Neometals

Vanadium Production in Europe

Carbon-neutral, zero-waste vanadium recovery from slag

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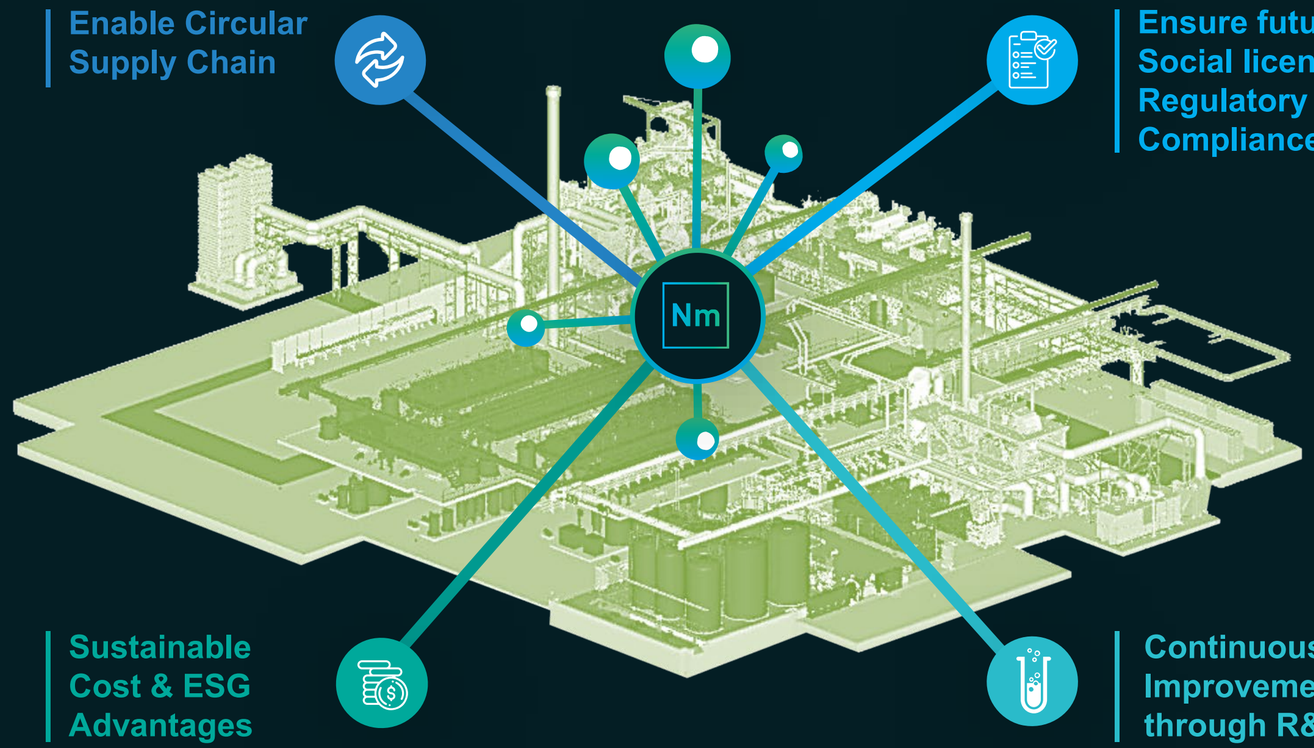
ASX: **NMT** | AIM: **NMT** | OTCQX: **NMTAY** | DEU: **9R9**

Focus (What We Do)

Neometals

Commercialising our portfolio of sustainable process technologies to recycle and recover critical materials from high-value waste streams



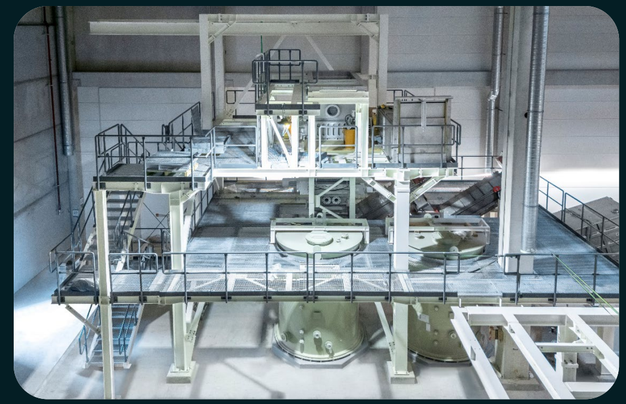
- Primobius JV is building Mercedes-Benz a 2,500tpa integrated spoke and hub pilot plant
- Product readiness for ~21,000tpa commercial plants expected 2H2025
- Lithium Chemical and Vanadium Recovery technologies approaching Industrial Partner Validation stage of development

Lithium-ion Battery (LiB) Recycling

Primobius (50:50 Joint-Venture with SMS Group)

Off-spec and used battery recycling to produce metal salts for battery production

- Demonstration Plant near Hilchenbach, Germany
- Battery shredder and feed material beneficiation
- Cu, Mn, Co, Ni and Li recovery and refining (hydromet circuit)
- Battery quality metal salts for return to battery manufacture
- Commercial plant under contract (Mercedes)
- Visit: www.neometals.com.au/business-units/core-divisions/lib/



Lithium Chemicals

ELi™ the direct production of lithium hydroxide

Reduced processing and lower cost production of LHM

- Processing lithium brine concentrates or spodumene leach solutions
- Patented purification of lithium chloride solution and electrolysis to convert directly to lithium hydroxide solution
- Bench and pilot demonstration, including 1,000-hour electrolysis demonstration of technology.
- Visit: www.neometals.com.au/business-units/core-divisions/lithium-chemicals/

Corporate

Vanadium Recovery Project (VRP)

Novana Oy

Hydrometallurgical recovery of vanadium from steel slag

- Background on SSAB and the vanadium rich steel slag
- Flowsheet Development
- Commercial Aspects
- Life Cycle Analysis and Project status
- Visit: www.neometals.com.au/business-units/core-divisions/vanadium-recovery

Vanadium Recovery

Vanadium Recovery Process Technology

100% Neometals

What is Vanadium?

Vanadium is a chemical element which appears as a hard, silvery-grey, malleable transition metal.

- Light – first row transition metal with +2, +3, +4 and +5 oxidation states.
- Supply and demand dominated by China.
- Consumption dominated by China and ferrovanadium (Rebar) production.
- Future – Vanadium Flow Batteries

Photo credit: Steffen Kristensen / public domain

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V

Vanadium

50.94

Where does the Story Begin?

From the ore to the smelter feed…

- LKAB iron ore mines in Malmberget, Sweden.
- The ore contains vanadium.
- LKAB iron pellets from Malmberget contain approximately 0.24% V_2O_5 (vanadium pentoxide).
- Pellets are sold worldwide, including to SSAB.


LKAB iron ore mines in Malmberget, Sweden

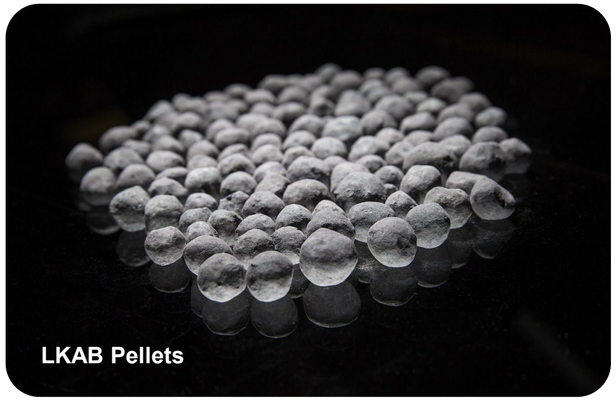

LKAB Pellets

Photo credits: Luossavaara-Kiirunavaara Aktiebolag (LKAB), Fredric Alm, Alm & ME

From the Ore to Steel Products

- LKAB iron ore pellets are one of the main ingredients in steel produced at the SSAB steel mill in Luleå and Oxelösund (Sweden), and Raahe (Finland).
- SSAB's Raahe plant has two furnaces producing raw iron that is refined into steel at the steel foundry.
- Steel billets are formed using the molten steel, which is rolled into products at the hot rolling mill.


Luleå, Sweden


Raahe, Finland

Photo credits: SSAB

Slag, By-Product

- Slag from the steel making process is poured onto the surface to cool.
- The vanadium has been concentrated in the steel making process. The slag now contains up to 4.4% V_2O_5 (vanadium pentoxide).
- Once the slag has cooled it is loaded and transported for screening.
- Slag is screened to separate lump which is returned to the blast furnace and fines which are stockpiled.


Slag from steel making process is poured onto the surface to cool


Slag is screened, returned to the blast furnace, then stockpiled

> 1.5 billion tonnes of steel were produced in 2023

150 – 200 kg of BOF slag is produced per tonne of steel

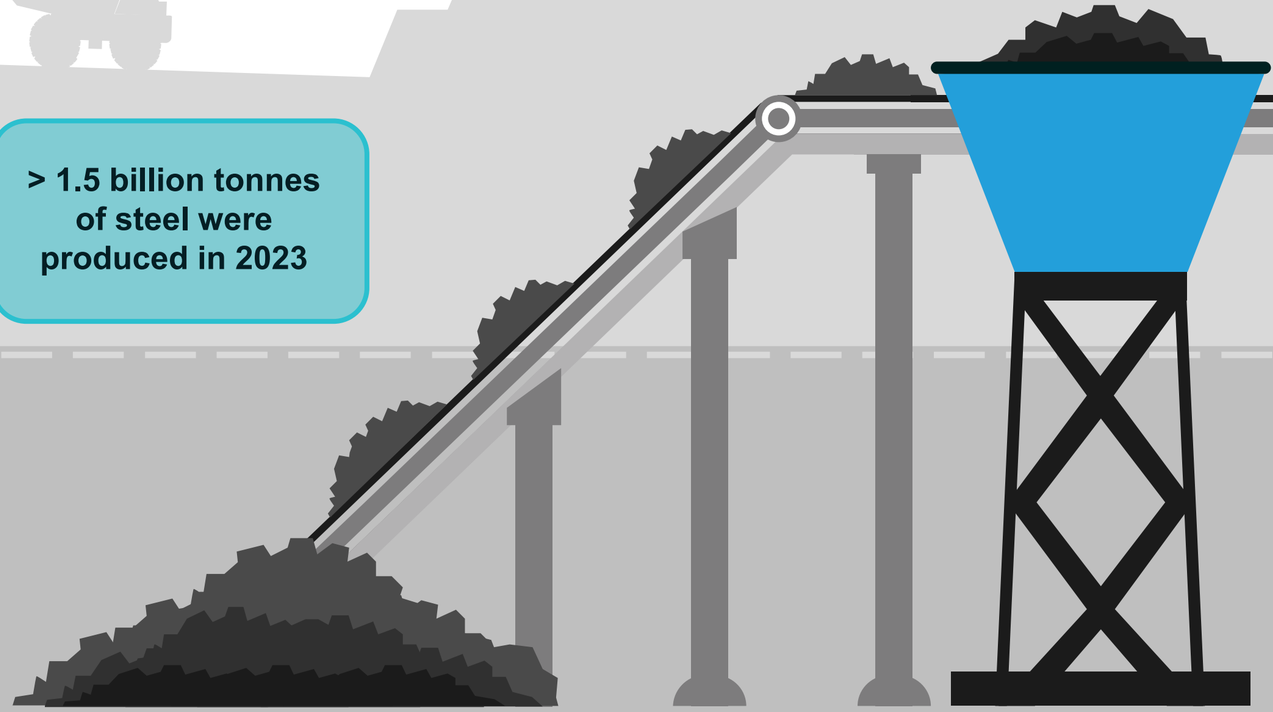
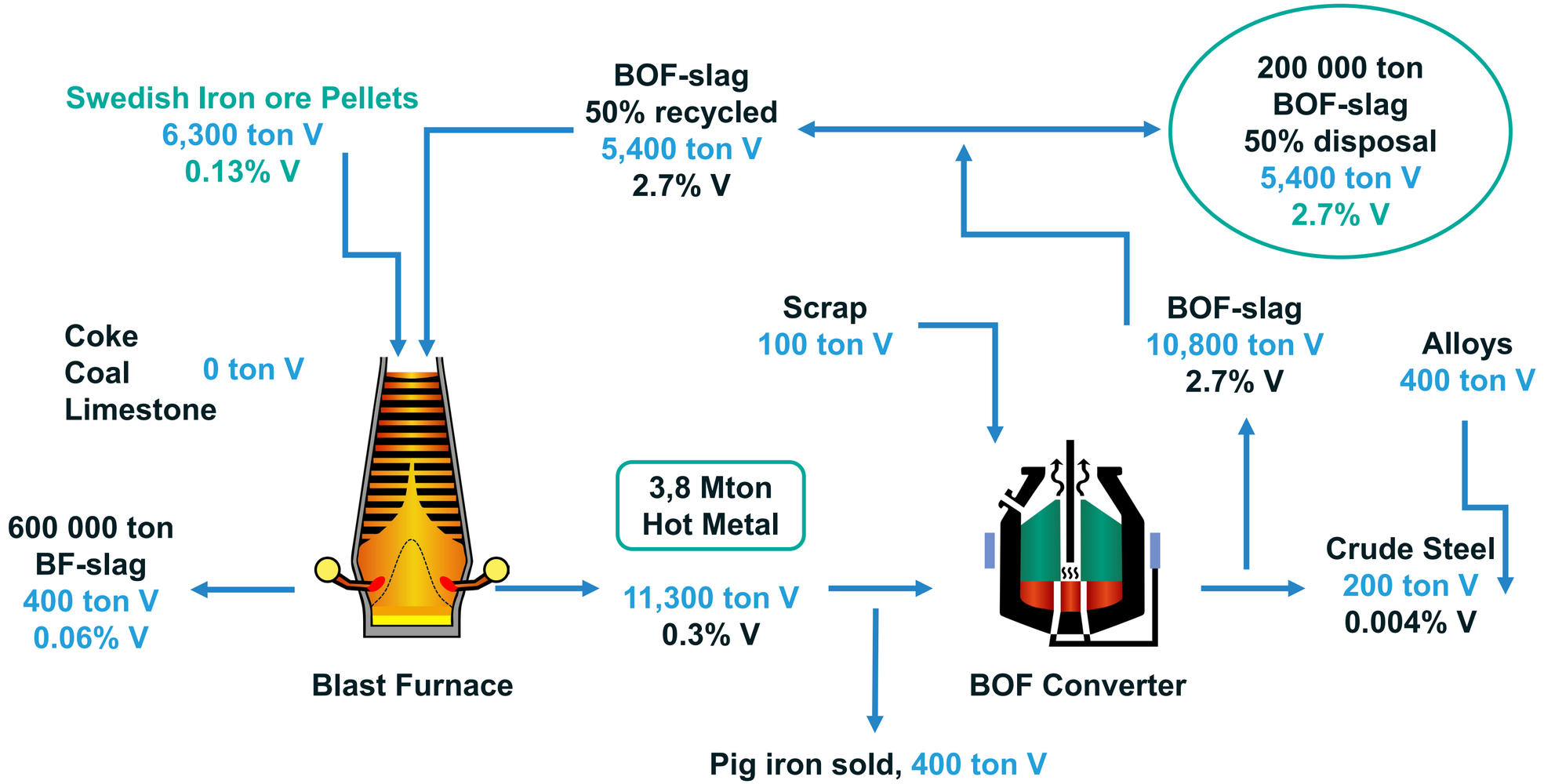


Photo credits: SSAB

High Level Steel Mill Flowsheet and Vanadium Deportment



Source: Guozhu Ye, Kim Kärsrud and Mikael Lindvall, Fray International Symposium, 2011

Location and Stockpiles

SSAB slag stockpiles and production

- Planned 300,000 tpa BOF slag feed.
- Potential feed slag already stockpiled and new arisings.
- Several potential suppliers in Europe (e.g. SSAB, Salzgitter, Tata, H2GS etc.) and elsewhere (e.g. CAP).

Vanadium Recovery

Project Development

1

Slag Characterisation

2

Hydrometallurgical Flowsheet

- Reprocessing the slag
- Generating high purity vanadium product and
- Avoiding a waste generating processes

3

Site selection, logistics and local factors

- Feed
- Product(s)
- Reagents
- Workforce
- Services

4

Permitting, environmental

5

Development timeline

- Late 2019: Opportunity identification
- Late 2019 to early 2020: Concept testing, bench scale
- Late 2020: Mini-pilot plant (120 hours at 1 kg slag/hour)
- Mid 2021: Full scale pilot plant (total 24 days in 3 campaigns, 25 kg slag/hour)
- Engineering and financing

Typical of SSAB BOF Slags

Mineralogy of the slag

Table 1: Typical chemical compositions of BOF slag

Radical	Composition range (Wt.%)	Phases
CaO	30 – 50	C_3S, C_2S, *CaO, RO
SiO_2	10 – 15	C_3S, C_2S, other silicates
Al_2O_3	1 – 3	Aluminosilicates,
MgO	5 – 15	Oxides and silicates
MnO	1 – 5	Oxides and silicates
Fe total	10 – 30	Ferrite, FeO, Fe_2O_3
[1]CaO	2 - 10	CaO
P_2O_5	1 – 3	Silicate phases
SO_3	0.1 – 0.3	

*CaO-free lime

Calcium silicates: $C_2S = 2CaO.SiO_2$ (Larnite) and $C_3S = 3CaO.SiO_2$ (Hatrurite)

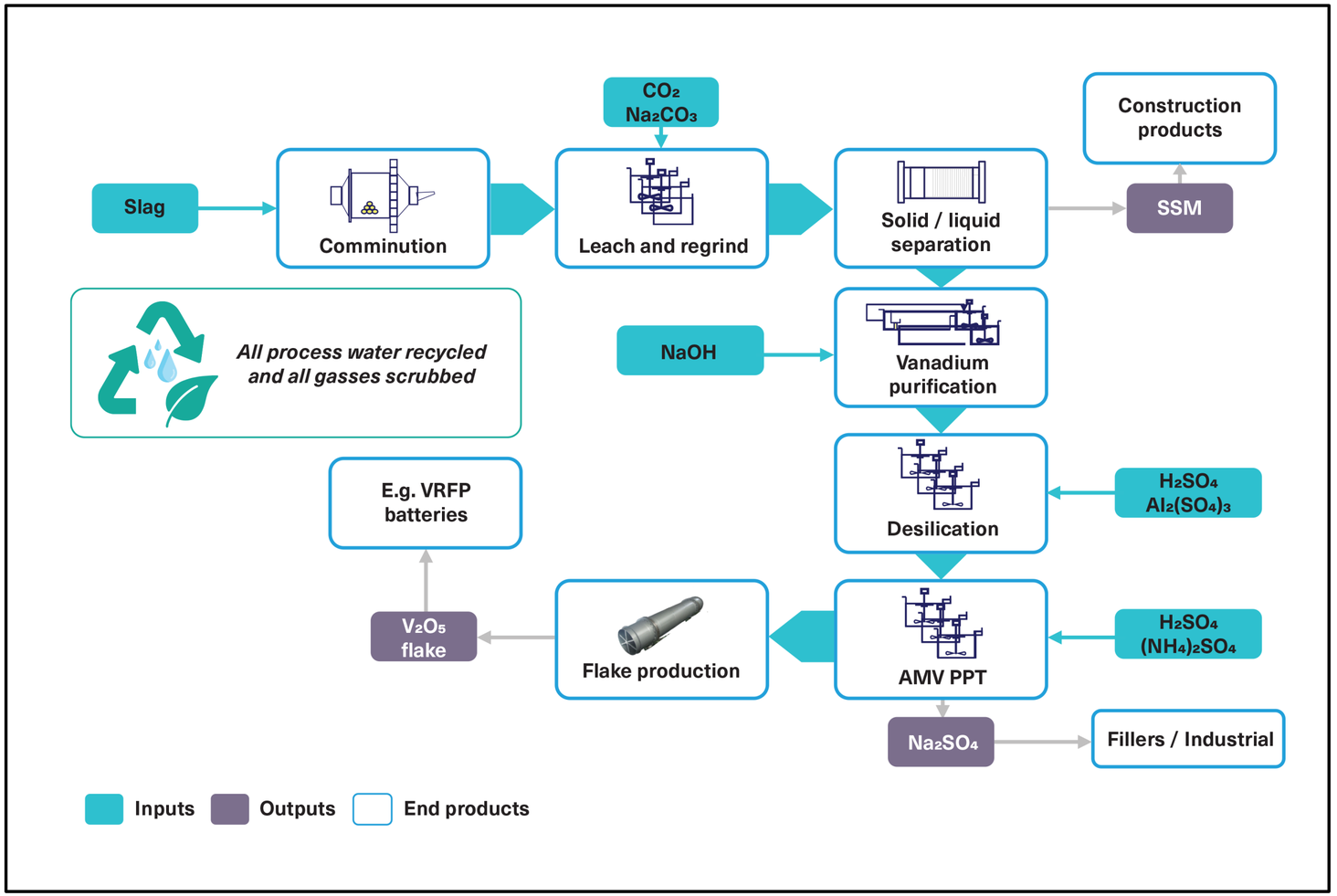
Composition of the slag

Indicative species

Compounds	Percentage (%)
CaO	40 – 50
Fe_2O_3	20 – 25
SiO_2	10 – 13
V_2O_5	3.0 – 4.5
Mn_2O_3	2.5 – 3.5
Al_2O_3	1.5 – 2.0
MgO	2.0 – 10.0
P_2O_5	0.5 – 1.0
Cr_2O_3	0.2 – 0.6
SO_3	0.1 – 0.2

Source: Thomas C, Rosales J, Polanco JA, Agrela F (2019) Steel slags. In: Brito J, Agrela F (eds) New trends in eco-efficient and recycled concrete. Elsevier, Amsterdam, pp 169–190.

High Level Flowsheet – Vanadium Recovery



Process Chemistry 1

Leach process, requires liberation through fine grinding with calcium chemistry the main feature:

- **Carbonation of calcium minerals and calcite formation**

  $Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CaCO_{3(solid)}$

  $CaO_{(solid)} + CO_3^{2-}{}_{(aq)} + H_2O \rightarrow CaCO_{3(solid)} + 2OH^-$

  $Ca(OH)_{2(solid)} + CO_3^{2-}{}_{(aq)} \rightarrow CaCO_{3(solid)} + 2OH^-$

- **Carbonate generation**

  $2OH^-_{(aq)} + CO_{2(gas)} \rightarrow CO_3^{2-}{}_{(aq)} + H_2O$

- **Lixiviant regeneration with CO_2 being the “consumed” reagent and carbon sequestration a byproduct of the process.**
- **Calcite precipitation on mineral surfaces leads to multi-stage leaching and regrind requirements.**
- **pH control for selective leaching and reduced impurities in PLS.**
- **Leach residue suitable for green concrete applications**

Process Chemistry 2

Purification and concentration by solvent extraction:

- **PLS conditioning and fines filtration**
  (Silica removal, prevention of crud)

- **Selective solvent extraction and return of the raffinate ($NaOH/Na_2CO_3$ solution) to the comminution/leach circuit.**
  Ion exchange of vanadate and hydroxide – long chain quaternary ammonium salt extractant and long chain alcohol phase modifier in an aliphatic diluent**.**

- **Optimisation of the O:A ratios to achieve vanadium concentration into the strip circuit**
  ([V] from ~ 5 g/L in the PLS to ~ 50 g/L in strip).

- **Optimise the V:Na ratio** in the strip to minimise NaOH use and by-product Na_2SO_4.

Process Chemistry 3

Vanadium Product Recovery:

Desilication [$Al_2(SO_4)_3$+H_2SO_4] followed by standard vanadium recovery steps:

- **AMV precipitation**

  $2VO_3^-{}_{(aq)} + (NH_4)_2SO_{4(aq)} \rightarrow 2NH_4VO_{3(solid)} + SO_4^{2-}{}_{(aq)}$

- **AMV deammoniation (high temp)**

  $2NH_4VO_{3(solid)} \rightarrow V_2O_{5(solid)} + 2NH_{3\,(gas)} + H_2O_{\,(gas)}$

- **Ammonia scrubbing – ammonium sulphate regeneration**

  $+ 2NH_{3(gas)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(aq)}$

- **Sodium sulphate by-product from AMV barren solution**

PFS based on Successful Mini Pilot Plant

- Successful demonstration of flowsheet in a 120-hour, continuous test fed at 1 kg/hr slag
- Exceptional product purity of > 99.5% V_2O_5
- Vanadium recoveries of around 75 %
- Leach residence times reduced by 50 % from Scoping Study design - positive implications for capital costs

For full details of Mini Pilot Plant results refer to ASX release dated 4th November 2020 titled “Successful Vanadium Recovery Mini-Pilot and commencement of PFS”

Feasibility Study based on Successful Pilot Plant

- Successful demonstration of flowsheet in continuous pilot plant; 3 campaigns, total 24 days of 25 kg/hr continuously fed slag
- Exceptional product purity of > 99.5 % V_2O_5
- Vanadium recoveries of averaged 74 %
- Leach residence times and SX further optimised - positive implications for capital costs
- Lixiviant regeneration and recycle demonstrated

For full details of Pilot Plant results refer to ASX release dated 11th August 2021 titled “Successful completion of Vanadium Recovery Pilot Plant Trials”

Pilot Plant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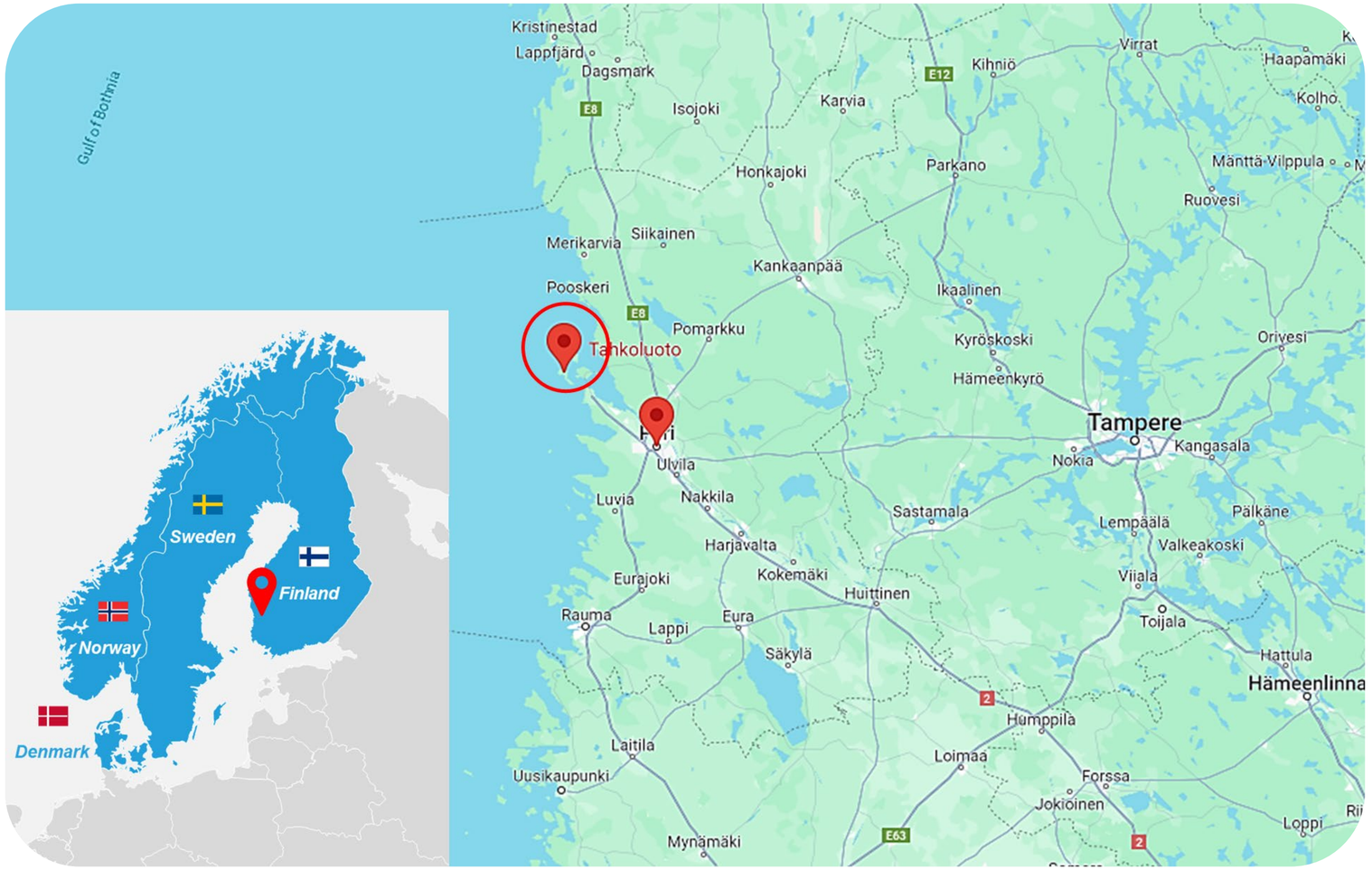
Vanadium Recovery Project
Pilot Plant

Pori, Finland – Tahkoluoto Port



Vanadium Recovery

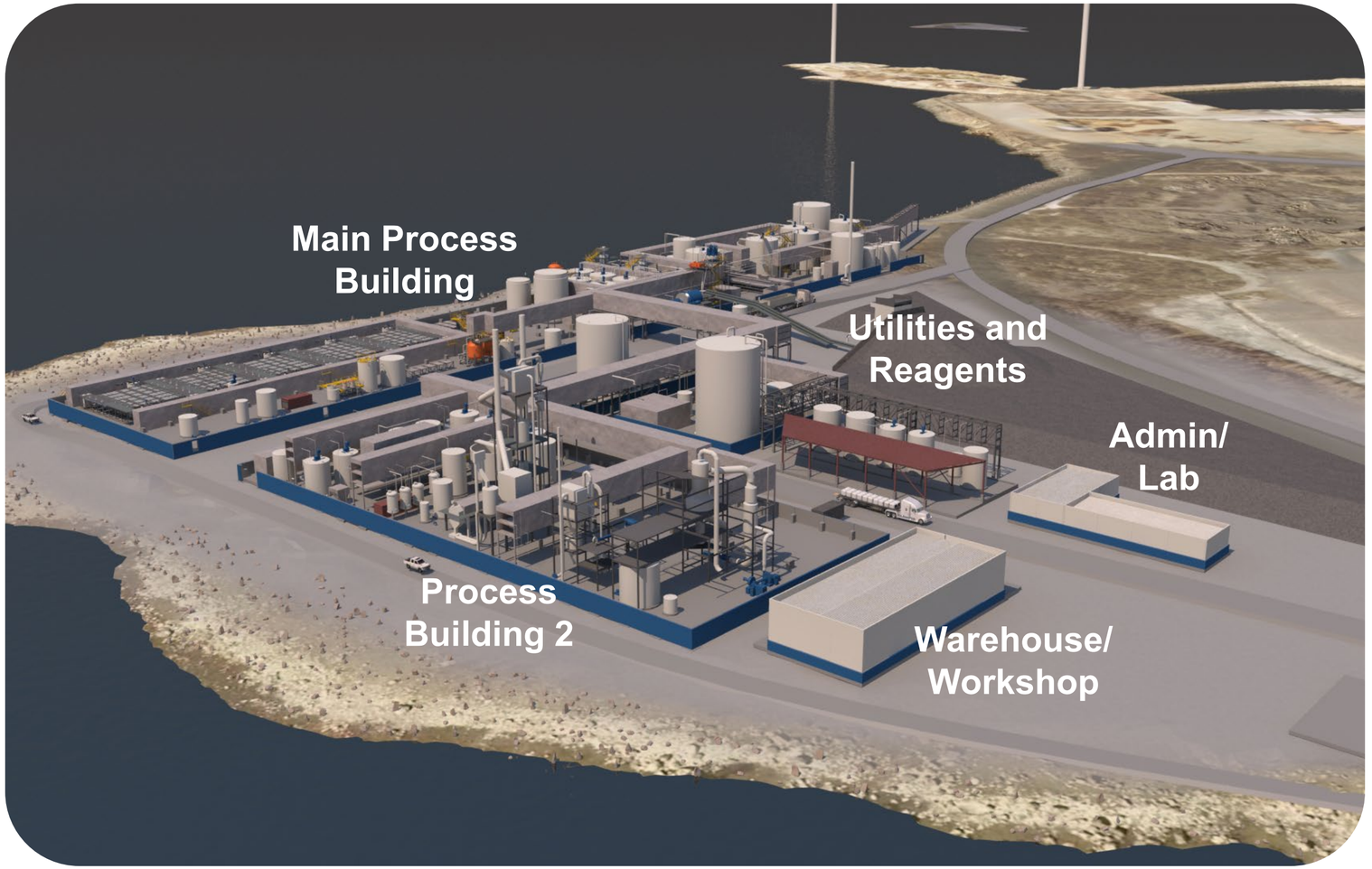
Site Location – Tahkoluoto

Pori, Finland – Proposed first Vanadium Recovery Plant

- City of 86,000 inhabitants with a long history as a hydrometallurgical center of excellence
- Access to a ‘build-ready’ 20 hectare industrial-zoned site adjacent to the deep water, year-round port with rail access to the bulk import/export and chemical berths
- Access to renewable power and other utilities and free access to its industrial sources of CO_2 for capture and sequestration in Neometals’ proprietary process flowsheet

For full details, refer to ASX release dated 8th March 2023 titled “Vanadium Recovery Project Delivers Strong Feasibility Results”

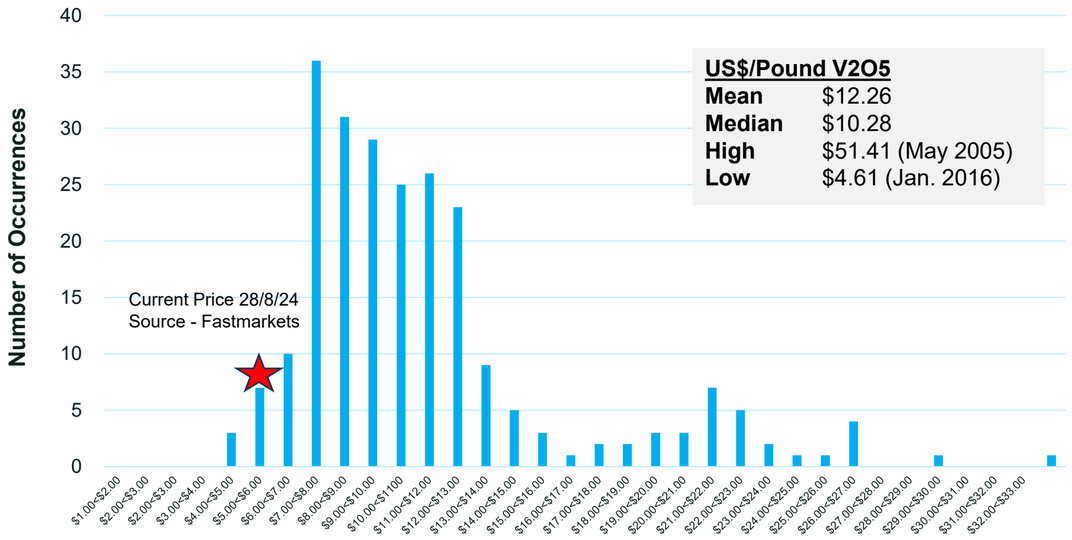
Process Building Layout



Lowest Quartile Cost Position

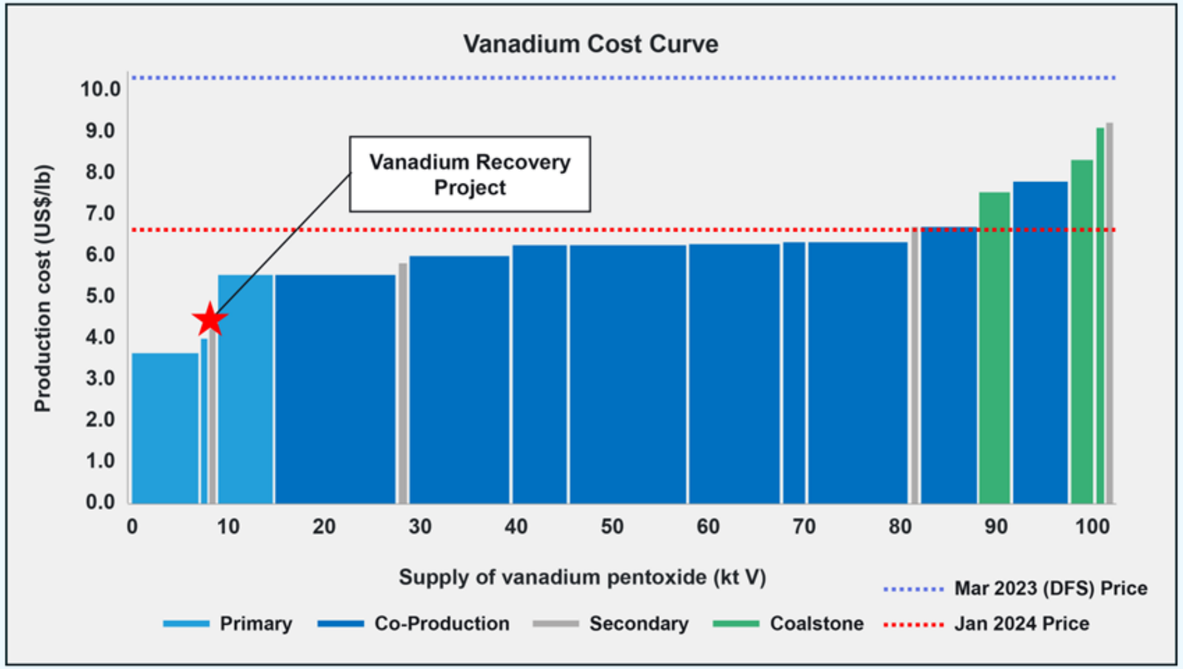
V_2O_5 Real Price Distribution Chart
Jan. 2004 - June 2024

Inflated to Jan 2024 US$



US$/Pound V2O5	
Mean	$12.26
Median	$10.28
High	$51.41 (May 2005)
Low	$4.61 (Jan. 2016)

Source Metals Bulletin publication, TTP Squared Inc. and Fastmarkets

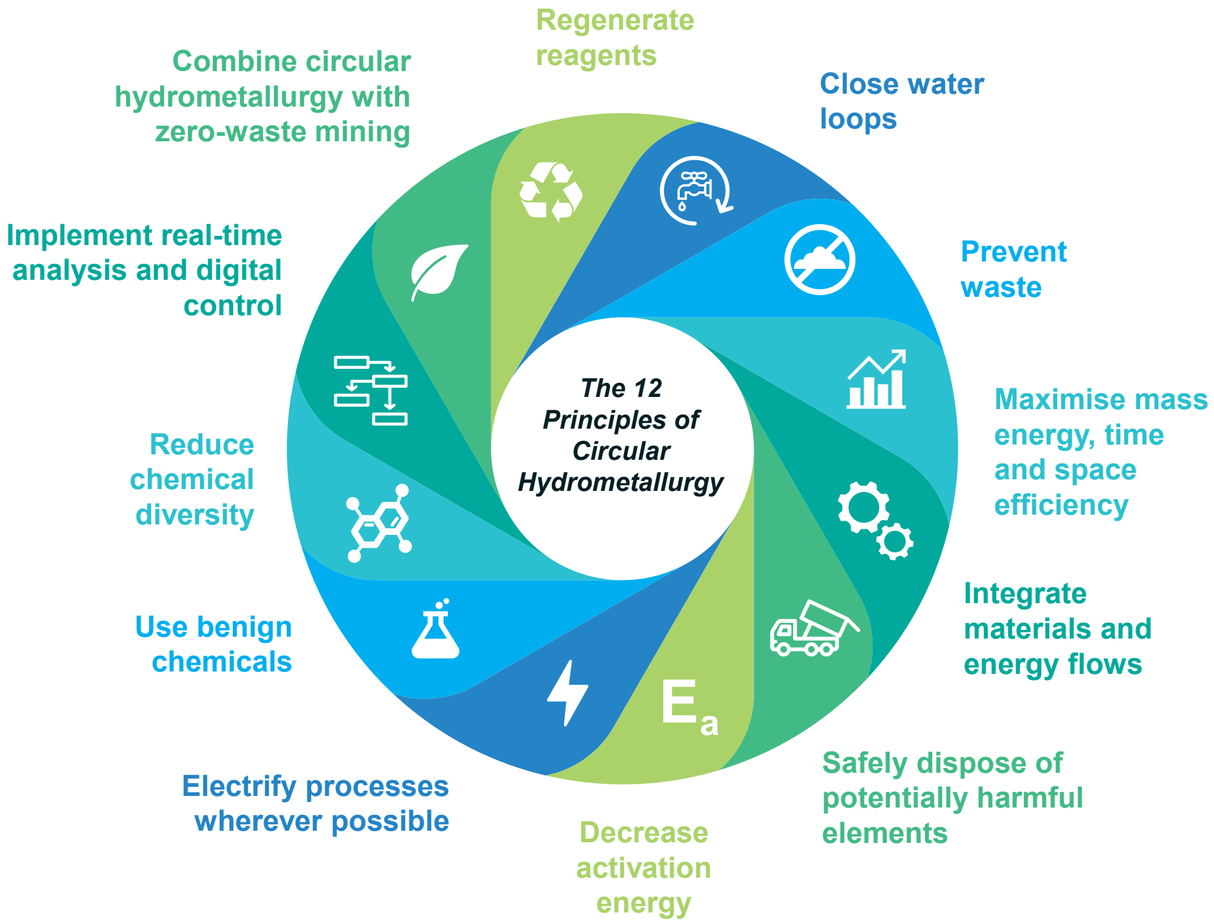


For further information, refer to ASX release dated 8th March 2023 – Vanadium Recovery Project Delivers Strong Feasibility Results

VRP vs Circular Hydrometallurgy

VRP meets many of the goals of Circular Hydrometallurgy

- Recovery of values from by-product slag
- Reagent regeneration and re-use
- Zero solids waste discharge
- Minimal liquid/gas discharge
- Use of green electricity
- Overall process produces carbon negative vanadium

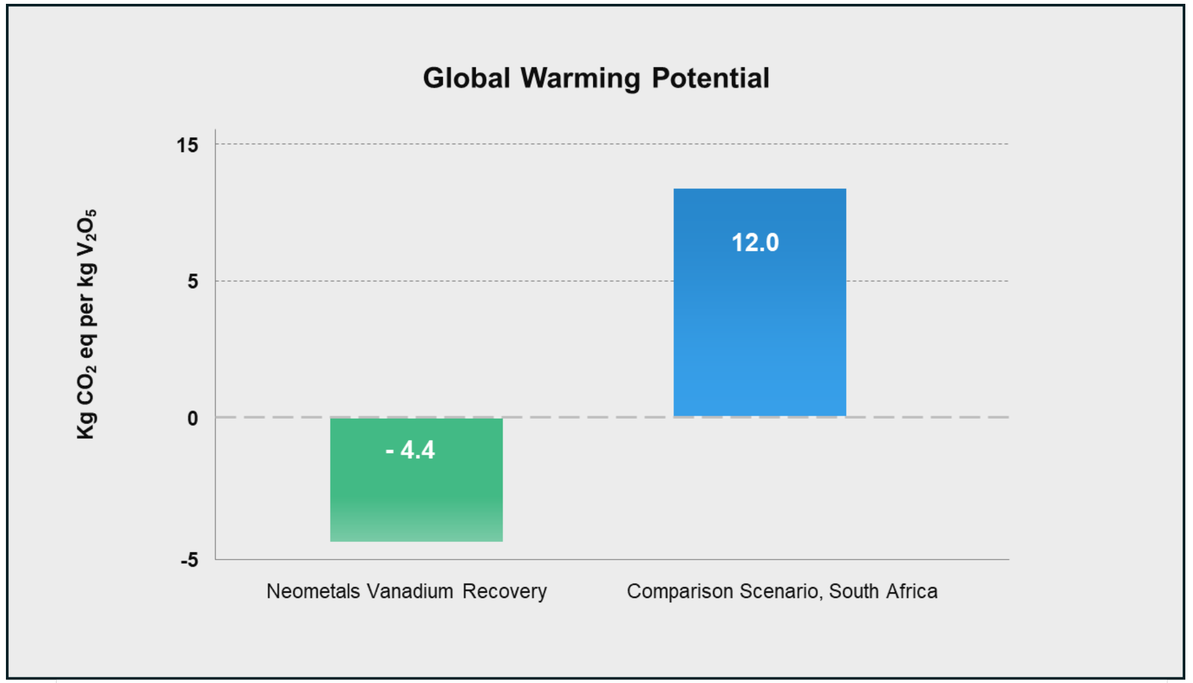


Source: Tom Jones, The Twelve Principles of Circular Hydrometallurgy, Journal of Sustainable Metallurgy 9 (1) (2023) 1-25.

Sustainability – CO_2

Processing slag waste material to recover valuable vanadium

- Life Cycle Analysis completed by Minviro (UK) as part of our studies
- Average CO_2 emissions for V_2O_5 production is negative 4 – 5 kg per kg of V_2O_5 equivalent



For full details, refer to ASX release dated 8th March 2023 titled "Vanadium Recovery Project Delivers Strong Feasibility Results"

Figure: Comparison of global warming potential impact for producing V_2O_5 at Pori Finland compared to South Africa

Neometals

Thank you

I’m happy to answer questions now or email me at:

drobinson@neometals.com.au

Vanadium Recovery Project

Pilot Plant (June 2021)

- **Process:**
  - Three separate campaigns, operating over 24 days (24 hour, 2-shift operation), one each focused on Luleå, Raahe and Oxelösund slag
- **Feed at 25 kg per hour**
- **Process:**
  - Crushed slag delivered (< 3 mm)
  - Ball Milled in process water to reduce particle size
  - Leach feed at selected pulp density and Na_2CO_3 concentration
  - 3 stages of leaching with two-interstage regrind mills warmed and held at selected pH with CO_2 sparging
  - Leach discharge washed on the filter and discharged to a repulp wash circuit
  - PLS prepared by further pH adjustment and filtration for Solvent Extraction
  - Vanadium strip solution taken through conventional steps of;
    - Desilication
    - Ammonium metavanadate precipitation, filtration and washing
    - Deammoniation to form vanadium pentoxide (V_2O_5)
- **July 25th completed 24 days (24 x 7) of pilot plant operation at 25 kg slag feed per hour.**