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Protean Energy Limited

ASX:POW

October 2018

INDEPENDENT
INVESTMENT RESEARCH

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Protean Energy Limited

Initiation - October 2018

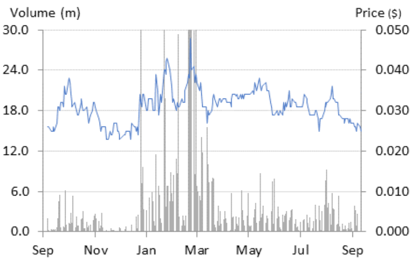
Note: This report is based on information provided by the Company as of October 24, 2018.

Investment Profile	
Share Price October 24, 2018	A$0.024
12 Month Low/High Price	A$0.023/ A$0.05
Issued Capital:	
Ordinary Shares	304.3 m
Unlisted Options	93.2 m
Performance Rights	8.1m
Fully Diluted	405.6 m
Market Capitalisation UD	A$7.30 m
Enterprise Value UD	A$3.22 m
Cash - June 30, 2018	A$2.42 m
Liquid Investments - Current	A$1.66 m

Board and Management
Mr Bevan Tarratt: Executive Chairman
Mr Wayne Loxton: Technical Director
Mr Young Yu: Non-Executive Director
Mr David Wheeler: Non-Executive Director

Major Shareholders	
Mr Jason Peterson (Direct and Indirect)	5.43%
Mr Wayne Loxton	3.20%
Board (inc Mr Wayne Loxton)	5.06%
Top 20	32.91%

Share Price Performance



Mark Gordon - Senior Analyst

The investment opinion in this report is current as at the date of publication. Investors and advisers should be aware that over time the circumstances of the issuer and/or product may change which may affect our investment opinion.

VERTICALLY INTEGRATED VANADIUM

Protean Energy Limited ("Protean" or "the Company") is developing a vertically integrated vanadium business, based on the 490 Mlb V_2O_5/18.4 Mlb U_3O_8 Daejon Vanadium-Uranium Deposit in South Korea ("Daejon"), and the V-KOR vanadium redox flow battery ("VRFB") technology. At Daejon Protean is in a 50:50 partnership with the KOSDAQ listed DST Company Ltd ("DST", 033430.KOS, formerly KORID Inc) with the Company now moving to a 60% controlling interest (from 50%) in KORID Energy, the holder of the V-KOR battery technology with the partner also being DST.

Electrolyte development is also part of the vertical integration strategy with KORID Energy successfully producing a high energy density product.

Recent times have seen a strong resurgence in the vanadium price (which is currently trading at a price of ~US$27/lb V_2O_5, after recent lows of US$5/lb), with this driven by a structural change in supply, and increasing demand with changing requirements for Chinese rebar, with this forecast to be further driven by the expected uptake in VRFBs - these factors present an ideal opportunity for Protean.

The Company has strong associations with South Korean groups and agencies, including the Korean Institute of Geoscience and Minerals ("KIGAM"). The Company has signed a technology transfer agreement for vanadium-bearing black shale processing intellectual property ("IP") with KIGAM, and has been granted access to a 1.2 tph pilot scale black shale processing plant for upcoming metallurgical test work. In 2013 KIGAM published details of a two stage atmospheric acid/alkali leach process to recover vanadium and uranium separately, with Protean to look at this as part of the upcoming work.

Success in developing a technically and financially viable metallurgical process route for the black shale mineralisation will be vital for Daejon, with the KIGAM tie-in being important given work conducted by the agency on this style of mineralisation - should the test work be successful significant value will be added to Daejon, and it may be transformed into a strategic asset to meet South Korea's vanadium and part of the uranium need, all of which is currently imported.

The target for the V-KOR battery technology is to develop a relatively low cost, low footprint and easily transportable unit, with this now advancing towards commercialisation. The Company is currently near completion of a four month trial of a 25 kW unit in Western Australia, with the proprietary V-KOR battery stack technology also recently being selected above those of competitors for a three year, 1 MW/4 MWh test being run by the Korean Institute of Energy Technology Evaluation and Planning ("KETEP").

One key aspect of this is that KORID Energy, the 60% held subsidiary that owns the V-KOR technology, will receive ~A$3 million from the ~A$10 million KETEP funded test programme over the next three years.

KEY POINTS

Strong vanadium markets: Due to structural changes in the markets and growing demand leading to supply deficits, recent months have seen very strong price rises for vanadium, with this now trading at a spot price of over US$30/lb V_2O_5, after reaching a low of under US$5/lb V_2O_5 in 2016; this has led to a strong resurgence in the markets, with the expectation that prices will "stay stronger for longer".

Large, shallow resource: At 76 Mt @ 0.3% V_2O_5/110 ppm U_3O_8 (containing 490 Mlb of V_2O_5 and 18.4 Mlb of U_3O_8) the Daejon Resource is large, and should work lead to a viable operation, should be able to support such an operation for a considerable time frame; in addition the resource is shallow, likely being suitable for open cut mining.

Positive results from V-KOR battery technology: This highlights the potential for the development of an efficient, low cost VRFB.

Stable, infrastructure rich jurisdiction: Despite generally being under the radar, South Korea has a history of mining, with a well developed law and supportive Government agencies; in addition it is well served by infrastructure and skilled personnel, and has the end users to take any vanadium and uranium produced by a future operation.

Experienced personnel: Company personnel have extensive experience in the junior resources industry, and hold a significant number of shares in the Company.

Ongoing news flow: There will be ongoing news flow over the coming six months, largely related to the metallurgical test work at Daejon and the V-KOR battery trial in Western Australia.

Well leveraged to success: With an enterprise value of only A$3.22 million (significantly lower than that of peers), the Company is well leveraged to any success in either Daejon or V-KOR.

SWOT ANALYSIS

Strengths

- **Experienced Personnel:** Company personnel have extensive experience in the resources sector as well as holdings in the Company.
- **Large, shallow resource:** This will help the economics of any future operation, in allowing for relatively low cost open cut mining and a long mine life.
- **Strategic asset:** Given that South Korea currently imports 100% of its annual requirements of ~9.5 Mlbs of V (16 Mlbs V_2O_5) in addition to uranium, Daejon presents as a strategic asset with the potential to supply both vanadium and uranium.
- **KORID IP and partnership:** KORID has developed significant IP in the battery and electrolyte development, which is key to the partnership; with the move to 60% Protean also now has control of this.
- **KIGAM IP**: The technology transfer agreement with KIGAM is important, given that the Korean agency has carried out extensive metallurgical test work on the Ogcheong black shales; this also includes access to the pilot scale plant.
- **Dual commodity:** The potential to produce both vanadium and uranium should enhance project economics, and can provide an in built hedge against adverse price changes in any one of the commodities.
- **Forecast strong vanadium and VRFB outlook:** Most commentators are seeing a strong outlook for vanadium for the foreseeable future, partly driven by expected growth in the uptake of VRFBs.
- **Forecast improving uranium markets:** Some forecasters see improvements in the uranium market and prices following a long bear market - increase in demand will be driven by new power generation, with ~240 nuclear reactors under construction or planned globally, and over 300 new reactors proposed.
- **Well funded:** With ~A$4 million in cash and liquid investments, Protean is well funded; in addition V-KOR will receive ~A$3 million in funding through the KETEP trial over the next three years. As announced to the market on October 17, a change in the shareholder deed will facilitate the sale of the ~A$1.77 million shareholding in DST.

Weaknesses

- **Low grade:** when compared to other projects the vanadium and uranium grades will necessitate a relatively low cost operation to be financially viable.
- **Expensive vanadium metallurgy:** Our view is that this is the key weakness in the Project, with work to date on Daejon highlighting the potential requirements for relatively expensive processing for vanadium; however successful commercialisation of a two phase leach process developed by KIGAM could mitigate this. Uranium is readily extracted using low opex acid leaching.

Opportunities

- **Metallurgy:** The key opportunity at Daejon is to develop and optimise a cost effective processing route for Daejon (and other South Korean black shale deposits) - this will be vital to the success or otherwise of Daejon.
- **Value return for shareholders:** If shown to be financially and technically viable, Daejon has the potential to develop into a valuable asset, with the Company then having options in how to return value to shareholders - these could include developing the asset, selling a stake or else selling the complete asset.
- **Battery development:** The key opportunity for V-KOR is to produce a relatively low cost, high energy density and high energy transfer battery using the proprietary battery stack IP that will give the Company an advantage should the VRFB markets develop as forecast; this also presents technology licencing opportunities.

Threats

- **Commodity prices:** These have a major effect on junior resource companies, both on the economics of any project and on the ability to raise funding. Given the grade and metallurgy, any operation at Daejon will require strong prices to be viable; this will also affect the ability to get future financing, including for exploration/evaluation and development..
- **Unsuccessful vanadium metallurgical test work:** This is the key technical threat to Daejon, and the one on which the project viability largely hinges.
- **VRFB demand:** Less than expected take up of VRFBs will have a double effect - firstly it will affect the V-KOR business, and secondly will change vanadium price fundamentals.

OVERVIEW

BACKGROUND AND STRATEGY

- The increasing vanadium price and forecast demand for VRFBs has resulted in renewed interest in the vanadium sector, which Protean is ideally placed to take advantage of.
- The Company's strategy is to develop a vertically integrated vanadium operation; the upstream asset is the Daejon vanadium-uranium deposit (Figure 1) with planned production targeting domestic vanadium and possibly uranium demand, with downstream activities concentrating on the development of VRFBs, which require high purity V_2O_5 flake for their operation.

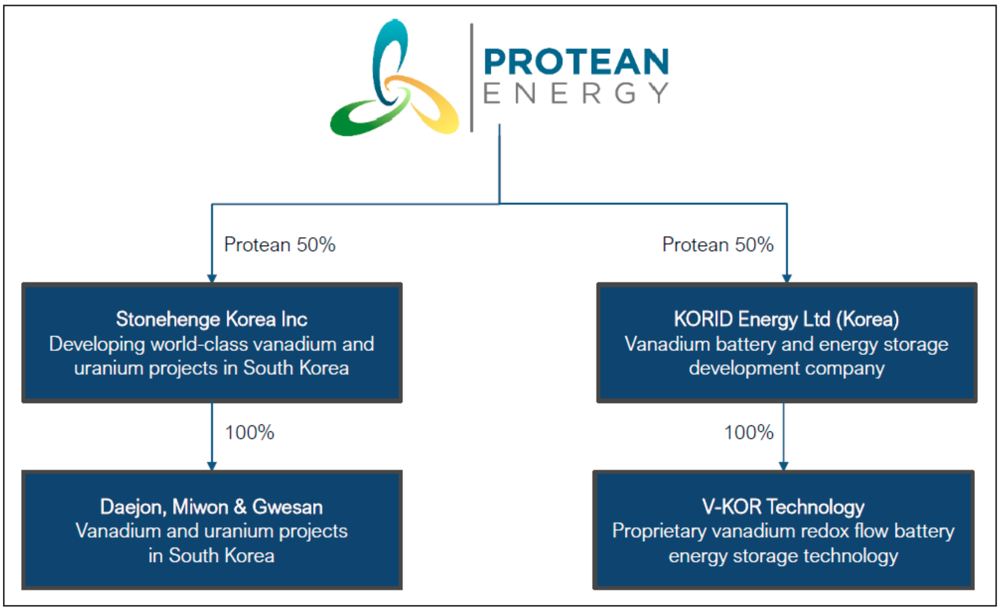
Figure 1: Korean Projects location map

Source: Protean

- Daejon is held 50% by Protean, with, as announced on October 17, 2018, Daejon's ownership of KORID Energy moving from 50% to 60% through the issue of A$750,000 worth of Protean shares at a deemed issue price of the greater of the 10 day VWAP prior to completion or A$0.03/share.
- The ownership structure shown in Figure 2; in both cases the partner is KOSDAQ listed DST Company Ltd ("DST", formerly KORID Inc).
- Daejon was originally acquired in 2010 as a uranium asset, with the interest in KORID Energy being acquired in 2016 - the Daejon acquisition also included the Miwon and Gwesan deposits (Figure 1) - some drilling has been completed at Gwesan, however given that the focus is on Daejon these won't be discussed further.
- The key to unlocking value from Daejon is metallurgy, with current work concentrating on that aspect; the deposit hosts a large vanadium-uranium resource which should be sufficient for a long term operation - the Company has access to the black shale metallurgical IP and pilot plant of KIGAM.
- Successful outcomes from this work should leave Protean with a valuable, strategic asset, with the potential to supply South Korea's vanadium and part of the uranium needs - the Company is open to options regarding the return of value to shareholders.

- South Korea uses around 4,300 mtV (9.5 Mlbs) per annum largely in steel production, all of which needs to be imported - 2017 steel production was ~71 Mt, with South Korea the sixth largest steel producer globally.
- On the uranium front South Korea currently has 24 nuclear reactors (with a further 21 planned, however with these in doubt due to the recently elected Government's stated aims to shut down the industry by 2045), which generate some 23 GWe, a third of the countries electricity generation - 4,730 mtU were imported in 2017, with this expected to rise to 5,300 mtU by 2020.
- The V-KOR battery has been under development for some 10 years, with Protean having an association with KORID Energy for some nine years, with, as mentioned above, a formal 50% equity stake being acquired in 2016, with this now moving to 60%.
- The battery technology has been successfully tested in cycle testing, and is now undergoing field tests in Western Australia, with the Company reporting that this has been successful to date.
- Aims of ongoing development are to significantly cut the costs of battery production; this includes a number of factors, including making the battery stack smaller and cheaper for a given capacity, and developing higher density electrolytes.
- This work is ongoing, and in addition the V-KOR 25 kW stack has been chosen to be part of a three year 1 MW/4 MWh battery test run by KETEP which will provide ~A$3 million in direct funding to KORID Energy.

Figure 2: Protean corporate structure - note KORID energy ownership is now moving to 60%



Source: Protean

COMPANY HISTORY

- Protean originally listed on the ASX in late 2006 as Stonehenge Minerals (ASX: SHE, "Stonehenge"), however following the acquisition of the Protean Wave Energy Conversion Technology ("WEC") in 2014,, with this also involving a change of business and hence the requirement to re-comply for ASX listing.
- The name was changed to Protean Energy in early 2016, in conjunction with completion of the re-compliance.
- A binding term sheet for the sale of the WEC to Pearl Clean Energy ("Pearl") was signed in August 2018, with Pearl required to spend A$700,000 on the WEC assets within five years of signing, and Protean to retain a 1.5% royalty on all revenue generated by the WEC assets.

FINANCIAL POSITION

- As of June 30, 2018, the Company had A$2.402 million in cash, and in addition holds 1.16 million DST shares, with a current value of ~A$1.75 million.
- As announced on October 17, 2018, a variation in the shareholders deed with DTC will facilitate the sale of Protean's shareholding in DTC at the volume weighted VWAP for the 10 days prior to completion.

- Additional funding of ~A$3 million over the next three years will also come as part of the KETEP battery test programme.
- Over the 2018 financial year the Company spent A$0.648 million on R & D and exploration, and A$1.164 million on administration and staff costs; over the same period investment in the South Korean JV's totalled A$0.478 million.
- Share issues over the 12 months to June 30, 2018 totalled A$4.149 million; this included a fully underwritten rights issue in July 2017 that raised A$3.149 million (before costs) at A$0.02/share, and a placement at A$0.025/share that raised A$1.000 million before costs in February 2018.

CAPITAL STRUCTURE

- The Company has 304.3 million fully paid ordinary shares on issue, 93.2 million unlisted options and 8.08 million performance rights on issue - unquoted securities are listed in Table 1, with only the 85 million A$0.037 options having a chance of being exercised.
- The top holder is Mr Jason Peterson, who holds 5.43% in direct and indirect holdings.
- Executive Director, Mr Wayne Loxton, holds 3.20%, with the Board (including Mr Loxton) holding 5.06% of fully paid ordinary shares.
- The top 20 hold 32.91%, and the Company has over 2,500 shareholders.
- The Company underwent a 1:30 consolidation in April 2017.

Table 1: Unlisted options and performance rights

Unlisted options			
Expiry Date	**Number**	**Exercise Price**	**Cash on Exercise**
31/12/2018	5,223,637	A$1.125	$5,876,592
30/11/2018	294,581	A$1.125	$331,404
30/11/2018	589,164	A$1.500	$883,746
30/11/2018	883,750	A$1.875	$1,657,031
30/11/2018	1,178,331	A$2.250	$2,651,245
30/11/2018	33,333	A$2.430	$80,999
30/06/2021	85,000,000	A$0.037	$3,145,000
Total	**93,202,796**	**N/A**	**$14,626,016**
Performance Rights	8,082,662	N/A	N/A

Source: Protean

DAEJON VANADIUM PROJECT - PROTEAN 50%

LOCATION AND TENURE

- Daejon, which covers an area of 2,282ha, is located 15km south of the city of Daejeon (Figures 1 and 3), South Korea's 5th largest metropolis with a population of ~1.5 million - the tenements are in good standing, expiring in June 2019, and will be renewed upon expiry of the current term.
- The area is well served by transport and power infrastructure, and is largely located over hilly wooded areas, with a local relief in the order of 150m; highways cross the central part of the tenement, with a water storage dam adjacent to this infrastructure - this area has been excluded from the Resource estimations.

ACQUISITION AND OWNERSHIP

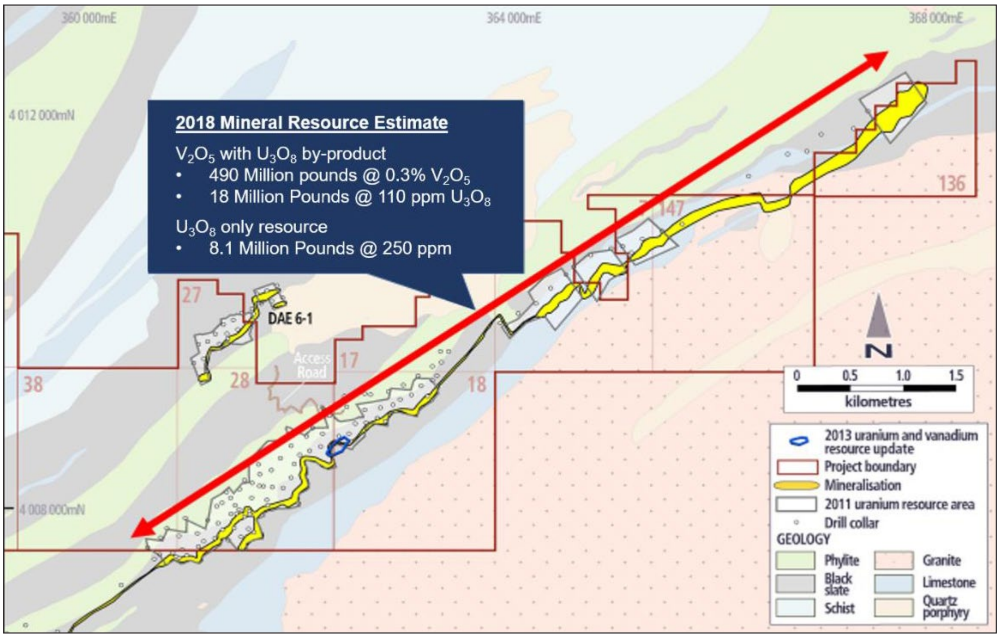
- Protean acquired the Project (along with the Gwesan and Miwon properties) in 2010, through the acquisition of local company, Chang Ma Mines Inc.
- The consideration was 10 million ordinary shares, 60 million performance shares and cash payments of US$910,000 - 100% ownership was reached in July 2011.
- In July 2014 the Company announced the signing of an MoU with DST (then Korea Resources and Development, "KORID") whereby the two companies would form a 50:50 joint venture ("JV") to progress Daejon, with the deal being finalised in July 2015.

- The consideration was ~A$2.5 million in KORID shares (at the time of completion this comprised 4,653,497 shares with a value of ~A$2.4 million), KORID to subscribe for placements totalling A$300,000 in Protean, and provide A$200,000 of in country support.
- As announced on October 17, 2018, a variation deed to the Stonehenge Korea agreement requires DST to fund the initial A$237,373 of the initial Stage 2 (feasibility) expenditure of which Daejon has now entered - after this expenditure the partnership will revert to a 50:50 share of costs.

GEOLOGY AND MINERALISATION

- Vanadium and uranium mineralisation is hosted in three black shale horizons, part of a NE striking sequence of folded and metamorphosed marine sediments of the Proterozoic Ogcheong Belt, with other units including limestone, schist and phyllite (Figure 3); intrusives including quartz porphyries and granites are also present in the area.

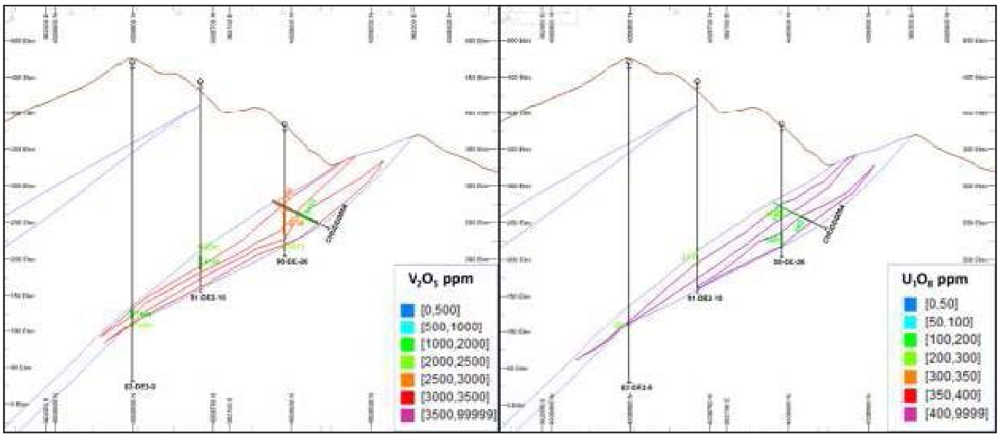
Figure 3: Daejon geology and tenement map



Source: Protean

- The variably mineralised shales have been traced for a total of ~10km along strike and dip at ~35° to the north-west (Figures 3 and 4); further details of the three horizons are as follows
  - South Horizon - strike length of 9,300m, intersected to a depth of 400m vertically (and still open), and with an average thickness of 19.5, ranging from 1.6m to 46.3m,
  - Mid Horizon - strikes for 2,700m along the western end of the tenement area, with the mineralised portion having a strike length of 1,300m in a number of anastomising lodes and a true thickness of between 1.0m and 67m (with an average of 25m); and,
  - North Horizon - vanadium mineralisation occurs in 700m of the total 1,090m strike of anastomosing lodes, and has a true thickness of between 3m and 46.9m (with an average of 17.0m), and has been intercepted to a depth of 220m.

Figure 4: Daejon cross section -SW end of deposit - vanadium assays on left, uranium on right



Source: Protean

- Mineralisation is generally associated with mica minerals and graphite - two styles of mineralisation have been identified; footwall and hanging wall grey slate zones, and a core zone of graphitic black shale (termed in some early releases as "graphitic coal").
- Mineralogical work completed in 2011 identified the readily leachable uraninite as the uranium mineral, with vanadium hosted in calcic amphiboles and feldspar; the comment was made that this was contrary to the previous understanding of vanadium being hosted in micas as is commonly the case in black shales.

HISTORICAL WORK

- Historic work during the 1970s and 1980s was undertaken by the Korean Institute of Energy Research ("KIER"), with the focus then being on uranium.
- Work included trenching (19 trenches), diamond drilling (264 holes for 36,293m) and the development of a ~300m long adit.
- Other activities have included two radiometric surveys, geological mapping and rock chip sampling.

WORK BY PROTEAN

- Since acquiring the Project in 2011, Protean has carried out a number of activities, with the focus being on metallurgy and resource estimation/expansion, with other work including geological mapping and rock chip sampling.
- Original work was targeted at uranium, however the focus changed to vanadium following the Fukushima accident and the subsequent fall in the uranium price, which remains subdued to this day.

Drilling and Resources

- In 2013 the Company drilled five drill holes for 1,760m at the Chubu uranium resource, intersecting up to 37m @ 5,047ppm V_2O_5, and 21m @ 308ppm U_3O_8; these results were used in the initial vanadium MRE of 2.5Mt @ 3,186ppm V_2O_5 (17.7Mlbs contained V_2O_5, with an updated uranium MRE of 95.2Mt @ 329ppm U_3O_8 (66.7Mlbs contained U_3O_8).
- The initial uranium MRE by Stonehenge of 46.8Mt @ 340ppm U_3O_8 (34.9Mlbs contained U_3O_8) at Chubu was completed in 2010, based on historic drilling and surface mapping - this was updated to 92Mt @ 320ppm eU_3O_8 (65Mlbs contained U_3O_8) in 2011 following further mapping and verification of drill collars and assay data - this included the smaller Yokwang prospect at the NE end of the recognised mineralisation.
- The latest MRE (Table 2) was completed in September 2018, following portable XRF ("pXRF") analysis of 78 of the KIER holes out of 91 that were available - these had not previously been assayed for vanadium, with the pXRF method validated by the comparison of results from Protean's drilling and the historical holes.
- The drill core is stored by the Korean Institute of Geoscience and Minerals ("KIGAM") at their Daejeon City core storage facility).

Table 2: Daejon JORC 2012-compliant MRE

Daejon JORC 2012-compliant MRE									
		V_2O_5 Resource with U_3O_8 by-product					U_3O_8 Only Resource		
Cutoff	Classification	Tonnes mt	V_2O_5 ppm	V_2O_5 mlbs	U_3O_8 ppm	U_3O_8 mlbs	Tonnes Mt	U_3O_8 ppm	U_3O_8 mlbs
V_2O_5 > 2,000ppm or U_3O_8 >200ppm	Indicated	3.6	3,000	24	140	1.1	-	-	-
	Inferred	72	3,000	470	110	17	15	250	8.1
	Indicated + Inferred	76	3,000	490	110	18	15	250	8.1

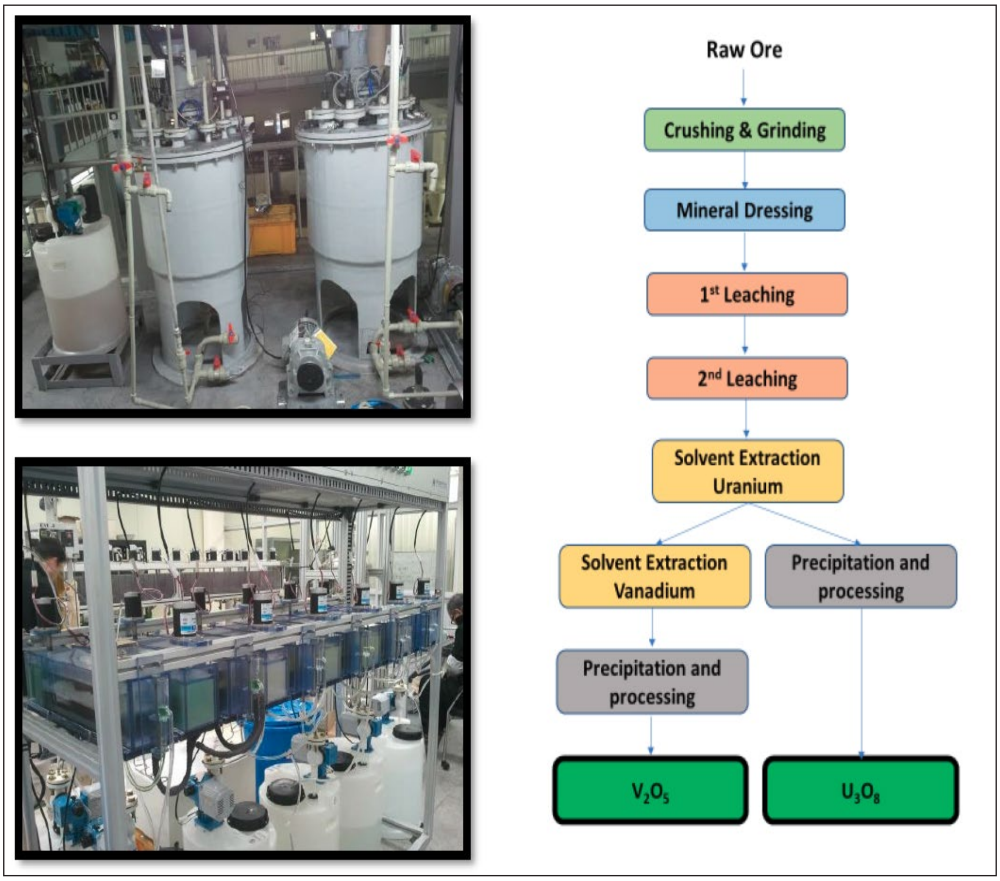
Source: Protean

Metallurgy

- Initial metallurgical test work included a review of historical work in 2010, with this highlighting the potential for recoveries of ~90% U_3O_8 by conventional acid leaching at ambient pressure and a temperature of ~50° C, however with high acid consumption of 80kg to 100kg/tonne of ore.
- The Company completed preliminary uranium and vanadium leach test work on two bulk samples in late 2010/early 2011, with the results of the uranium work in line with historic work, however with a significantly lower acid consumption of 10kg/tonne of ore.

- The preliminary vanadium test work highlighted the potential to extract ~50% of the vanadium under broadly similar conditions, however with a higher temperature of 95º C and a residence time of eight hours, but with the same acid consumption.
- A conceptual scoping level flow sheet was developed from this work, with estimated operating costs of US$58.26/lb U_3O_8 before vanadium credits, and US$24.50/lb U_3O_8 after vanadium credits.
- Further test work then looked at increasing the vanadium recovery, with two processing routes considered:
  - Pressure oxidation leaching between 120º C and 180º C to extract uranium and vanadium simultaneously; and,
  - Atmospheric acid leaching to selectively produce uranium followed by vanadium salt roasting of the leach residue to extract vanadium.
- Test work using the former method (at 180º C and 750 kPa oxygen overpressure) resulted in the average extraction of 92.8% of the U_3O_8 and 70.9% of the V_2O_5 from five samples.
- Since 2011 there has been a hiatus in reported metallurgical test work by Protean, however this has now recommenced, with a number of bulk samples held in Perth to be used for this work; the planned work also follows on from ongoing research by KIGAM scientists resulting in a two stage atmospheric leach process to produce both uranium and vanadium (Figure 5).
- As part of the planned work Protean has signed a "Processing Optimisation Project Agreement" with KIGAM allowing the company access to KIGAM's proprietary black shale processing IP and access to KIGAM's 1.2tpd black shale processing pilot plant.
- The pilot plant is located in the Daejeon City, and includes crushing, grinding, leaching and solvent extraction circuits; and in the years of operation from 2012 to 2015 largely investigated the leaching of U_3O_8 from deposits along strike from Daejon.
- The processing optimisation project will look at numerous metallurgical aspects, with samples from Daejon (being shipped from Australia) to be supplemented by ones held by KIGAM; one of the aims will be to produce high purity +99.5% V_2O_5 that will be suitable for VRFB electrolyte.

Figure 5: KIGAM black shale pilot plant (L) and process flow sheet (R)



Source: Protean

V-KOR VRFB PROJECT - PROTEAN 50%, MOVING TO 60%

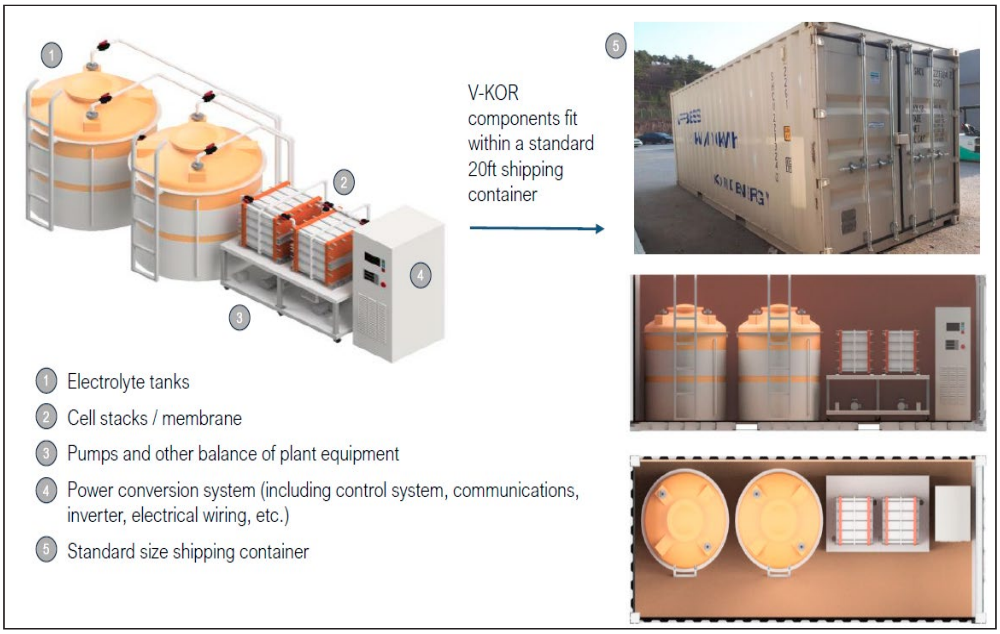
ACQUISITION AND OWNERSHIP

- Protean has been involved with the V-KOR battery technology for over nine years, prior to being acquired by Stonehenge, and with the subsequent change of name of Stonehenge to Protean.
- As for Daejon, Protean's partner, is DST, with both parties having a 50% interest in KORID Energy Ltd (Korea), the owner of the V-KOR technology.
- Protean formally finalised the acquisition of 50% of KORID Energy in March 2017, with the consideration being 190 million Protean shares at a deemed price of A$0.01/share (pre-consolidation), valuing the transaction at A$1.9 million.
- As announced on October 17, 2018, Daejon's ownership of KORID Energy moving from 50% to 60% through the issue of A$750,000 worth of Protean shares at a deemed issue price of the greater of the 10 day VWAP prior to completion or A$0.03/share.

BATTERY TECHNOLOGY

- V-KOR is developing proprietary VRFB technology, with this now undergoing field tests in Australia and cycle testing by the Korean Conformity Laboratories.
- To date four battery stack sizes have been developed, including 2.5kW, 5kW, 10kW and 25kW. Given the modular nature of the stacks, larger capacity requirements can be met by installing a number of individual modules, and there is also the potential to custom make larger battery stacks.
- Battery modules have been designed to fit inside a standard 20 foot shipping container (Figure 6), making them easily transportable.
- As part of their design and construction, the Company is investigating different and innovative construction methods to bring down battery costs (with the stacks making up some 50% of the battery cost), and to increase stack capacity.
- Cycle testing has been carried out on both 5 kW and 25 kW V-KOR units by Korea Conformity Laboratories ("KCL"), an independent national testing laboratory.
- As reported to the market on June 12, 2018, the 5 kW unit had been tested for over 3,000 cycles, and the 25 kW unit for over 1,000 cycles, with the results indicating no significant degradation in performance - these results are important, in that one of the key advantages of VRFBs over other types is being able to deliver consistent performance, without degradation, over a long life, typically quoted as at least 20 years of daily cycles.

Figure 6: V-KOR VRFB



Source: Protean

Western Australian Field Trial

- KORID is undertaking a site test of 25 kW/100 kWh battery at OzLinc Industries ("OzLinc") in Perth, Western Australia.

- The first stage of the test, which the Company reports has been successfully completed, commenced in June 2018, and involved the integration of the battery in a micro-grid (a standalone grid isolated from the main grid), in combination with a 21 kW solar PV system and 21 kW diesel generator.
- The second Stage, which is currently underway, includes the integration into the Western Power grid.

KETEP Project - 1 MW/4 MWh Trial

- V-KOR has been selected to participate in a ~A$10 million 1 MW/4 MWh trial installation in South Korea being run by KETEP, with this to provide ~A$3 million in direct funding over three years to the development of V-KOR.
- The test, which involves a number of other participants (Figure 7), will test and measure a number of performance parameters and will use KORID's 25 kW battery stack, which was chosen above those of a number of South Korean competitors.
- Another aim of the test is to double the energy density of the electrolyte (this is discussed further later).

Figure 7: KETEP project participants

Source: Protean

Electrolyte Development

- As part of the V-KOR programme, the Company has announced that KORID has developed a new generation of electrolyte that it says improves energy density by up to 25% - given that this is proprietary technology no details have been released.
- In addition to vanadium ions, electrolytes usually contain counter anions, acids, water and additives, and are the highest cost component of a VRFB outside of the stack - increasing energy density of the electrolyte is therefore important in bringing down battery costs; as such there has been significant global research into electrolytes and improving the energy density.
- Factors that can affect energy density include increasing the solubility of the vanadium, through the use of different additives and acid mixes.
- Another effect of increasing electrolyte energy density is that it can lead to a smaller battery footprint due to the need for lesser electrolyte and hence smaller electrolyte tanks for a given battery size.
- KORID is also looking at producing electrolyte from ammonium metavanadatae ("AMV", NH_4VO_3), which, given that it is an intermediate product in the production of vanadium pentoxide, could further cut costs; one hurdle however will be the removal of impurities that are usually removed in the conversion to V_2O_5 which is the usual electrolyte feedstock.

UPCOMING NEWS AND ACTIVITIES

- Activities on Daejon will include metallurgical test work, and with all going well this will be incorporated into a Scoping Study that is targeted for commencement in Q1, 2019.
- This test work will include the pilot plant work with KIGAM, and looking at the production of high purity V_2O_5.
- The Company expects to release the results of the Western Australian battery trial later this year, with this preceded by an interim report.
- Activities in South Korea will continue on the further development of the battery, with a key aim including cost reduction.

PEER GROUP ANALYSIS

- There are a number of vanadium focussed companies both private and listed on the ASX and other exchanges, with these listed in Table 3 - for those listed overseas, we have converted the EV to AUD using current exchange rates.
- These companies fall into three main groups:
  - Those with mafic intrusive deposits, with vanadium hosted in magnetite,
  - The Toolebuc oil shale focussed companies; and,
  - Other sedimentary/graphite hosted projects.
- The three groups have different characteristics, particularly with regards to metallurgy, and hence are not directly comparable; in addition some companies have other projects that we have not considered when calculating the EV.
- The only producer is Largo, which is the only new vanadium start-up in recent years.
- This highlights the extremely low EV of Protean, and hence the opportunity for uplift.

Table 3: Vanadium company comparison

Vanadium company comparison							
Company and Project	**Deposit Type**	**Global Reource Tonnage**	**V_2O_5 Grade**	**Contained V_2O_5 - Mt**	**EV A$m**	**Stage**	**Notes**
Largo - Maracas	Intrusive	50.6 Mt	1.01%	0.51 Mt	$2,336	Production	Q2 2018 production of 2,458t V2O5 produced from the Menchen Mine at the Maracas Project. Initial estimated capex was US$250m for a planned production of 9,200t V2O5
Bushveld Minerals	Intrusive	440 Mt	0.64%	2.82 Mt	$539	PFS	
Syrah - Mepiche	Graphitic	214.3 Mt	0.43%	0.92 Mt	$367	Scoping	Graphite focussed project
Neometals - Barrambie	Intrusive	280.1 Mt	0.44%	1.23 Mt	$89.2	PFS	Largely a titanium project
TNG - Mt. Peake	Intrusive	160 Mt	0.28%	0.45 Mt	$86.8	DFS Completed	Ti and Fe co-products in proposed TIVAN hydrometallurgical plant
King River Copper	Intrusive	4,711 Mt	0.30%	14.13 Mt	$61.1	Scoping	Activities focussed on other assets
Australian Vanadium - Gabanintha	Intrusive	175.5 Mt	0.77%	1.35 Mt	$59.2	Engineering Concept Study completed	Has other projects, and is in the VRFB supply, installation and maintenance market
Technology Metals - Gabanintha	Intrusive	119.9 Mt	0.80%	0.96 Mt	$32.2	PFS Completed	
Intermin - Richmond	Oil Shale	2,579 Mt	0.32%	8.25 Mt	$26.8	Resource	Private company AXF earning in, Intermin has other assets
Liontown - Toolebuc	Oil Shale	84 Mt	0.30%	0.25 Mt	$25.0	Resource	Main assets are lithium in WA
Vanadium Corp	Intrusive	113.5 Mt	0.43%	0.49 Mt	$21.9	Resource	

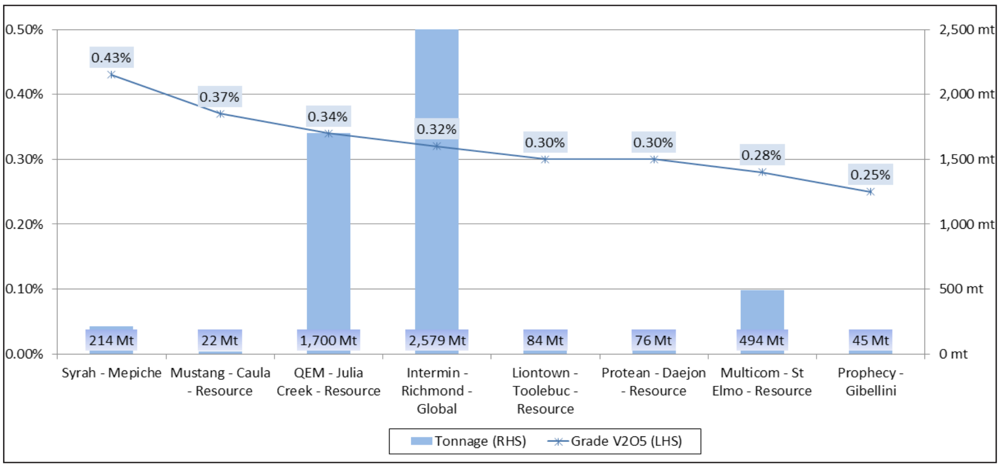
Vanadium company comparison

Company and Project	Deposit Type	Global Reource Tonnage	V_2O_5 Grade	Contained V_2O_5 - Mt	EV A$m	Stage	Notes
QEM - Julia Creek	Oil Shale	1,700 Mt	0.34%	5.78 Mt	$11.0	Scoping completed	64 l/t oil yield
New Energy Minerals - Caula	Graphitic	22 Mt	0.37%	0.08 Mt	$8.93	Scoping Completed	Graphite is main focus
Audalia - Medcalf	Intrusive	31.8 Mt	0.45%	0.14 Mt	$6.61	PFS completed	
Protean - Daejon	Black Shale	76 Mt	0.30%	0.23 Mt	$3.22	Resource	Has uranium credit, also developing VRFB technology
Multicom - St Elmo	Oil Shale	494 mt	0.28%	1.38 Mt	N/A	Resource	Unlisted
Atlantic - Windimurra	Intrusive	243 mt	0.48%	1.16 Mt	N/A	C & M	Private company

Source: IRESS, Company reports

- Below we compare tonnages and grades of sedimentary/graphite hosted deposits - of these, four are located in the Toolebuc Formation near Julia Creek in Queensland, two (Mustang and Syrah, graphite associated) are located in Mozambique with two shale hosted examples; Protean and Prophecy, which has the Gibellini Project in Nevada.
- Although broadly similar, the Toolebuc Formation and black shale hosted deposits have significantly different metallurgical properties, although they have similar grades - the Toolebuc deposits are generally more difficult metallurgically (particularly in fresh mineralisation), than the black shale deposits, although there is the potential of petroleum products as a co-product.
- One company of interest is Prophecy, with their Gibellini project in Nevada, for which a PEA was recently completed.
- The PEA is predicated on a heap leach, SXEW operation, with recoveries of 60% for primary ore, 70% transitional and 52% for fresh, with it being noted in the document that heap leaching and solvent extraction has not been done for vanadium before - the bulk of material treated will be oxide and transitional.
- The PEA estimated total operating costs of US$4.77/ lb V_2O_5, an AISC of US$628/ lb V_2O_5, and a break-even price of US$7.76/ lb V_2O_5, and an upfront capex for a US$117 million for a 13 year, 3 million short tonne per annum operation.
- One difference between Gibellini and Daejon however is the mineralogy; whereas the vanadium at Daejon is within silicates, including feldspar and amphiboles, that at Gibellini is hosted largely within a series of secondary vanadium oxides in fractures - in the fresh material it is hosted in kerogen, similar to vanadium in the Toolebuc Formation in Australia.

Figure 7: Sedimentary hosted resources



Source: Company reports, IIR analysis

RISKS

- **Exploration and resource** – Given the style of mineralisation and the results of work completed to date this is not (except for the vanadium grade) a risk for Protean - the current MRE has the potential to support a long term operation for both vanadium and uranium should any future project prove feasible.
- **Vanadium metallurgy** – This is a key risk with regards to Daejon - previous test work, although technically successful, has highlighted high potential costs of production and "tricky" metallurgy; this is amplified by the low grade of the resource.
- **Commodity prices and exchange rates** – These are key for the success (and a decision to go ahead) of any potential resource project, and a factor in which the operators have no control. After seeing a nadir in early 2016 and relatively flat prices following, the last 12 months, and particularly the last 6 months have seen significant rises in vanadium prices, pointing towards a possible longer term recovery in the metal. Depending upon the results of metallurgical test work, uranium prices, which are currently at low levels, may also determine the viability of any potential oil production operation.
- **Development funding:** Although down the track, the ability to raise project development funding will depend upon markets at that time, as well as the market capitalisation of the Company; this can also be particularly difficult for specialist metals with a volatile price history.
- **Permitting:** Given that Daejon is considered an asset of national importance in South Korea, permitting may be easier than otherwise, however being located close to infrastructure and urban areas may hamper any future permitting process; this is however somewhat mitigated in that quarrying operations have been undertaken in the immediate vicinity of Daejon.

BOARD AND MANAGEMENT

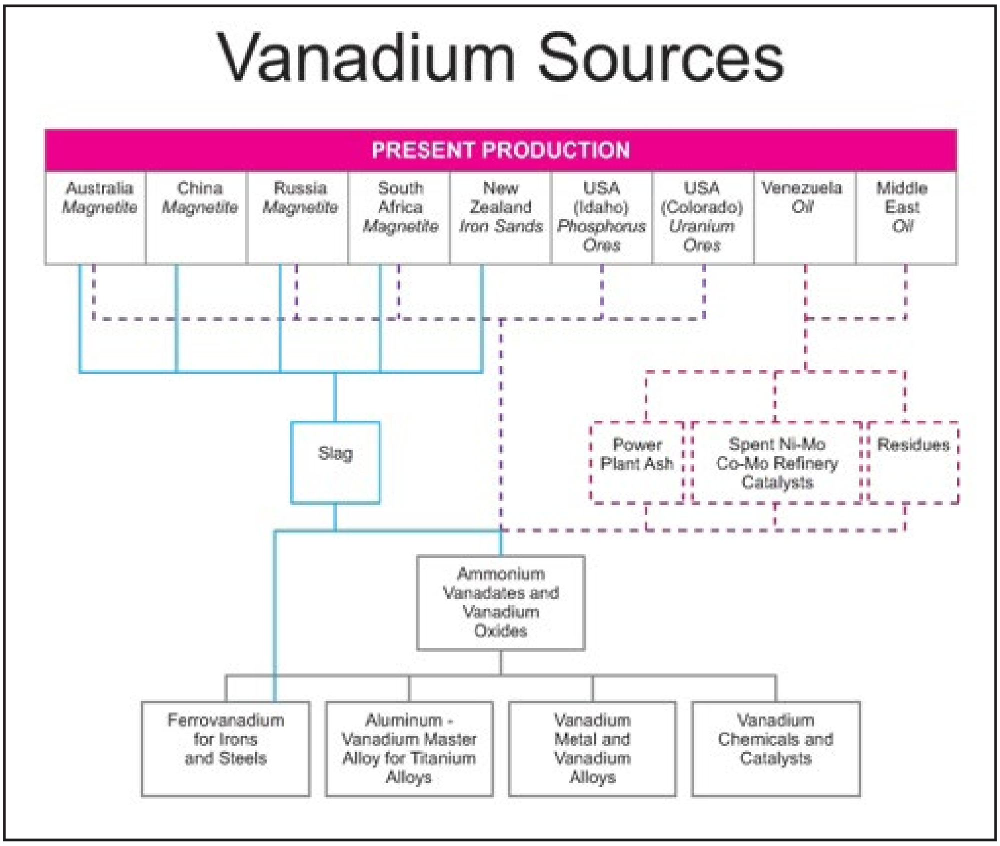
- **Mr Bevan Tarratt, B.Com - Executive Chairman:** Mr Tarratt has an extensive background in the accounting and financial services industries having worked in various local accounting and broking firms for the past 10 years. He is a former director of Pura Vida Energy NL an Australian-based African oil explorer listed on the ASX. In addition Mr Tarratt has a comprehensive practical business background having owned various medium sized retail businesses.
- **Mr Wayne Loxton - Executive Director:** Mr Loxton has experience spanning 30 years including formulating project development strategies, completing feasibility studies, conducting due diligence, executing capital raisings, mergers, acquisitions, asset divestments and introduction of best practices. In the resource sector Mr Loxton has corporate and operational experience in gold, base metals and bulk commodities incorporating both underground and open-pit mining operations. Mr Loxton has been involved in numerous project evaluations within Australia and overseas including the completion of strategic and commercial due diligence studies, bankable feasibility studies, project construction and the negotiation of offtake agreements. Mr Loxton has been directly involved in Perilya Ltd, Allied Gold Ltd and Zapopan NL.
- **Mr Young Yu, B Bus, MBA, CPA – Non-Executive Director:** Mr Yu is an experienced professional businessman with private and public sector experience in finance, consulting, trade and international business in both Australia and Korea. He is a Certified Practising Accountant and holds a Bachelor of Business (Accounting) Degree and an MBA from Curtin University in Western Australia. Mr Yu worked as the Trade Commissioner to the Australian Trade Commission within the Australian Embassy in Seoul, Korea and was responsible for Mineral & Resources, Industrial and Investment sectors since 2008. He was the Regional Director / Representative for the Western Australian Trade and Investment Office in Seoul, Korea for four years since 2004.
- **Mr David Wheeler -** Non-Executive Director: Mr Wheeler has more than 30 years executive management experience, through general management, CEO and managing director roles across a range of companies and industries. He has worked on business projects in the USA, UK, Europe, New Zealand, China, Malaysia, and the Middle East (Iran).

VANADIUM AND VRFBS

INTRODUCTION

- The main use of vanadium is as a steel additive in high-strength steel, which accounts for about 92% of the current global demand of ~100,000t of vanadium metal (equivalent to ~180,000t V_2O_5, with the oxide containing 56% V).
- Other uses include chemicals, catalysts and in batteries - vanadium is produced as two main products – FeV for steel-making and V_2O_5 for chemical and battery applications.
- Just for clarity, throughout this document vanadium has been quoted in terms of vanadium metal (V) and vanadium pentoxide (V_2O_5) - the latter contains ~56% V, therefore 1.78 t of V_2O_5 contains one tonne of V metal; ferrovanadium (FeV) contains anywhere from 35% to 85% V.
- We also use the term "mtV" - this is shorthand for metric tonnes of vanadium.
- Global production was reportedly ~83,181 mtV in 2017, with the largest source being as a by-product from slag produced from the smelting of titaniferous magnetite ores for steelmaking (Figure 8) – it is estimated that this accounts for ~73% of total supply, with 17% being derived from mining as a primary product and the remainder from secondary sources, including oil residues and fly ash.

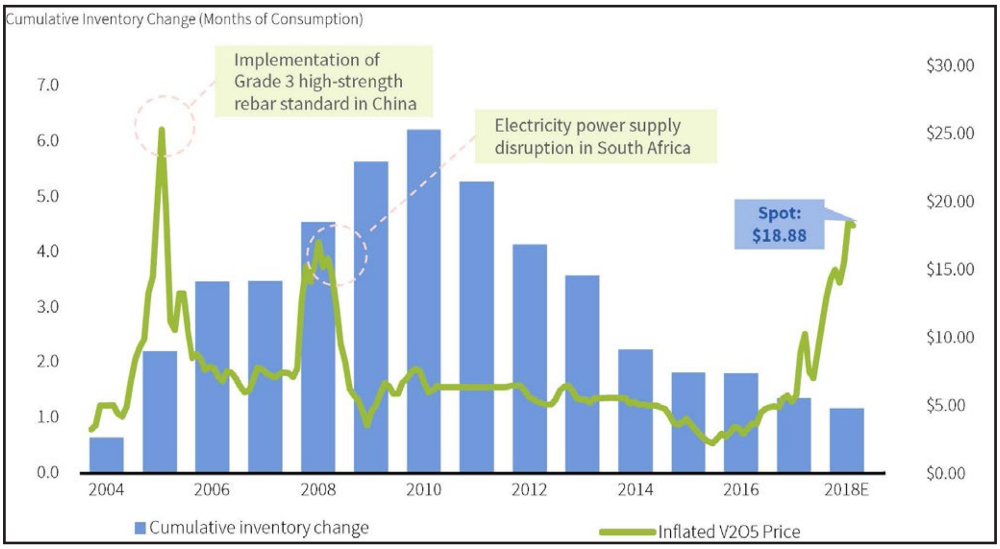
Figure 8: Vanadium sources



Source: Vanitec

- However estimated consumption in 2017 was over 100,000t, of which ~9,000t was high purity material, used in aerospace, chemical catalyst and battery electrode applications.
- Supply is concentrated, with over 80% of vanadium products produced in South Africa, China, Russia and Brazil.
- The only recent development is Largo Resources Maracas Project in Brazil, which is now in full production, and exceeding the planned output of 9,200t of V_2O_5 per year, with a planned FeV plant to be added at a later date.
- Demand has outstripped supply since 2010, with successive draw downs on inventory; part of this has been due to industry rationalisation and environmental constraints in China, with this now resulting in the inventories being depleted and hence a recent increase in prices after falling for over 10 years (Figures 9 and 13).
- In addition mine closures in South Africa have severely impacted on supply.

Figure 9: Vanadium Inventory change



Source: Protean

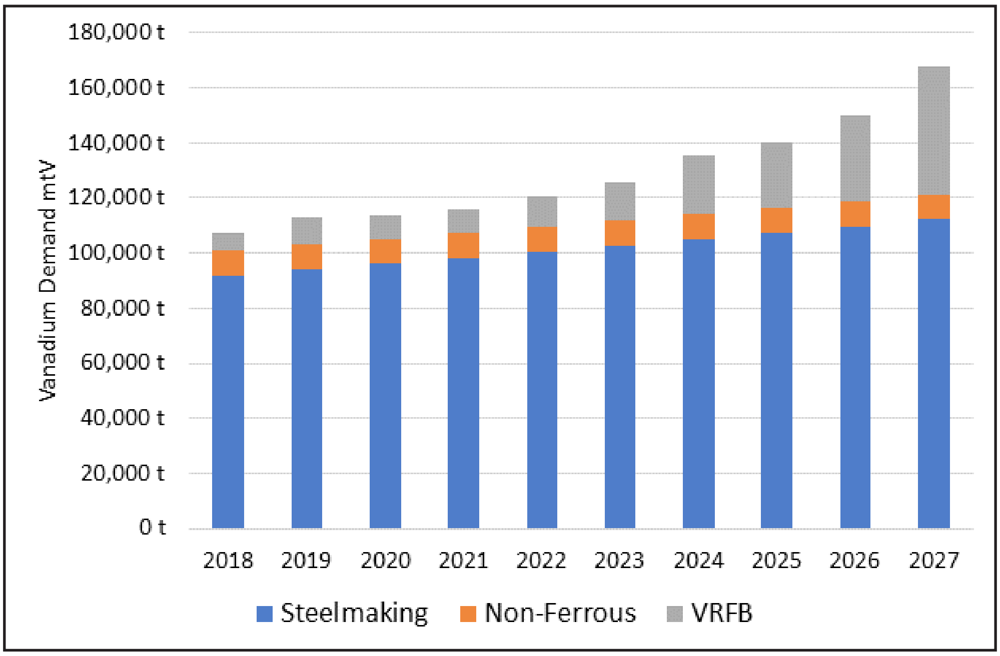
- This is pointing towards a major structural change in the industry, with the potential to result in a significantly higher price floor in the longer term.

DEMAND DRIVERS

Introduction

- As mentioned earlier, the base demand is in steel, with this making up ~90% of current demand of ~100,000 mtV - batteries currently make up ~2% of this; China is the largest consumer, accounting for ~44% of global demand.
- However, as a base case we may expect to see steel demand grow by 33,000t, or 37% over the next 10 years, due both to increased steel making, and increased V intensity in steel.
- Over the same period we could also see the use in batteries grow from negligible amounts currently to close to 50,000 mtV in 2027, leading to a 60% increase in total V demand over that period (Figure 10).

Figure 10: Forecast vanadium demand



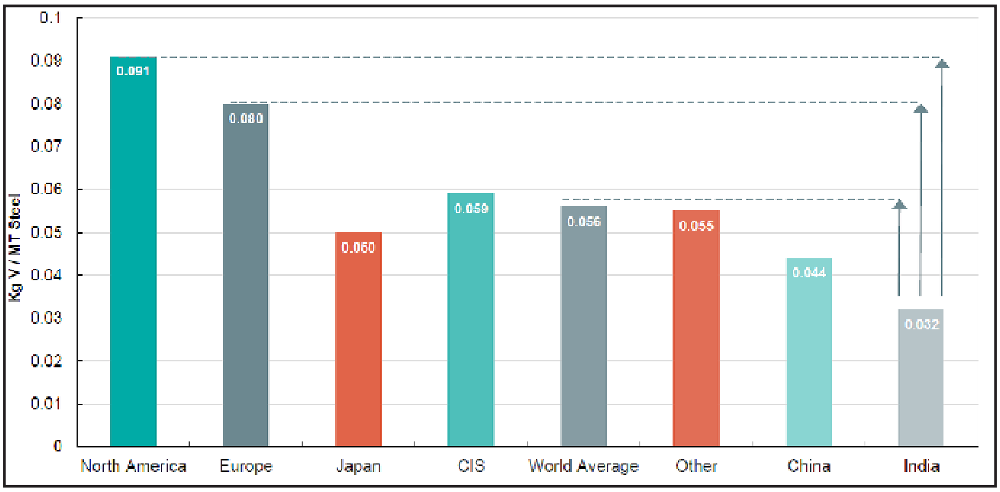
Source: Roskill in Highveld "Vanadium 101 presentation", IIR analysis

Steelmaking

- The current key demand driver is as an additive in steel – demand for vanadium closely follows the production of steel. This includes two factors – firstly the natural organic growth in steel production and secondly increasing vanadium intensity in steel with the move to lighter weight and higher strength steels – the addition of just 0.2% vanadium to steel increases steel strength by up to 100% and reduces the weight of steel required in relevant applications by up to 30%.

- This second factor is particularly relevant in China, where there is increasing vanadium intensity in rebar due to changes in building standards (with new regulations set to become effective in November 2018), partly following on from the 2008 earthquake - there is still a fair way to go with this and thus significant potential growth in use in this application, however this has the potential to increase Chinese vanadium consumption by up to 24,000tpa.
- Roskill estimate that, although steel production will only grow at 1.76% CAGR over coming years, the increasing intensity of vanadium in steel along with other end uses will result in a long term demand growth for vanadium in steel of 3.24% CAGR from ~90,000tpa V in 2017 to~123,000tpa contained V in 2027, with the forecast supply deficits now being seen.
- Figure 11 shows the relative vanadium intensities in rebar between various jurisdictions.

Figure 11: Vanadium steelmaking intensity



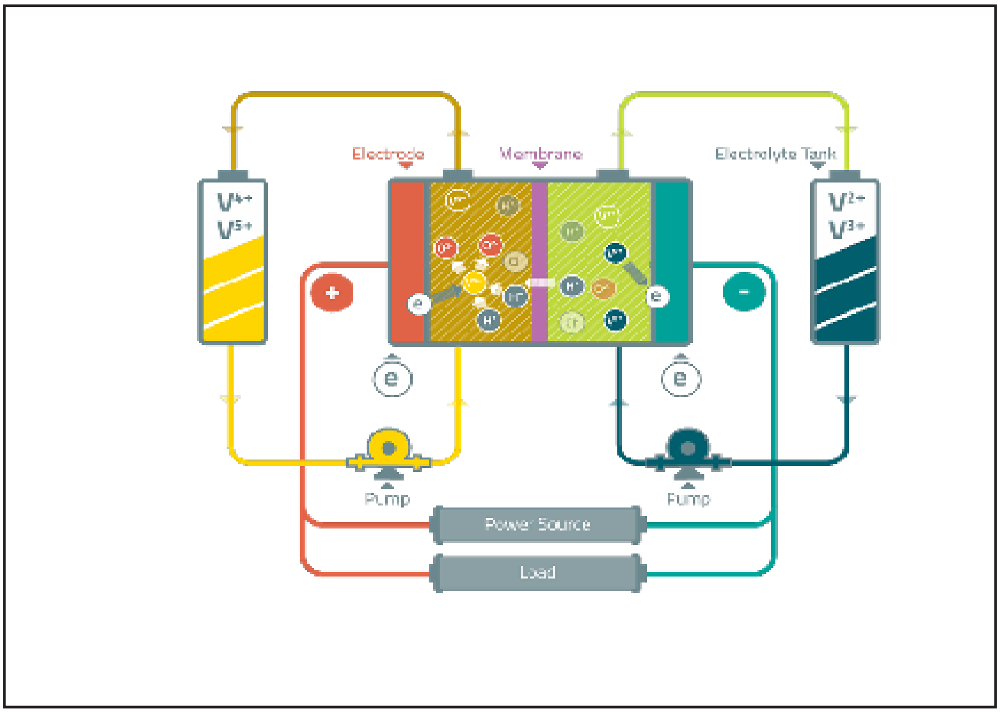
Source: Australian Vanadium

Energy Storage – VRFB's and Li-Ion Batteries

- The blue sky in demand, and the potentially disruptive technology is in grid scale battery usage - the key here will be the adoption of VRFB's that have the capacity for multi-megawatt scale storage - this makes them useful for grid scale applications, including grid balancing and storing energy from variable output sources, including wind turbines and solar cells.
- The batteries are inherently simple, relying on the changing redox state of vanadium to store and then supply power (Figure 12).
- Other attributes of these batteries include:
  - Scalability
  - Long lifespan – up to 20 years
  - Up to a 1 year charge retention
  - 100% discharge without damage, and,
  - Only one element – V in various oxidation states – in electrolyte.
- There are a number of active VRFB developments globally at the moment, reportedly with the largest being the development of a 200MW/800MWh battery in Dalian, China, which reportedly uses 6,950 tonnes of V_2O_5, at an intensity of 8.7 t/MWh (4 mtV/MWh).
- Other recent developments include a US$200 million, 15MW/60MWh facility by Sumitomo on the Japanese island of Hokkaido.
- Development of VRFBs has been partly hamstrung by the lack of a suitable battery grade V_2O_5 supply – batteries require a higher purity product than that used in steelmaking, and hence arises the opportunity for manufacturers of high purity material.
- There are widely differing forecasts on the growth in VRFB's, however some commentators see the potential for VRFBs to provide up to 30% of the growing energy storage market, with forecasters estimating that the stationary energy storage deployment to reach between 20GWh and 40GWh by 2025, with a minimum cumulative forecast of 88GWh.

- Taking the base case of 20GWh deployment in 2025 with 25% provided by VRFBs, and a V usage intensity of 5t/MWh, results in an additional annual demand of 25,000t of V (44,500t of V_2O_5) in that year alone.

Figure 12: VRFB schematic



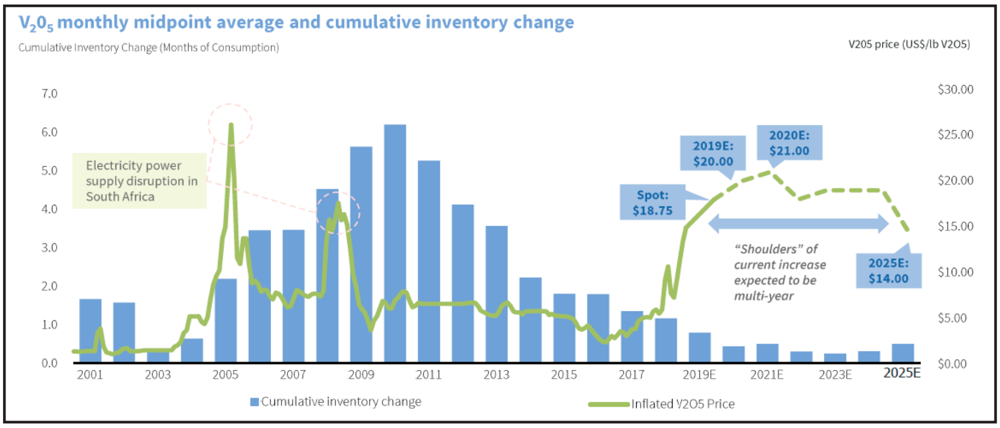
Source: Australian Vanadium

- Some forecasts see the Australian energy storage market reaching 3,000MWh by 2030 – should the VRFB penetration reach an estimated 25% of the market this will result in the requirement of 750MWh of VRFB capacity over the same period.
- Australia is an ideal market for fringe-of-grid and off-grid storage facilities given the extended power networks and large off-grid areas, thus potentially providing a domestic market for any V_2O_5 producers.
- Assuming a capital intensity of A$2,000,000/MWh, this equates to a A$1,500 million market, and using a V_2O_5 intensity of 8.9t/MWh, this results in a potential domestic demand for an additional 8,000t of V_2O_5 by 2030 in Australia.
- There is also forecast demand (~1/3 of that for VRFB's) for vanadium in Li-ion batteries.

PRICING

- Figure 9 above highlights the recent price recovery to over US$30/kg (US$14 - US$14.50/lb) largely due to de-stocking of inventories over recent years and supply constraints due to rationalisation of the iron ore industry in China (with vanadium being a major by-product) along with environmental constraints leading to a sharp decline in production
- Figure 13 presents a longer term chart of real V_2O_5 prices adjusted to November 2016, and shows the commencement of the recent recovery, which has followed a period of sustained falls in prices, largely post the GFC.

Figure 13: FeV price and stocks chart



Source: Largo presentation

- The 30 year average price has been US$11/kg V_2O_5, with the inflation adjusted mean since 2014 being ~US$16/kg as shown in Figure 14 (note that Figure 14 is in US$/pound, with one kg = 2.205 pounds).
- It is expected that pricing may remain reasonably strong, although as shown in Figure 11 vanadium pricing has a history of volatility.
- The market is not particularly transparent, and also prices do not correlate with steel production even though this is the key demand driver.
- As mentioned earlier wide acceptance of VRFBs may go some way to breaking the price "spike-collapse" pattern over recent times, due to the requirement for a consistent supply of high purity V_2O_5 for the electrolyte.

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