate:

- Prairie Lake Project, Ontario, Canada

NI 43-101: Estimated Resources at Prairie Lake (2022)				
Category	Tonnage (Mt)	TREO (ppm)	Nb_2O_5 (%)	P_2O_5 (%)
Indicated	15.6	1,670	0.16	3.71
Inferred	871.8	2,010	0.10	3.39
Note: The Prairie Lake MRE has a cut-off NSR of $30/t.				

Source: Prairie Lake NI 43-101 MRE (2022)

NI 43-101: Estimated REO Resources at Prairie Lake (2022)		
Category	**Indicated**	**Inferred**
Tonnage (Mt)	15.6	871.8
REO	**Grade (ppm)**	**Grade (ppm)**
Nd_2O_3	344	409
Pr_6O_{11}	96	82
Sc	10	12
Sc_2O_3	15	18
CeO_2	754	905
La_2O_3	300	388
Sm_2O_3	58	79
Ta_2O_5	28	17
Y_2O_3	100	127
TREO	**1,670**	**2,010**
Note: The Prairie Lake MRE has a cut-off NSR of $30/t.		

Source: Prairie Lake NI 43-101 MRE (2022)

4.1.13 Platina Resources Limited (ASX: PGM | OTC: PTNUF | FSE: P4R)

Summary:

- In April 203, **Platina Resources** sold the Owendale Scandium Project in Australia to **Rio Tinto** for A$14 million (US$9.3 million).
- See the **Rio Tinto** section for more information.

Website:

- https://platinaresources.com.au/

4.1.14 Rio Tinto Group (LSE: RIO | NYSE: RIO | ASX: RIO)

Summary:

- **Rio Tinto** is a multinational mining corporation based in London, UK. It was founded in 1873 and has since grown to become one of the largest mining companies in the world, with operations in over 35 countries.
- The company's primary focus is on the extraction and production of minerals and metals, which include aluminum, copper, diamonds, gold, iron ore, and uranium.
- In May 2022, **Rio Tinto** announced that it became the first producer of Sc_2O_3 in North America from its Rio Tinto Fer et Titane's (RTFT) metallurgical complex in Sorel-Tracy, Quebec, Canada. The facility operates an open-pit ilmenite mine at Lac Tio in Quebec, producing titanium dioxide, pig iron, steel, and metal. Scandium is produced from the waste streams.
- In April 2023, **Rio Tinto** purchased the Owendale Scandium Project in Australia from **Platina Resources** for A$14 million (US$9.3 million).
- The Owendale Scandium Project's DFS was completed in 2018 at 20 t/y of Sc_2O_3 but has the potential to produce up to 40 t/y for an estimated 30 years.
- The post-tax $NPV_{8\%}$ was A$234 million with a post-tax IRR of 29%. Total CAPEX was estimated at A$84 million with a 5.3-year payback period. Annual revenue was estimated at A$77 million and A$47 million of EBITDA.
- The project is a laterite-hosted orebody with scandium, cobalt, and nickel and is one of the highest-grade scandium deposits. The DFS used a long-term Sc_2O_3 assumption of US$1,550/kg.
- The Owendale acquisition will allow Rio Tinto to more than double its annual scandium production.

Website:

- https://www.riotinto.com/

Stage of Scandium Project:

- Feasibility Study

Scandium Project Resource/Reserve Estimate:

- Owendale Scandium Project, New South Wales, Australia

JORC: Estimated Reserves at Owendale (2018)								
Category	Tonnage (Mt)	Grades				In-situ Metal Content		
		Sc (ppm)	Sc_2O_3 (ppm)	Co (%)	Ni (%)	Sc_2O_3 (t)	Co (t)	Ni (t)
Proven	3.05	575	882	0.10	0.13	2,696	2,945	4,054
Probable	0.97	550	844	0.07	0.08	816	654	767
Total	**4.02**	**570**	**874**	**0.09**	**0.12**	**3,512**	**3,599**	**4,821**

Notes:

- *The Owendale Reserve MRE has a 450 ppm Sc cut-off.*
- *Sc_2O_3 product is calculated from scandium metal using a 1.53 factor.*

Source: Owendale JORC MRE (2018)

JORC: Estimated Resources at Owendale (2018)										
Category	Tonnage (Mt)	Grades					In-situ Metal Content			
		Sc (ppm)	Sc_2O_3 (ppm)	Pt (g/t)	Ni (%)	Co (%)	Sc_2O_3 (kt)	Pt (koz)	Ni (t)	Co (t)
Measured	7.8	435	667	0.42	0.13	0.07	5.2	105	9,900	5,400
Indicated	12.5	410	629	0.26	0.11	0.06	7.8	106	13,400	8,100
Inferred	15.3	380	583	0.22	0.08	0.05	8.9	106	12,400	7,000
Total	**35.6**	**405**	**621**	**0.28**	**0.10**	**0.06**	**22,000**	**317**	**35,700**	**20,500**

Notes:

- *The Owendale Resource MRE has a 300 ppm Sc cut-off.*
- *Sc_2O_3product is calculated from scandium metal using a 1.53 factor.*

Source: Owendale JORC MRE (2018)

4.1.15 Scandium International Mining Corp. (TSX: SCY | OTC: SCYYF | FSE: 0E6)

Summary:

- **Scandium International** is a Canadian mining company focused on REE, scandium, and other specialty metals such as nickel, cobalt, boron, manganese, tantalum, titanium, and zirconium. It operates projects in Australia, Finland, and the US.
- The Nyngan Scandium Project, located in New South Wales, Australia, is the company's flagship project. The company aims to become a significant global producer of scandium with yearly Sc_2O_3 production of 37.7 tonnes with an 83.7% recovery rate.
- The project's FS was published in 2016 with a CAPEX of US$87.1 million, an after-tax $NPV_{10\%}$ of US$177.5 million, an after-tax IRR of 33.1% over a 20-year mine life, and a payback period of 3.3 years.
- **Scandium International** used a long-term Sc_2O_3 price assumption of US$2,000/kg.

Website:

- https://scandiummining.com/

Stage of Scandium Project:

- Feasibility Study – Nyngan Scandium Project, New South Wales, Australia.

Scandium Project Resource/Reserve Estimate:

- Nyngan Scandium Project, New South Wales, Australia
  - The FS was completed in 2016.

NI 43-101: Estimated Resource at Nyngan (2016)			
Category	**Tonnage (Mt)**	**Grade Sc (ppm)**	**Grade Sc_2O_3 (ppm)**
Measured	5.69	256	393
Indicated	11.23	225	345
Measured and Indicated	**16.92**	**235**	**360**
Note: The Nyngan Resource MRE has a 100 ppm Sc cut-off.			

Source: Nyngan NI 43-101 MRE (2016)

NI 43-101: Estimated Reserve at Nyngan (2016)			
Category	**Tonnage (Mt)**	**Grade Sc (ppm)**	**Grade Sc_2O_3 (ppm)**
Proven Reserve	0.79	394	604
Probable Reserve	0.64	428	656
Total Reserve	**1.43**	**409**	**627**
Note: The Nyngan Resource MRE has a 100 ppm Sc cut-off.			

Source: Nyngan NI 43-101 MRE (2016)

4.1.16 Sunrise Energy Metals Limited (ASX: SRL | OTC: SREMF | FRA: 4CQA)

Summary:

- **Sunrise Energy Metals** is an Australian mining company focused on mineral asset exploration and development in Western Australia.
- The company's current focus is advancing its flagship Sunrise Ni-Co-Sc Project, which is one of the largest battery materials projects in Australia.
- The Sunrise Project's FS was published in 2018 and a Project Execution Plan (PEP) with updated financials was issued in 2020.
- The PEP projected an $NPV_{8\%}$ of US$1.21 billion and a post-tax IRR of 15.44% over 25 years of operations but with a 50-year Mineral Reserve life. CAPEX was estimated at US$1.8 billion with a five-year payback period. Annual production of 21.3 kt of nickel and 4.4 kt of cobalt for the first ten years, with scandium production, ramping from 2 t/y to 20 t/y, starting in year three. If the market demand increases, scandium capacity can be expanded to 80 t/y.
- **Sunrise** used a long-term Sc_2O_3 price assumption of US$1,500/kg.

Website:

- https://www.sunriseem.com/

Stage of Scandium Project:

- Feasibility Study

Scandium Project Resource/Reserve Estimate:

- Sunrise Ni-Co-Sc-Pt Project, New South Wales, Australia
  - Host rock: Laterite

JORC: Estimated Reserves at Sunrise (2020)

Category	Tonnage (Mt)	Grades			
		Ni (%)	Co (%)	Sc (ppm)	Sc_2O_3 (ppm)
Proven	65.4	0.67	0.11	55	84
Probable	77.9	0.07	0.07	41	63
Proven and Probable	**143.2**	**0.59**	**0.10**	**47**	**72**

Notes:

- *The Sunrise Resource MRE has a 0.35% nickel equivalent cut-off grade.*
- *Sc_2O_3 product is calculated from scandium metal using a 1.54 factor.*

Source: Sunrise JORC MRE (2020)

JORC: Estimated Resource at Sunrise (2020)											
		Grade					In-situ Metal Content				
Category	(Mt)	Ni (%)	Co (%)	Sc (ppm)	Sc_2O_3 (ppm)	Pt (g/t)	Ni (Mt)	Co (kt)	Sc (kt)	Sc_2O_3 (kt)	Pt (Moz)
Measured	69	0.65	0.11	61	94	0.23	0.45	73	4.2	6.4	0.50
Indicated	89	0.49	0.09	79	121	0.19	0.44	76	7.0	11.0	0.54
Measured and Indicated	**160**	**0.56**	**0.09**	**71**	**109**	**0.21**	**0.89**	**150**	**11.0**	**17.0**	**1.00**
Inferred	17	0.26	0.10	289	443	0.15	0.04	18	5.0	7.7	0.08

Note:

- *The Sunrise Resource MRE has a 0.35% nickel equivalent cut-off grade.*
- *Sc_2O_3 product is calculated from scandium metal using a 1.54 factor.*

Source: Sunrise JORC MRE (2020)

4.1.17 Texas Mineral Resources Corp. (OTCPK: TMRC)

Summary:

- **Texas Mineral Resources** is a publicly traded mineral exploration and development company headquartered in the US. The company's primary focus is the exploration and development of REE, uranium, and beryllium.
- The company aims to establish itself as a national supplier of heavy REE, to reduce the US' dependence on China for the supply of these critical minerals.
- The company's flagship project is the Round Top property in Hudspeth County, Texas.
- The Round Top Project also included scandium recovery in its process plans, however, the 2014 PEA resource does not include any scandium grades.

Website:

- http://tmrcorp.com/

Stage of Scandium Project:

- PEA Stage

Scandium Project

- Round Top Project, Texas, US – No scandium resource identified.

4.2 Company Spotlight – Imperial Mining Group Ltd. (TSXV: IPG | OCTQB: IMPNF)

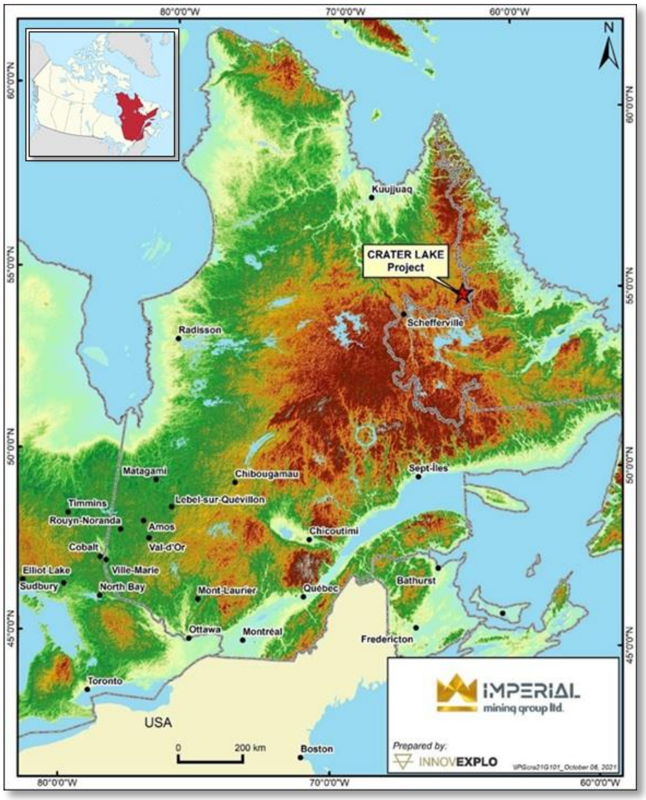
Company Description:

- **Imperial Mining** is a Canadian mining exploration and development company engaged in exploring, acquiring, and developing technology and precious metal projects in Canada.
- The company is led by a team of experienced geologists, engineers, and financiers who are committed to advancing its projects in an environmentally and socially responsible manner.
- **Imperial Mining's** flagship project is the 100%-owned Crater Lake scandium-REE property in Quebec, Canada, which has the potential to become a low-cost producer of high-purity Sc_2O_3 for the aerospace, automotive, and defense industries.
- The Crater Lake Project is one of the highest-grade scandium deposits and also contains other REE mineralization, including dysprosium, lanthanum, neodymium, praseodymium, and terbium.

Crater Lake Location and Infrastructure:

- The Crater Lake Property is located in north-eastern Quebec, close to the Quebec-Labrador border, and approximately 1,000 km northeast of Quebec City, the provincial capital of Quebec, Canada (see Figure 5).
- The project is located in the low-risk and highly-rated mining jurisdiction of Quebec, Canada, and ranks in the top 10 according to the 2022 "Survey of Mining Companies" report by the **Fraser Institute**.
- Quebec is also a leader in aluminum production and **Imperial Mining** has been awarded $0.8 million in program funding and R&D grants from Canadian and Quebec provincial government entities for its exploration, hydrometallurgical, and R&D efforts.
- The Crater Lake Project could benefit from the Quebec government's Northern Action Plan ("Plan Nord"), which is a strategic initiative to foster a sustainable "Living in the North" environment, addressing the priorities identified by stakeholders in Quebec's northern region.
- The nearest major town is Schefferville, Quebec, which is approximately 200 km southwest and has the nearest railhead, with access to the seaport at Sept-Iles, Quebec.
- The project is also 190 km southwest of Nain, Newfoundland and Labrador (NL), which is also the nearest seaport, and 300 km northwest of Happy Valley-Goose Bay, NL.
- The property comprises two contiguous mineral claim blocks (Crater Lake and Crater Lake Extension) covering approximately 47.0 km² (over 11,600 acres) with a total of 96 mineral claims (see Figure 6):
  - Crater Lake: The Crater Lake claim block consists of 57 contiguous claims spanning 27.9 km², fully owned by **Imperial Mining**. A 2% net smelter return (NSR) royalty applies to these claims;
  - Crater Lake Extension: An additional 39 mining claims, covering around 19.1 km², were obtained as the Crater Lake Extension claim package. **Imperial Mining** owns these claims without any royalties.

Figure 5: Crater Lake Property Location – North-Eastern Quebec



Source: Crater Lake PEA Report (2022); eResearch (insert)

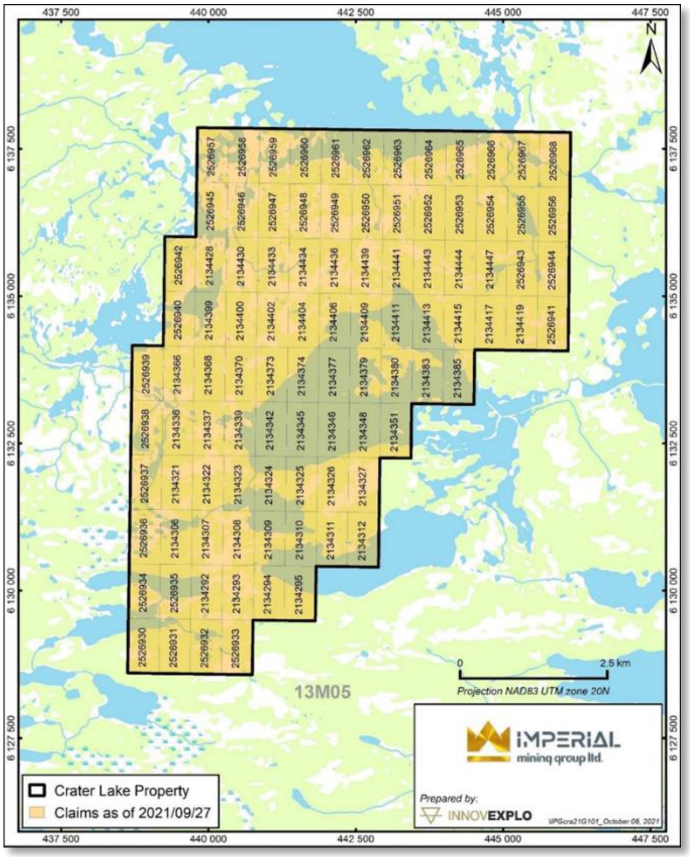
Crater Lake PEA:

- Crater Lake's PEA was published in 2022 with an estimated post-tax $NPV_{10\%}$ of $1.72 billion and an after-tax IRR of 32.8% over 25 years of operations.
- Total gross revenue was $15.2 billion and gross earnings after-tax was $6.25 billion.
- Total CAPEX was estimated at $870.1 million with a three-year payback period.
- Total mined metal production over the mining life was estimated at 110 t Sc_2O_3, 57,298t of Sc-Al Master Alloy, and 23,578 t of REE hydroxide concentrate.
- Average Sc_2O_3 mill recoveries were 90% and hydromet recoveries were 81%.
- **Imperial Mining** used a long-term Sc_2O_3 price assumption of US$1,500/kg.

Crater Lake – Metallurgical Process

- **Imperial Mining** has been working on methods and processes for the extraction of scandium and REE from Crater Lake Project mineralization. Central to this endeavour is the hydrometallurgical flowsheet development program. This program, which began in early 2019, is anchored on a patent-pending, two-stage hydrometallurgical process.
- Recent optimization efforts have increased Sc recovery to 96% and REE recovery to 94% at the leaching stage, with a mine-to-precipitate recovery of 76% for Sc and 60% for REE.
- These enhanced recovery rates could have a positive impact on the financial model, as highlighted in the company's 2022 PEA, which would help drive down both operating and capital costs.

Figure 6: Crater Lake Property – Mineral Claim Map – 96 Contiguous Mineral Claims



Source: Crater Lake PEA Report (2022)

Crater Lake Project Resource Estimate:

- The Crater Lake Project hosts an NI 43-101 compliant resource (updated in 2023):
    - Indicated: 11.8 Mt of an Indicated Resource with grades of scandium at 275.9 ppm, dysprosium at 66.4 ppm, lanthanum at 605.5 ppm, neodymium at 596.9 ppm, praseodymium at 160.1 ppm, and terbium at 11.7 ppm.
    - Inferred Resource: 15.9 Mt of an Indicated Resource with grades of scandium at 268.4 ppm, dysprosium at 66.1 ppm, lanthanum at 606.9 ppm, neodymium at 595.6 ppm, praseodymium at 159.8 ppm, and terbium at 11.6 ppm.
- The resource comes entirely from the Northern Lobe of the TGZ Target with the potential for resource expansion from the Northern, Hilltop, and STG targets, and the Boulder Lake Zone (see Figures 7 and 8).

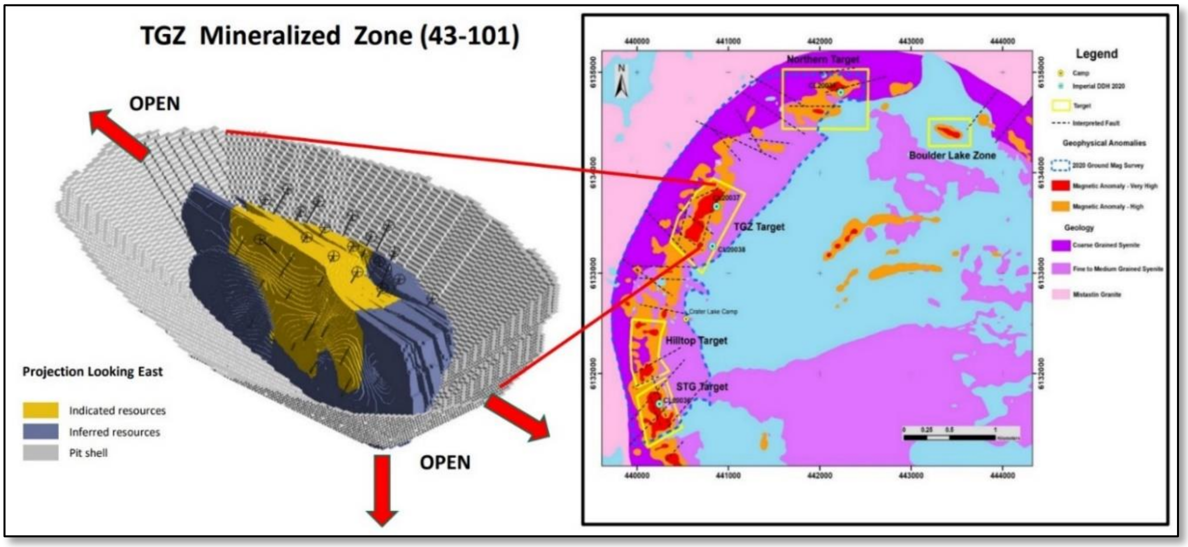
NI 43-101: Estimated Resources at Crater Lake (2023)

Category	Tonnage (Mt)	Sc (ppm)	Sc_2O_3 (ppm)	Dy_2O_3 (ppm)	La_2O_3 (ppm)	Nd_2O_3 (ppm)	Pr_2O_3 (ppm)	Tb_4O_7 (ppm)
Indicated	11.8	179.9	275.9	66.4	605.5	596.9	160.1	11.7
Inferred	15.9	175.0	268.4	66.1	606.9	595.6	159.8	11.6

Note: The Crater Lake MRE has a cut-off Net Smelter Return (NSR) of $110.10/t.

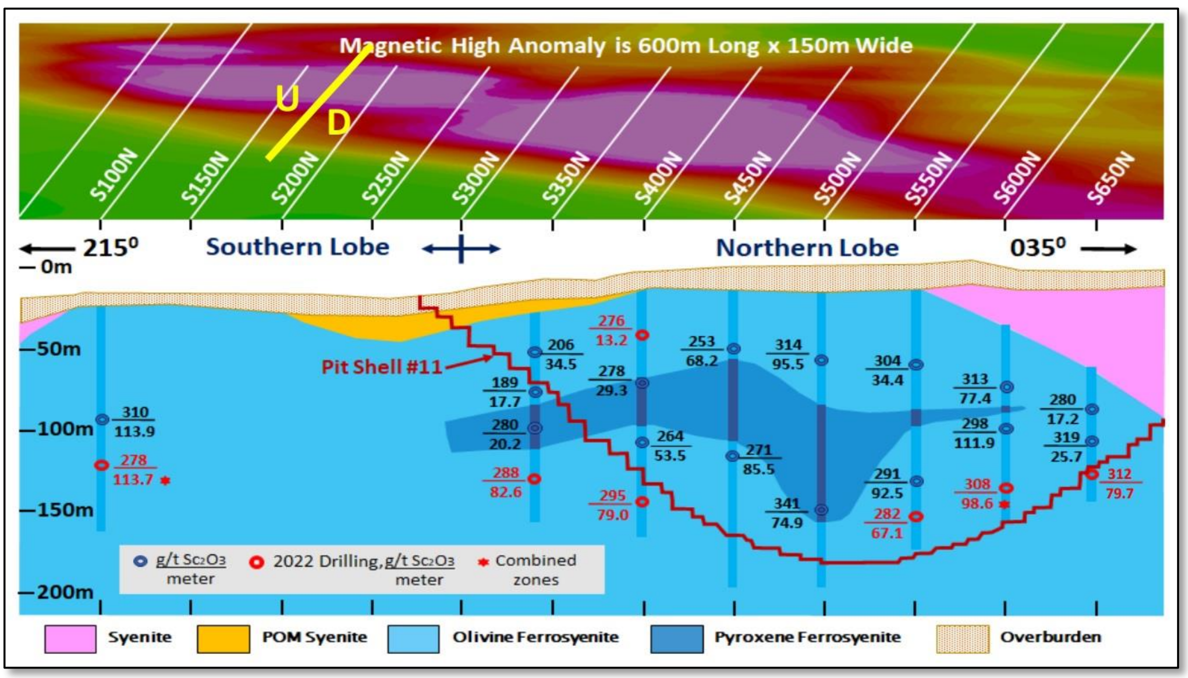
Source: Crater Lake NI 43-101 MRE (2023)

Figure 7: Pit Shell Illustrates Resource Entirely from the TG Scandium Zone (Still Open) and Resource Expansion Possible from Other Zones



Source: Company Presentation (August 2023)

Figure 8: Correlation between Magnetic High Anomaly (top) and Resource (bottom) with the Potential for Resource Expansion into the Southern Lobe



Source: Company Presentation (August 2023)

Strategic Partners:

- **Imperial Mining** is working with Canadian and US government agencies and the aluminum, aeronautics, defense, EV, and space industries to secure financing and offtake agreements to reduce production risks and shareholder dilution.
- **Imperial Mining** also signed a Memorandum of Understanding with **Albecour** to explore the potential of producing specialty Al-Sc alloys in Quebec. The project aims to develop value-added products using scandium for low-carbon aluminum production, catering to sectors like electric vehicles, aerospace, space, offshore wind, and defense.

Imperial Mining is Fully Funded for the Short Term

- In July 2023, **Imperial Mining** announced the completion of a non-brokered private placement of almost 17.78 million units, generating gross proceeds of $1.6 million.

Protecting IP with Patents:

- **Imperial Mining** filed patent applications for its two-stage hydrometallurgical methods and processes for the extraction of scandium and REE from Crater Lake Project mineralization.
- The patent was filed in December 2022, with the United States Patent and Trademark Office (USPTO) and the Canada Intellectual Property Office (CIPO).

Other Projects:

- **Imperial Mining** also holds several other projects, including the Opawica and La Ronciere projects, with gold, copper, zinc, silver, and palladium potential in Quebec's Abitibi region.
  - The Opawica Project, located 20 km east of Desmaraisville in Quebec, Canada, is primarily a gold project. The project comprises approximately 42 contiguous claims, covering an area of about 23.45 km^2 (almost 5,800 acres).
  - The La Ronciere Project, located 35 km east of Desmaraisville in Quebec, Canada, is primarily a gold project. The project comprises over 45 contiguous claims, covering an area of approximately 25.1 km^2 (over 6,200 acres).

Short-term Catalysts

- Fully ramp up the Crate Lake Prefeasibility and Feasibility studies, continue permitting, and design and engineering studies.
- Continues discussions to finalize near-term offtake agreements.
- Find a strategic partner and/or build government support to fully fund the project.
- Build out the necessary infrastructure to support the mine development and the potential 25+ year mine life.
- Expand the current resource from the North zone and other targets to extend mine life or support higher operations throughput.

4.0 Scandium Pricing

As there is no exchange-traded market for scandium or scandium oxide (Sc_2O_3), they are typically negotiated between buyers and suppliers through offtake agreements, which outline the terms and conditions of the transaction.

Offtake agreements, while commonly used in various industries, have certain drawbacks compared to commodities like gold, which have spot prices and are actively traded on exchanges. The drawbacks include a lack of transparency, limited price discovery and liquidity, price volatility, counterparty risk, and long-term commitments.

Also, Sc_2O_3 pricing in the world market has historically presented a complex dynamic due to the relatively low supply and correspondingly high costs.

The complex pricing structure is also attributed to scandium's nature as a by-product of other mining operations. As a result, scandium has faced challenges in terms of accessibility and affordability, which have significantly influenced its market dynamics.

According to market research by Gambogi, from 2013 to 2020, Sc_2O_3 prices consistently ranged between US$3,800 and US$5,000 per kilogram and reflected the scarcity of scandium and the challenges associated with its extraction and processing.

Figure 9 provides a summary of Sc_2O_3 pricing from 2019 to 2030 and outlines a supply versus demand scenario and pricing forecasts ranging from US$3,000 to US$4,000 per kilogram even as demand increases from 200 tonnes per year to over 600 tonnes per year of Sc_2O_3.

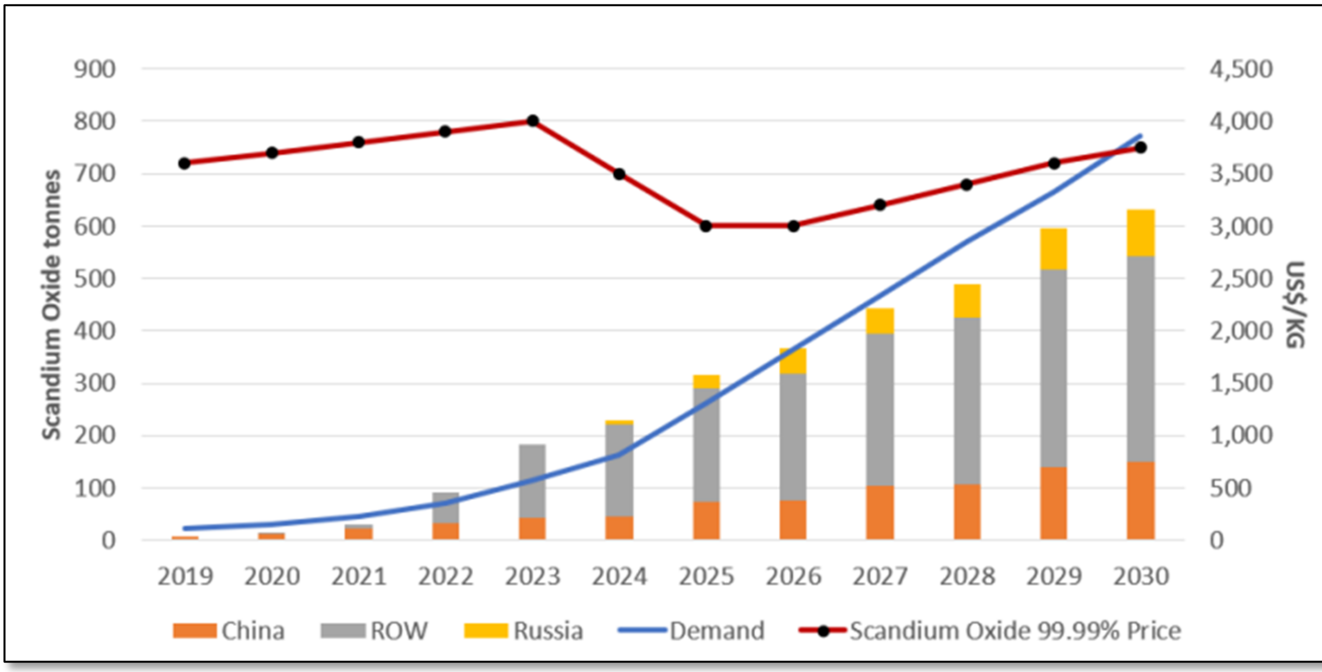
In the PEA, Scoping, PFS, and FS outlined in Section 4.1, the companies used long-term Sc_2O_3 price assumptions that ranged from US$700/kg to US$2,000/kg.

The primary factors contributing to the pricing of Sc_2O_3include:

- Limited Supply Sources:
  - Scandium is predominantly obtained as a by-product of other mining activities, particularly from rare earth and nickel laterite ore processing. This limited supply source constrains the overall availability of scandium in the market.
- Complex Extraction:
  - The extraction of scandium from its source materials is a complex and resource-intensive process. This complexity involves various stages, including leaching, purification, and refining, all of which contribute to production costs.
- Research and Development Costs:
  - Ongoing research and development efforts to optimize scandium extraction processes and expand supply sources require significant investments. These costs are often passed on to the market.
- Demand versus Supply:
  - The growing demand for scandium in industries such as aerospace, automotive, and renewable energy, combined with its limited supply, exerts upward pressure on prices.
- Market Niche:
  - Scandium's niche applications in high-performance alloys, solid oxide fuel cells (SOFCs), and other advanced technologies further elevate its market value.

Despite its potential to contribute to sustainability goals in various industries, scandium remains relatively underutilized due to these cost-related constraints. As technological advancements and supply diversification efforts progress, the future pricing of Sc_2O_3 may see fluctuations and, potentially, a more competitive position in the market.

Figure 9: Scandium Oxide Pricing Actual and Estimates (2019-2030)



Source: Australian Mines Limited Corporate Presentation (2023)

Appendix A: Abbreviations and Element Information

The following abbreviations have been used:

- CAPEX: Capital Expenditures
- CREE: Critical Rare Earth Element
- EV: Electric Vehicle
- HEV: Hybrid Electric Vehicle
- NPV: Net Present Value
- OPEX: Operating Expenditures
- REO: Rare Earth Oxides
- SGS: SGS Canada Inc.

Rare Earth Elements (REE)

- Rare Earth Elements (REE)
    - Scandium (Sc)
    - Yttrium (Y)
    - 15 lanthanide elements (cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, neodymium, praseodymium, promethium, samarium, terbium, thulium, and ytterbium)
- Light Rare Earth Elements (LREE) Grouping
    - Ce – Cerium
    - La – Lanthanum
    - Nd – Neodymium
    - Pr – Praseodymium
    - Pm – Promethium
    - Sm – Samarium
- Heavy Rare Earth Elements (HREE)
    - Dy – Dysprosium
    - Er – Erbium
    - Eu – Europium
    - Gd – Gadolinium
    - Ho – Holmium
    - Lu – Lutetium
    - Tb – Terbium
    - Tm – Thulium
    - Yb – Ytterbium
    - Y – Yttrium
- Total Rare Earth Elements (TREE) = LREE + HREE + Scandium (Sc)
- Parts per million (ppm): 10,000 ppm = 1% = 10 kg/tonne

Appendix B: eResearch Disclosure

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