

# Mining Flash Note

## Bushveld Minerals\*

BMN LN

BUY

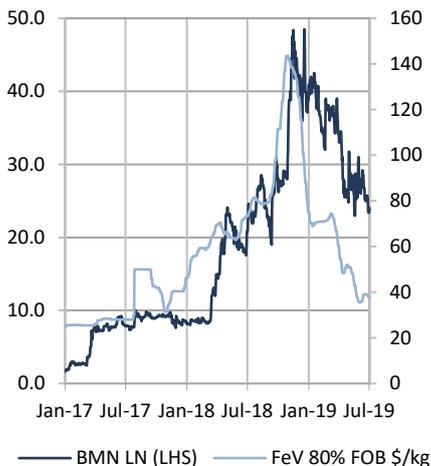
Target 90p

2 July 2019

### Stock Data

Ticker	BMN LN
Share Price:	24p
Market Cap:	£269m

### Price Chart



## Vanadium rental / leasing structure to accelerate value creation. Vanadium forecasts adjusted.

**Bushveld Minerals** holds 74% of Vametco, an integrated vanadium mining, processing and technology business and is buying 100% of Vanchem. 26% of Vametco held by a BEE group. **Bushveld Energy** (84%) is developing vanadium redox batteries for grid use in South Africa. **Lemur Holdings** (100%) is developing a thermal coal mining & power project in Madagascar. **AfriTin** separately listed on AIM in London. Bushveld retain a minority stake in the company

- We are adjusting our valuation in Bushveld Minerals following our review of value offered by the new Vanchem business, Bushveld Energy and the other business units.
- We have also adjusted our assumed vanadium price forecasts to account for the recent price correction.
- Bushveld Minerals recently announced it is to acquire the operating Vanchem vanadium business in South Africa, a move which should bring low-cost expansion and greater flexibility to the group.
- Bushveld agreed to pay US\$68m to acquire the Vanchem plant and facilities to be settled in two stages. US\$6.8m was paid on 30 April 2019, US\$61.2m will be settled no later than 31 October plus a 12 month period after completion of the Transaction. A further US\$0.5-1m will be paid to VVP, which provided services to Vanchem.
- Vanchem is currently producing around 80mtV of vanadium per month but is also in Business Administration in South Africa. This is similar to being in Administration in the UK though the process appears to be more helpful to the longer term operation of businesses than our own medieval system.

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Vametco & Vanchem		2018A	2019e	2020e	2021e	2022e
Price V205	\$/lb	19.2	11.6	10.3	10.3	10.3
Ferro Vanadium	US\$/kg	81.2	50.0	45.0	45.0	45.0
Vanadium sales	mtV	2573	3096	4370	5432	6422
Sales	US\$m	185.4	148.5	188.7	234.6	277.3
Operating costs	US\$m	101.5	78.9	98.3	120.0	139.7
Operating costs	US\$/kg	39.4	25.5	22.5	22.1	21.7
Operating profit	US\$m	83.9	69.6	90.4	114.6	137.7
Pre-tax profit	US\$m	83.2	60.9	85.3	110.5	132.9
Tax	US\$m	23.7	17.4	24.3	31.5	37.9
Post-tax profit	US\$m	59.5	43.6	61.0	79.0	95.1
EPS	US\$/s	5.4	3.9	5.5	7.1	8.6
PE	x	5.7	7.8	5.6	4.3	3.6
EV/EBITDA	x	4.3	5.2	4.0	3.1	2.6
EBITDA	US\$m	83.9	69.6	90.4	114.6	137.7
Free Cash Flow	US\$m	69.1	35.0	57.0	77.9	98.0
Vametco Cash Flow	US\$m	74%	69.1	41.1	48.7	57.3
Vanchem Cash Flow	US\$m	100%	0.0	-6.1	8.2	20.6

SP Angel forecasts: Figures based on 100% of Vametco plant. Bushveld now hold an effective 74% of the Vametco plant. Bushveld hold 100% of Vanchem. \*An SP Angel mining analyst and nomad have visited the Vametco in South Africa.

\*SP Angel acts as Nomad & Broker to Bushveld Minerals.

**Vanadium price assumption:**

- We are pulling back our Ferro-vanadium price forecasts for 2019 to \$50/kgV from \$60.4/kgV in response to the fall in ferro-vanadium prices to around US\$36/kgV FOB China. For 2020 we assume \$45/kgV and we maintain our longer term price forecast at \$45/kgV.
- We still see vanadium demand and prices rising in China in response to better compliance with the legislation introduced in November last year.
- Demand for vanadium electrolyte for Vanadium Redox Flow Batteries VRFBs should also come into the market to support our estimate price assumptions.
- While demand for vanadium for electrolyte may be price sensitive we see the invention of new lease finance structures for the vanadium in VRFB's as enabling the financing of VRFBs at higher vanadium price levels going forward.

**Bushveld Energy:**

- Bushveld's vanadium rental financing service should accelerate the planning and ordering of new VRFB systems to support South Africa's power grid.
- Critically it should reduce the cost of financing and spread the cost of the vanadium in the electrolyte over a longer period rendering the cost of vanadium less critical.
- We are raising our valuation for Bushveld Energy to US\$149m as we see the 'VRFB' business as offering a practical solution for the storage of growing solar and wind power in South Africa. This assumes a relatively low margin on electrolyte sales for VRFB batteries and a more normal project finance type cost for VRFB unit sales.
- While there are other battery solutions on offer, many of these suffer from high parasitic losses, high component renewal costs or increased risk of outright failure leaving VRFB's as the preferred grid-scale storage solution for power utilities.
- ADROIT market research forecast CAGR growth of 8.3%pa for grid power storage in Europe to hit \$1.11bn by 2025 with VRFBs expected to account for 83.8% of the total market share.
- Bushveld Energy aims to participate in 1,000 MWh of opportunities in Africa by 2020 and there is sufficient current demand in the market for vanadium electrolyte to support the installation of a 200 MWh capacity facility in South Africa.
- We have cautiously assumed a more modest market of just 300,000MWh in 2021 and for Bushveld to be involved in the development of around half the VRFB installations and electrolyte sales.
- Bushveld's current VRFB JV is being trialled at ESKOM should have a peak output of 450kWh as a single unit. It should be relatively simple to roll out multiple units to support the rapid growth in wind and solar farms being installed in South Africa as ESKOM moves to supplement its ageing coal-fired infrastructure.

**Valuation:**

- we value Bushveld Energy at US\$149m representing 8.8 pence per share to our valuation on Bushveld Minerals. We have added 7.93p/s for Bushveld's other assets, cash and subsidiaries including Lemur and the P-Q Iron and Titanium project. Our revised ferro-vanadium price forecast adjusts our valuation for the Vametco-Vanchem vanadium business to £801m representing 72 pence per share.

**Conclusion:** Bushveld is extraordinarily well placed to participate in the high-tech Vanadium Redox Flow Battery business. The integration of the business to produce vanadium electrolyte from its in-house vanadium feedstock gives its security of supply, while the new and innovative lease-finance model for the vanadium in electrolyte should make the financing of VRFB's less sensitive to spot vanadium prices. We see this as a major advantage for Bushveld placing the company at the very centre of this valuable growth market.

Bushveld's location in South Africa should also help in the participation of a World Bank funded ESKOM renewables Support Project which is designed to facilitate accelerated development of large scale renewable energy capacity in support of the long-term carbon mitigation strategy of South Africa.

## Vanchem acquisition

- Bushveld's acquisition of Vanchem for \$68m cash adds real value due to its combination with Bushveld's nearby Mokopane project which can supply much-needed fresh ore to Vanchem.
- Vanchem technically has capacity of 5,000mtVpa but currently produces just ~960mtVpa.
- **Capex est. \$45m** to restore capacity plus \$20m for new Mokopane mine construction.
- Our Mokopane/Vanchem NPV looks good at US\$483m, IRR 49% under our revised vanadium price forecasts due to low capital outlay and faster production growth on 10% discount rate.
- Vanchem currently in business administration due to lack of own resources and feedstock from closure of Highveld steel in 2016.
- Production running off just one of three kilns at Vanchem.
- Low-risk expansion using existing kilns, and equipment, simply replaces lost production.
- Vanchem's vanadium chemicals business helps diversify sales while the increase in production still leave scope for further expansion at Vametco.
- Bushveld management have been looking over the fence at Vanchem in South Africa as combining the assets appears to be the best and most cost-effective way of developing their Mokopane vanadium project.
- The deal to acquire Vanchem out of Business Administration for \$68m in cash is subject to regulatory approvals and gives Bushveld immediate access to an additional 960tpa of vanadium production capacity plus infrastructure to expand to 4,200tpa.
- Payment: US\$6.8m is to be paid in cash on 30 April 2019 plus US\$61.2m settled no sooner than 31 July 2019 and no later than 31 October 2019.
- Vanchem is currently operating one out of three furnaces with production currently reduced to just 960mtVpa due to a lack of suitable feedstock and constrained resources, though this should more than double in 2021 as the Mokopane mine comes on stream.
- Capital expenditure of \$45m is planned to restore the plant to 5,000mtVpa of capacity in the form of various vanadium chemical products.
- Mokopane: Developing the new open cast mine and infrastructure at Mokopane will cost just \$20m which added to the \$68m acquisition cost and \$45m of capital is just \$133m vs the previously estimated development cost at Mokopane of \$298m.
- Mokopane ore is a very high 70% magnetite which serves to offset transport and logistics costs when compared with Vametco.
- The acquisition adds immediately to Bushveld vanadium production without adding any new vanadium to the market enabling management to take advantages of current vanadium prices.
- Vanchem is a cheap deal for Bushveld as the business was starved of feedstock and was forced into business rescue by the closure of Highveld which formerly supplied slag and Mapochs mine feedstock to the Vanchem plant. We note some modification will be done to adjust to feedstock from Mokopane.
- Comparing the Vanchem acquisition with the original Mokopane PFS shows the Vanchem deal to work better on virtually every metric and critically the deal serves to simply take over and replace Vanchem production which was lost to the market last year.
- **Chemicals:** Vanchem is a large chemicals business focussed on vanadium chemicals and products. It has multiple product streams and lots of big kit for spare capacity. It is also

well connected to Vametco and Mokopane by rail and road which gives increased flexibility in its operations and potential for create for more value-added products.

- **Cheaper acquisition:** Vanchem is a significantly cheaper acquisition on a per tonne of capacity basis than the Vametco deal due to its distressed state, need for feedstock and capex requirements.
- The capital intensity of the Vanchem deal is around \$17,000/t of V2O5 on our figures vs around \$31,000/t in the Mokopane 2016 PFS.
- Production is currently running off just one of three existing kilns at Vanchem and the new \$45m capital program to restore production over the next five years is seen by management as relatively cautious.
- The plan allows for existing production to continue while refurbishing capacity which was recently mothballed for lack of feed. Hopefully reality will be faster given the presence of so much infrastructure at site.
- **Replacing lost capacity:** The strategy simply replaces vanadium production which was lost to the market after Highveld closed and should have little impact on vanadium prices.
- Highveld Steel closed in 2016 left for dead by Evraz, its Russian owner which cut around 1,800 jobs in the process. We have seen reports suggesting the plant may reopen sometime though this may require higher steel prices, a weaker South African rand or both.
- **Vanadium deficit:** Vanadium remains in structural deficit in the market according to Bushveld supported by 2.5% compound demand growth from steel and chemicals and potential for CAGR growth of up to 8.4% driven by vanadium redox batteries.
- Vanadium prices have fallen this year due to China's failure to fully implement its new standards on vanadium content in steel rebar. The result is that many smaller steel mills are still making brittle steel by quenching and tempering which is not good if corroded or unexpected strain is put on its reinforced structure.
- Chinese officials are being punished for failure to implement government policies and we expect more officials to move to impose standards rather than risk several years in a correctional facility.
- We have adjusted our model to replace our forecast \$150m expansion at Vametco with new and less capital-intensive production from Vanchem.
- While we suspect management will be busy restoring production at Vanchem it is possible that Vametco could also expand further in time if the supply deficit widens and prices continue to support additional supply.
- This is good news for consumers as it offers the prospect for an additional vanadium supply into a market which could potentially see longer term constraint as banks may struggle to finance many other vanadium projects.
- We suspect ferro-vanadium prices may dip further before recovery later in the year as Chinese officials better implement government regulations introduced last year.
- **Production:** We have combined our production assumptions for the Vametco and Vanchem plants. Our new production figures reflect our best guess for the combined output of the two plants. We see an acceleration in the increase in vanadium production but are more cautious as we assume production is around 80% of capacity going forward.
- The combination of Mokopane with Vanchem is a great way forward for Bushveld Minerals. The deal given immediate access to production and near-term expansion at relatively low capital cost and technical risk.
- It broadens the range of value-added vanadium products and enables greater operational flexibility with vanadium pentoxide to feed Bushveld Energy's planned electrolyte plant.

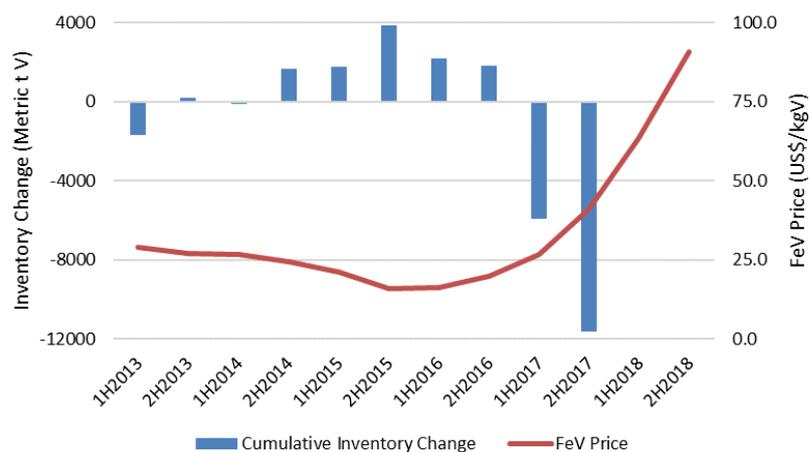
- This should give the team greater confidence to take on contracts for vanadium electrolyte for the next generation of VRFB batteries to be built in South Africa for energy storage and grid balancing.
- A worrying number of fires in Li-ion storage facilities suggests that VRFB may not only be a more economic way forward but may also be the only relatively fire-safe way forward for Megawatt-scale grid storage.

### Vanadium price assumptions

- Vanadium prices were historically held back by high levels of by-product vanadium in China from slag production as a by-product of titano-magnetite and other iron ore feedstock processing.
- We assume in our modelling Ferro-vanadium price forecasts for 2019 at \$50/kgV in response to the fall in ferro-vanadium prices to around US\$36/kgV FOB China.
- For 2020 we assume \$45/kgV and we maintain our longer term price forecast at \$45/kgV.
- **Demand** is now driven by infrastructure activity and higher rebar standards in China starting in November and potentially some stockpiling by consumers and traders. China also banned imports of vanadium in slag.
- **Demand expected to significantly outstrip supply going forward:** ~10% deficit in 2017.
- China may need a further 17,000t of vanadium to meet demand if much of its hardened steel production moves to the new Grade 3 standard. This could represent an increase of 21% on total 2017 global vanadium production.

### Reducing global vanadium availability:

- Global inventories of vanadium should tighten again if China ensures better compliance of regulations on environmental legislation and vanadium content across China. Global cumulative inventories are contracting to levels around 12,000t deficit in H2 2017 according to Vanitec and Metal Bulletin data, which is supporting rapid price appreciation.



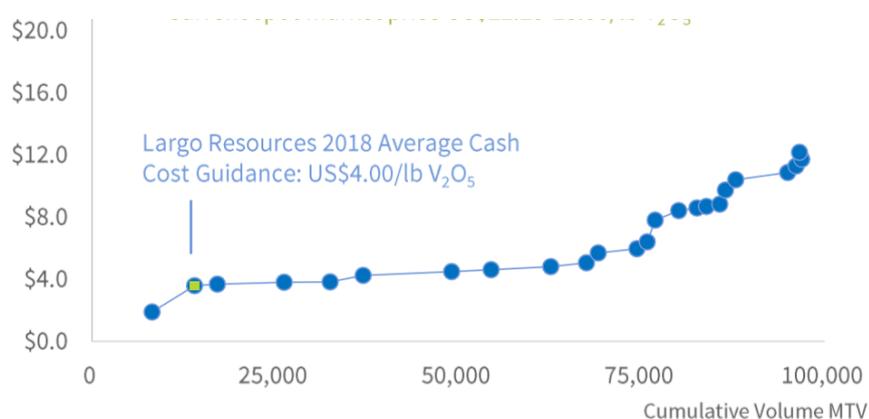
- Supply has been impacted since the liquidation of Evraz Highveld, removing ~11,000tpa following the closure of the major Mapochs mine in South Africa in February 2016. Sustained low commodity prices and subsidised steel imports impacted on the viability of the operation. Subsequently Vanchem, a major producer of high-purity V2O5, also closed due to a lack of feedstock from Highveld.
- The global vanadium market fell into an 8,000t deficit during 2017, with demand forecast to continue exceeding supply through 2020, creating sustained market tightness and an elevated price environment in the near-term. The commonly traded 98% pure vanadium

pentoxide has risen more than 800% since the start of 2017 to approximately \$34/lb in October.

- While some market participants are calling a peak to prices, topping its previous 2005-06 high of \$25/lb, structural changes in the market could sustain further price appreciation. Analysts at Roskill are forecasting sustained growth in demand with 2025 consumption reaching 133,000t, growing 51% from current levels.
- The market is forecasting a significant shortfall with significant investment required to develop global reserves given the lack of near-term primary ore projects. Consequently, some investors are forecasting prices to top \$40/lb.

**Environmental legislation impacting traditional Chinese supply:**

- The cost curve indicates positive margins encouraging potential for expansion across the supply spectrum.

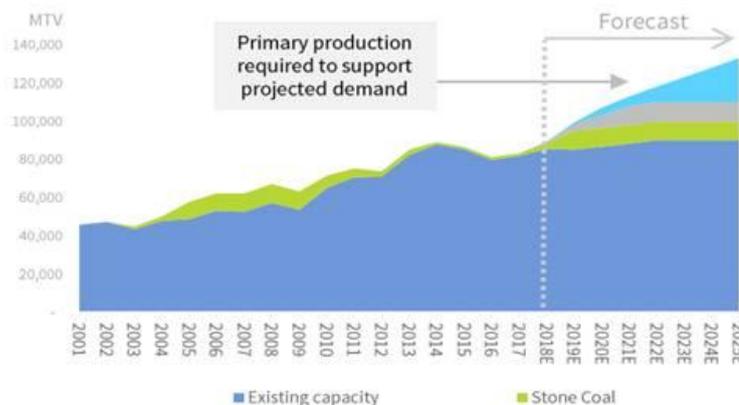


**2018 projected cash costs:**

<b>Co-product steel slag</b>	US\$3.23-9.47/lb V2O5
<b>Primary vanadium ore</b>	US\$4.15-4.50/lb V2O5
<b>Chinese stone coal</b>	US\$6.22-12.0/lb V2O5
<b>Secondary</b>	US\$8.22-11.88/lb V2O5

- The market is principally driven by co-production from the steel industry, reprocessing waste slag to extract vanadium. However, recently China moved to ban imports of waste material, removing some Russian supply to reduce the feedstock to Chinese slag producers.
- Following an announcement by the Chinese Ministry of Environmental Protection all four categories of vanadium scrap were due to be ‘forbidden’ to be imported into China under regulations at the beginning of 2018.
- Additionally Chinese rationalisation was expected to close numerous high-cost, low quality domestic iron ore mines which supply vanadium-titanium magnetite ore, while ‘Blue Sky’ environmental campaigns are creating sustained demand for high-purity iron ore which contains no vanadium.
- The raw material supply base is largely not responsive to changes in the vanadium market price, and environmental legislation changes are only expected to hamper the ramp-up in production.
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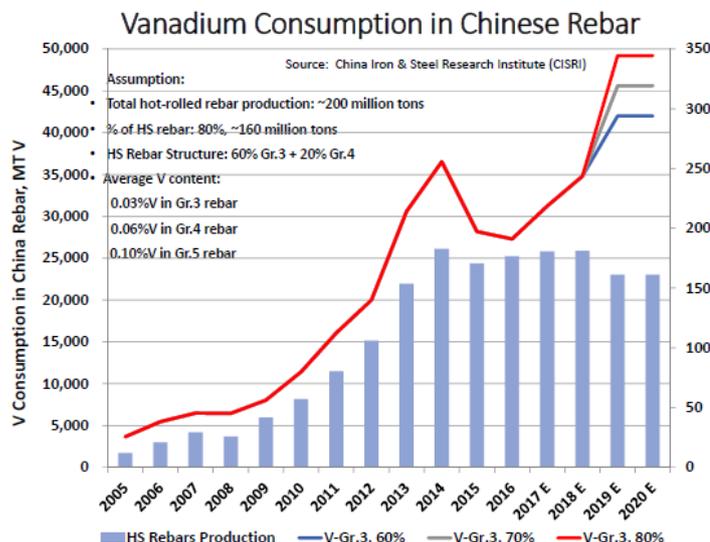
### Global Vanadium Production Forecast (2)



- Production from existing sources (including all idle capacity and expansion of existing primary mines) is forecast to grow at 3.7% CAGR, reaching 111,000t in 2025 according to TTP Squared, a vanadium market consultancy.
- The vanadium deficit is therefore expected to widen significantly by 2025.

#### Rebar standards:

- In 2016 some 27,000t of vanadium was consumed in high strength rebar in China down significantly from 37,000t in 2014. In fact vanadium consumption fell an estimated 27% in high strength rebar and 5% overall causing prices to drop to unusually low levels as Chinese melt-shops introduced induction 'Q&T' Quench & Tempered steel which they sold as grade 3 high-strength rebar despite its lack of vanadium, poor ductility and substandard strength.
- Small steel mills sold this Q&T steel till the authorities tightened the regulations and also introduced a new test which measures the true strength of the steel throughout the metal and not just at its surface. This means that Q&T steel should not now pass the strength test.
- Some 70mt of induction melt-shop capacity has now been shut, saving power, improving overall productivity, cutting pollution and improving steel quality.
- A further 40mt of Grade 2 rebar has also been eliminated by the regulations as it is not suitable for use in seismic areas indicating that a further 40mt of Grade 3 rebar with the higher vanadium content should be produced to replace the lost capacity.
- The net result is that vanadium demand should be around 54,000tpa assuming the manufacture of 180mt of Grade 3 steel, with no niobium substitution.
- Vanadium demand is expected to grow to 42,000t if only 60% of the high strength rebar is produced with vanadium. See chart below from the China Iron & Steel Research Group:



- Collectively global consumption of vanadium is expected to rise significantly, with China fronting the climb in demand. While global vanadium demand could rise by 55% to 133,205t by 2025.
- Chinese consumption is forecast to rise a massive 89% from 2017 levels.

**Scrap (Secondary 10% of market):**

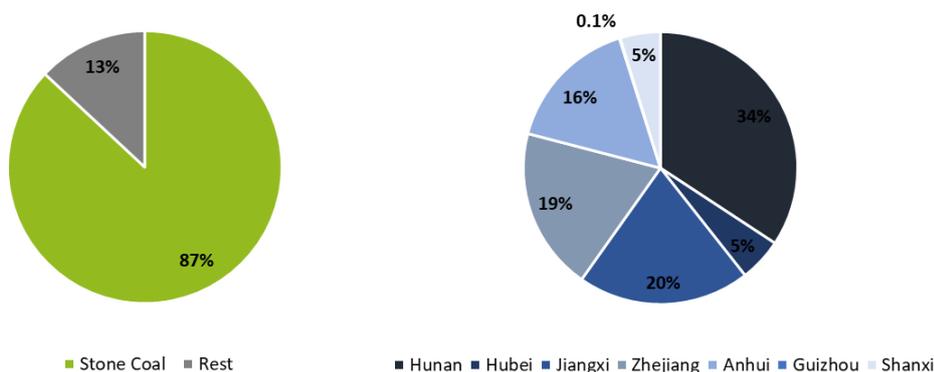
- Removal of all four categories of vanadium scrap imports as “forbidden” by the Ministry of Environmental Protection under new regulations came into effect after December 31, 2017 helped to tighten the scrap market limiting the availability of raw material.

**Steel Slag production (72% of total vanadium supply):**

- China’s **Green Shield environmental policies** combined with rising power costs have caused many steel producers to shift to higher-grade Australian iron ore which does not contain much vanadium.
- Using higher grade iron ore in steelmaking reduces energy consumption, cuts process times, increases capacity and cuts emissions. Rio Tinto and BHP are also reliable shippers delivering their high-grade product on time and according to specification reducing the need for high port stock levels and so much inventory financing.
- Restricted supply of iron ore from Vale switched more steel producers to Rio Tinto and BHP raising iron ore prices in the process.
- Details regarding the scale of environmental inspections and restrictions across China are thin at best, but the trends are still observable with Chinese vanadium production falling 35% in August 2017 as environmental inspections restricted production in Sichuan province.
- The removal of Russian slag feedstock is expected to impact around 50,000tpa of vanadium-bearing slag with 10-20% V<sub>2</sub>O<sub>5</sub>, equivalent to 4,500-5,500tpa.

**Stone coal environmental restrictions:**

- Domestic supply has historically also been supported by output from stone coal. The Asian nation hosts significant gross reserves totalling 61.88bn tonnes, equating to ~118Mt V<sub>2</sub>O<sub>5</sub> and accounts for around 87% domestic reserves (source: Hydrometallurgy).



- The number of producers is limited as the vanadium content low, extraction costly (US\$6.22 12.0/lb) and the roasting process generates significant quantities of caustic gasses, such as Cl<sub>2</sub>, HCl and SO<sub>2</sub>, which cause severe environmental harm.
- Australian Vanadium managing director and Vanitec committee member, Vincent Algar notes “it’s a very dirty process that’s done by various small corporations throughout China. It’s extremely environmentally damaging. It introduces toxins and acid into the environment”.
- As a consequence, Chinese environmental regulators have refused to issue permits to existing stone coal operators, thereby eliminating a sizable domestic source of vanadium. “It’s outlawed by the Chinese authorities and they have been very clear...it is a matter of

*record that they will not accept that environmental degradation under any circumstances. No market conditions will allow corporations in China to pollute both the air and the land”.*

- The introduction of washing plants may enable stone coal mines to regain permits if the coal can be sufficiently upgraded and cleaned, though they create their own environmental issues.
- Reports by FerroAlloyNet suggest factories extracting vanadium from stone coal are undergoing major upgrading to transform the process into cleaner operations, however commercial potential will remain limited and highly constrained. Facilities, principally located in Hunan and Shaanxi, may adopt more competitive low salt roasting-cyclic oxidation or biohydrometallurgical routes to minimise environmental controls.
- Alternative experimental, cleaner leaching methods may or may not restore some production from this source though the cost is also likely to be high.
- The removal (potentially temporary) of stone coal production, increased pressure falls on primary mine supply to match the growing global shortfall.

#### Substitution (Niobium):

- **Niobium** can be used as a substitute for vanadium but only for certain grades of steel and under specific conditions. Elevated price above ~US\$20/kgV create an economic motivation to replace V with Nb or Nb+Ti, however the result is an inferior quality product with higher rejection levels.
- Given the relatively small scale of the Niobium market, the few companies with niobium metal stocks and a total market of just 64,000tpa with just one mine producing some 89% of the global market we do not expect many users to turn to niobium in place of vanadium.
- Given that prices of vanadium have risen about the level necessary for substitution it is believed the vast majority of any substitutional loss of market has already occurred.

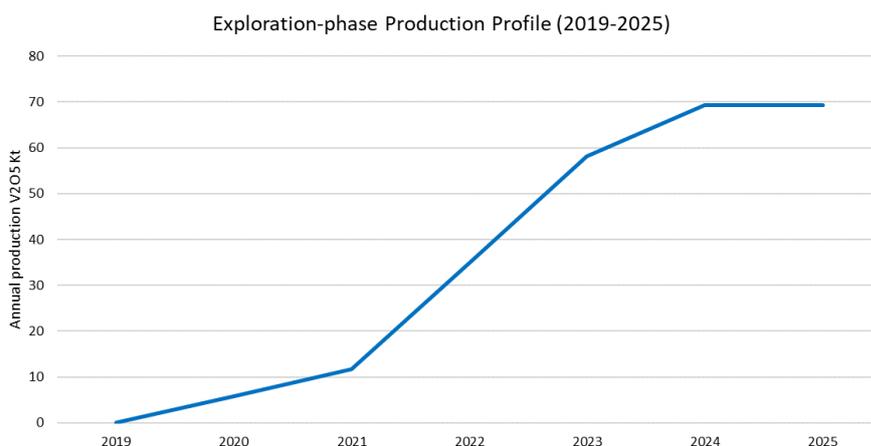


#### Primary (Mine) production (18% of market):

- There is limited primary production entering the market with a number of projects with primary JORC resources undergoing studies to meet the growing requirement for ferrovanadium and vanadium pentoxide. The recent fall in vanadium prices will ensure that most are significantly if not indefinitely delayed.
- Existing project expansions have the upper hand with significantly lower capital costs and shorter timescales to production. Ferro-Alloy Resources in Kazakhstan is one of few new projects to start up with a modest 150tpa of vanadium pentoxide but plans to raise production to 1,500tpa of pentoxide in stages.

- Production could come as a by-product of graphite and some other proposed poly-metallic projects in future years. The fastest of these new co-product supplies is likely to be from smaller graphite mines but will still take time to build co-product process lines.
- Project development time scales are generally in the region of 3 to 10 years for primary vanadium and often similarly for by-product output though some are sooner indicating the market for vanadium could see significant deficit for some years.
- Due to the long lead times in developing advanced-stage exploration assets, the forecast new supply is not expected until after 2021. This delay period is expected to only exacerbate the tightening market and continue to drive prices higher. The supply gap is therefore expected to become more heavily reliant on existing operators who are required to expand capacity to match the booming demand.

#### Vanadium market production profile:



#### Largo Resources (Brazil):

- Largo Resources runs Maracas Menchen, one of the world's highest-grade vanadium mines in Brazil has a market capitalisation on the TSX in Canada of around C\$1bn.
- Largo are expanding the mine to 12,000tpa and could take this to 13,200tpa with certain other upgrades. The mine recently achieved a daily run rate of 10.7tpa of V<sub>2</sub>O<sub>5</sub> at a cost of around \$4.11/lb

#### Glencore (South Africa):

- Swiss-based Glencore, produced 20.9Mlbs (equivalent 9,300t) vanadium pentoxide in 2017 from the Rhovan open-pit vanadium mine and smelter complex near Brits in South Africa.

#### Energy Fuels (US) vanadium byproduct from uranium production:

- Vanadium production has been running at around 70kgV per month with production rising to around 82,000kgV per month (~1,000tpa).

#### Ferro-Alloy Resources (Kazakhstan):

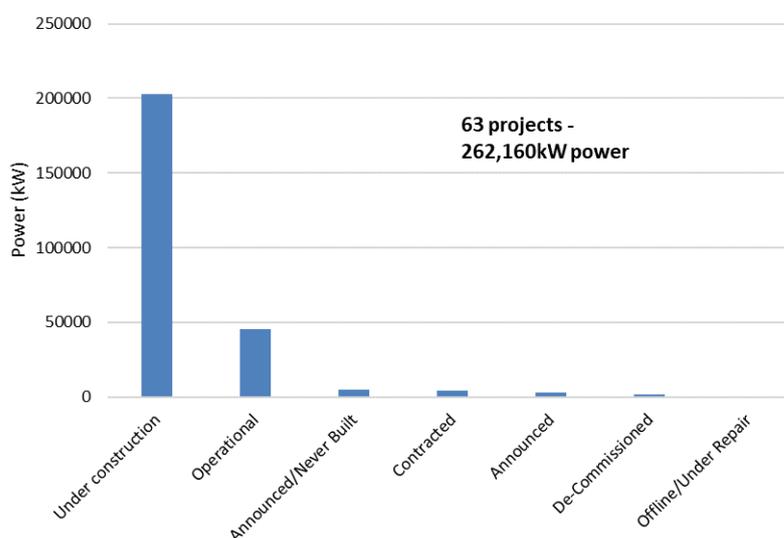
- Ferro-Alloy Resources Group in Kazakhstan have plans to rapidly ramp up production currently in the form of ammonium metavanadate to 22,400tpa vanadium pentoxide in a multi-stage development.
- Balasausqandiq vanadium deposit initially targets a proposed 5,600tpa V<sub>2</sub>O<sub>5</sub> in Stage 1.

#### Developers and explorers with high grade projects are:

- **Australian Vanadium:** Gabanintha (Australia) – 175.5Mt Resources @ 0.77% V2O5
- **Atlantic Ltd:** Windimurra (Australia) – 235Mt
- **TMT Ltd:** Gabanintha (Australia) – 16.7Mt Reserve @ 0.96% V2O5
- **VanadiumCorp:** Lac Doré (Canada) – 99.1Mt @ 0.43% V2O5
- **Tando Resources** (South Africa) – 513Mt Inferred (SAMREC) @ 0.78%
- **Golden Deep** (Namibia) – 1.12Mt Inferred @ 1.28%

**Redox flow battery demand:**

- Vanadium in electrolyte may be leased as part of the financing for ‘Vanadium Redox Flow Batteries’. The leasing of the vanadium units should enable the financing of large-scale units for high speed grid back up, grid balancing and general grid storage.
- VRFBs could replace large numbers of standby diesel and gas generators and more efficiently balance renewable energy power supply from solar and wind power. Flow batteries are ideally suited for long-duration peak shifting or demand-shifting and may be combined with short-duration services where high cycle life is required. The round-trip AC-to-AC efficiency for flow batteries is typically 65-75% which is not bad for a battery.
- Lithium-ion battery installation round trip losses are difficult to find but *“the round-trip efficiencies for the EES systems have been calculated as between 83 percent and 86 percent, falling to between 41-69% where parasitic loads are included,”* according to one study.
- It is therefore difficult to judge but the market for VRFBs but Li-ion battery installations over the next five years could grow by 55%pa from 2GWh in 2017 to 18GWh in 2022 according to GTM Research. VRFBs could replace or support Li-ion battery installations in time, especially give there are 63 current grid-level VRFB projects globally according to the DOE global energy storage database.



**Risk to supply forecasts:**

- The removal of Q&T steel production in China combined with the increase in vanadium content in strengthened steels should push the market to deficit if more fully implemented in China. So far, we understand, the authorities have been slow to fully implement the regulations with smaller steel mills while ensuring compliance at larger and more critical steel producers.
- Chinese producers of stone coal may work out how to wash the coal to meet new environmental standards, though we suspect the cost is prohibitively high.

- Former Chinese vanadium slag processors might also come up with a cleaner hydrometallurgical solution to the production of vanadium from steel slag.
- Other by-product and primary vanadium might come to the market faster than we are anticipate.
- Innovation might enable the strengthening of steel through substitution using other metal alloys.



**In conclusion:**

If China maintains its Green Shield environmental policies and steel producers continue to use Australian iron ore in preference to other, less clean, sources of iron feedstock then the vanadium market should see a very substantial deficit and prices could remain at relatively high levels for the next few years.

The risk is that the market situation may become so severe so quickly that that consumers will have to either slow production or find ways to either substitute vanadium (niobium) or to produce vanadium from other feedstock or to increase the tensile strength of steel in other ways.

Vanadium prices indicate the market is still relatively tight with few new sources of production in the short term.

**Short term:**

It is difficult to see much new production coming through till 2020 indicating the potential for ferro-vanadium prices to average significantly higher price levels than previously seen in past cycles.

**Longer term:** Much of the new primary production is also likely to carry higher operating costs when it comes in requiring further cost analysis. We therefore expect new vanadium supply to return to the market from a higher cost base needed to repay new capital and higher operating costs.

*\*SP Angel act as Nomad and broker to Bushveld Minerals.*

Note: *Bushveld Minerals controls and holds an effective 84% of Vametco and has agreed to buy 100% of Vanchem.*

*\*An SP Angel mining analyst and nomad have visited the Vametco vanadium mine and processing facilities in South Africa.*

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Recommendations are based on a 12-month time horizon as follows:

Buy - Expected return >15%

Hold - Expected return range -15% to +15%

Sell - Expected return < 15%