



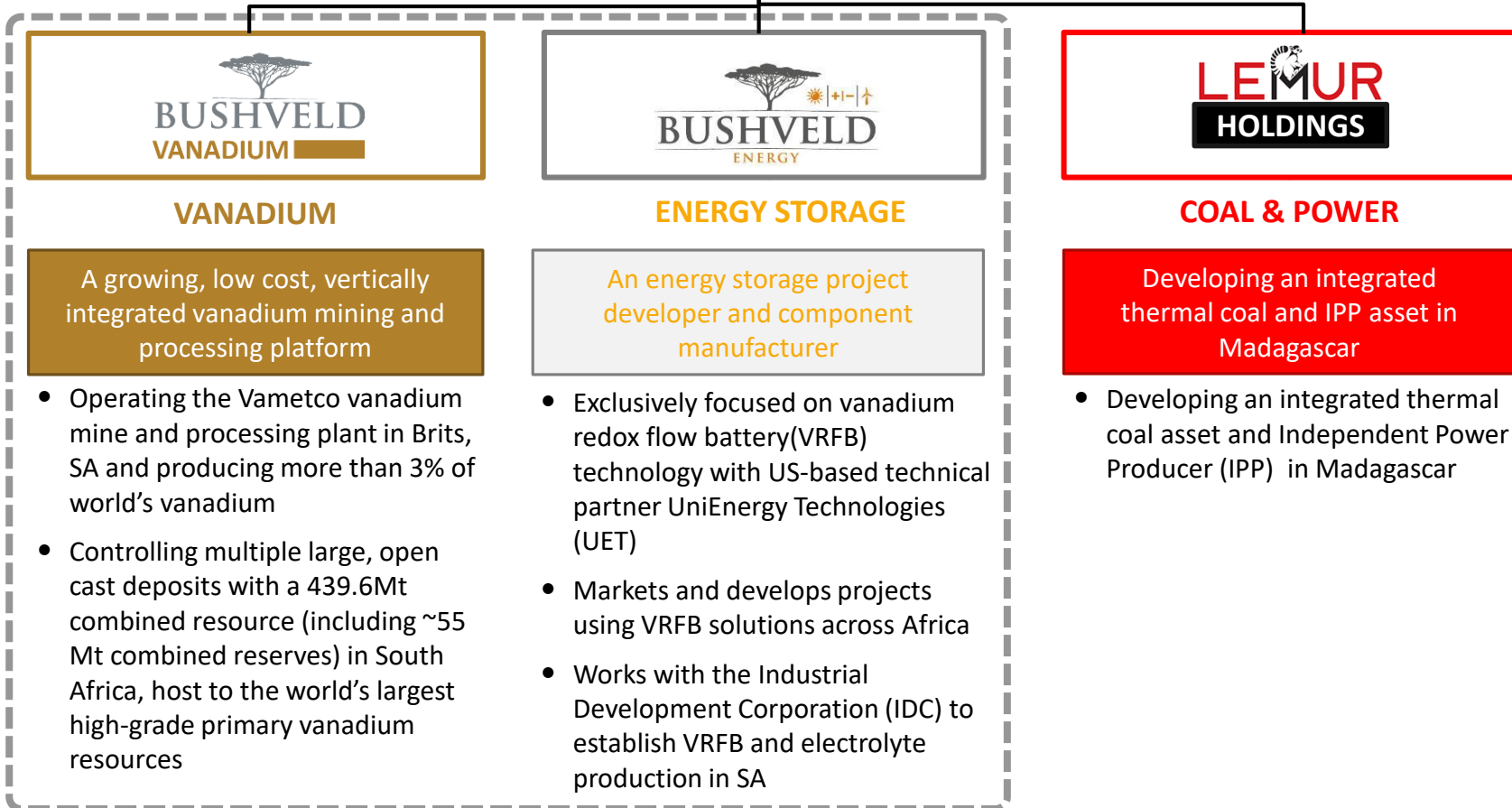
Vanadium value chain innovation to reduce energy storage costs

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Bushveld Minerals is an integrated vanadium-based platform which spans from extraction to manufacturing to deployment



Integrated vanadium minerals company with a R6 billion market capitalisation, listed in London¹



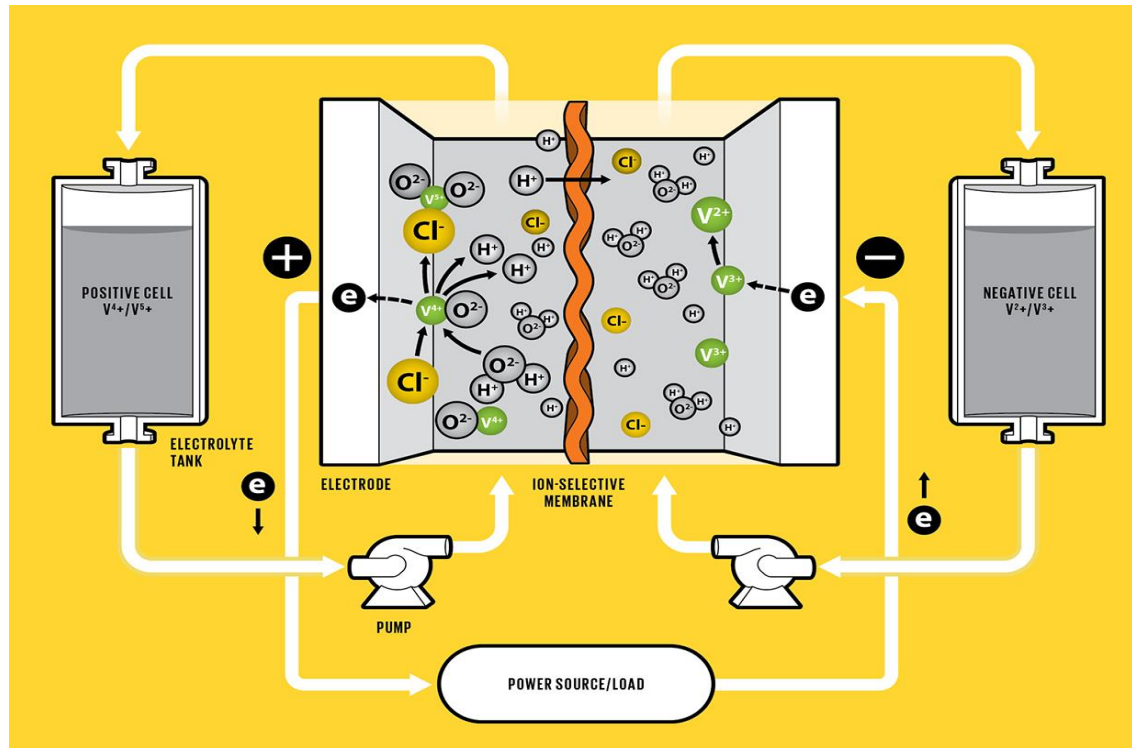
Flagship platform

1. The Company holds a 10% shareholding in AIM-listed AfriTin Mining Limited

Vanadium is the simplest and most developed flow battery

How does a vanadium redox flow battery (VRFB) work?

- A flow battery was first developed by NASA in the 1970s and is charged and discharged by a reversible reduction-oxidation reaction between the two liquid vanadium electrolytes of the battery
- Unlike conventional batteries, electrolytes are stored in separated storage tanks, not in the power cell of the battery
- During operation these electrolytes are pumped through a stack of power cells, or membrane, where an electrochemical reaction takes place and electricity is produced



- Vanadium can exist in four different states, allowing for a single element to be used
- Benefits include simplicity and no cross-contamination
- In 2010, US DoE funded research at PNNL yielded an improved electrolyte formula

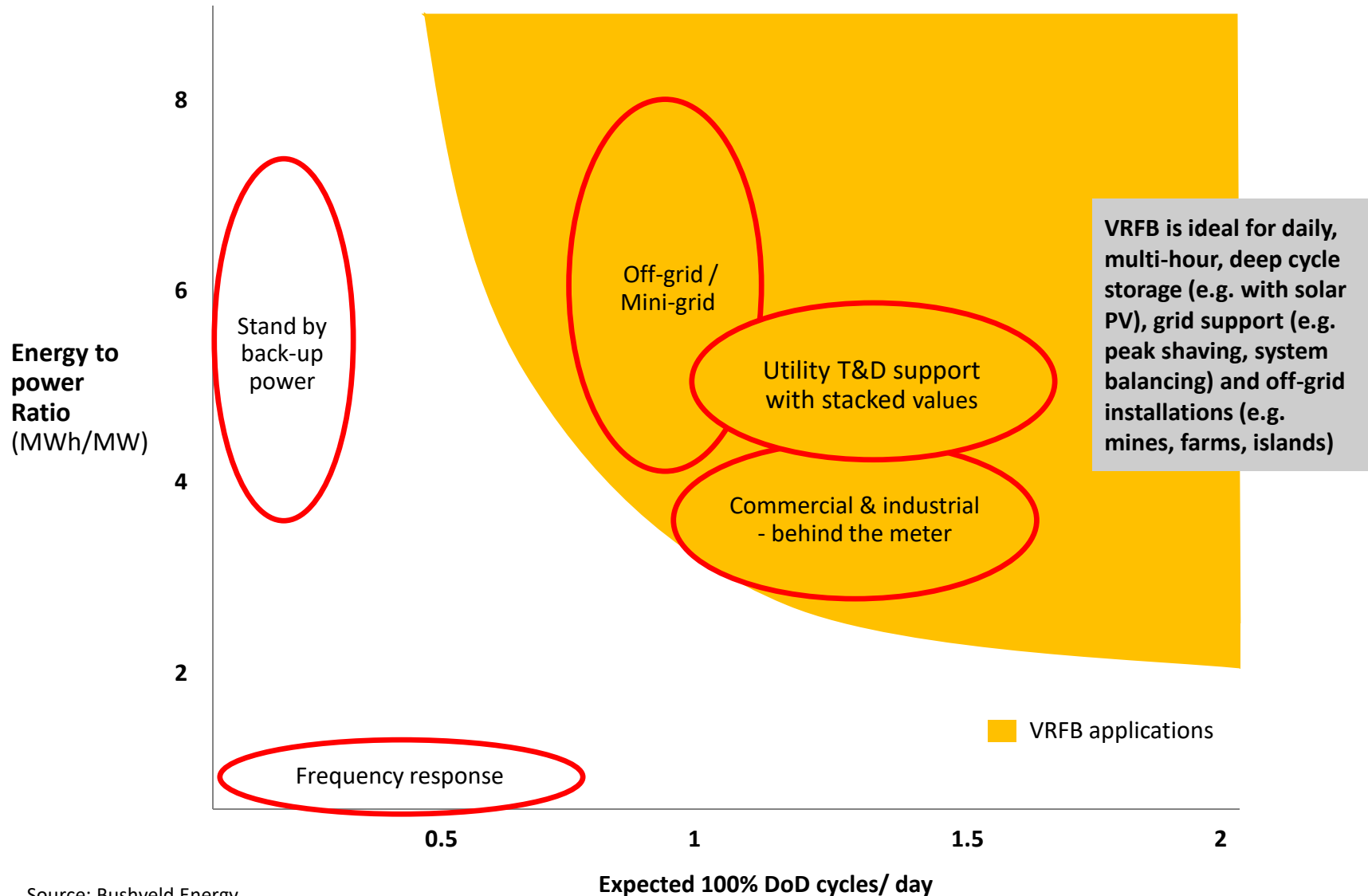
VRFB technology has significant benefits

- + Long life and minimal reduction in performance during its life
 - + 100% depth of discharge
 - + Nearly unlimited number of cycles
- + Lowest cost per kWh when fully used once daily (or more frequently)
- + Easily scalable, as energy and power ratings are independent
- + Safety (no fire) and sustainability (100% of vanadium is reused at end of life)
- + The Vanadium is usable at the end of the lifespan of the battery.



VRFB's value proposition is to equalise power distribution and bridges gaps in power generation over longer durations

Stacking storage applications based on daily usage and storage requirements



Technically, a VRFB is intrinsically safer than solid state batteries because it has no “thermal runaway”

Fire safety is an inherent risk of solid state batteries



Unsurprisingly, VRFBs are safer across a broad range of factors, when compared to lithium-ion (or other technologies)

Analysis of typical hazards by ESS Type

Risk	Lithium-ion	Flooded Cell	Sodium Sulfur	VRB Flow Battery
Voltage	X	X	X	
Arc-Flash/Blast	X	X	X	
Toxicity	X	X	X	X
Fire	X	X	X	
Deflagration	X	X		
Stranded Energy	X	X	X	

“VRFB along with lead acid is the only battery chemistry to receive a letter of no objection from the New York Fire Department.”

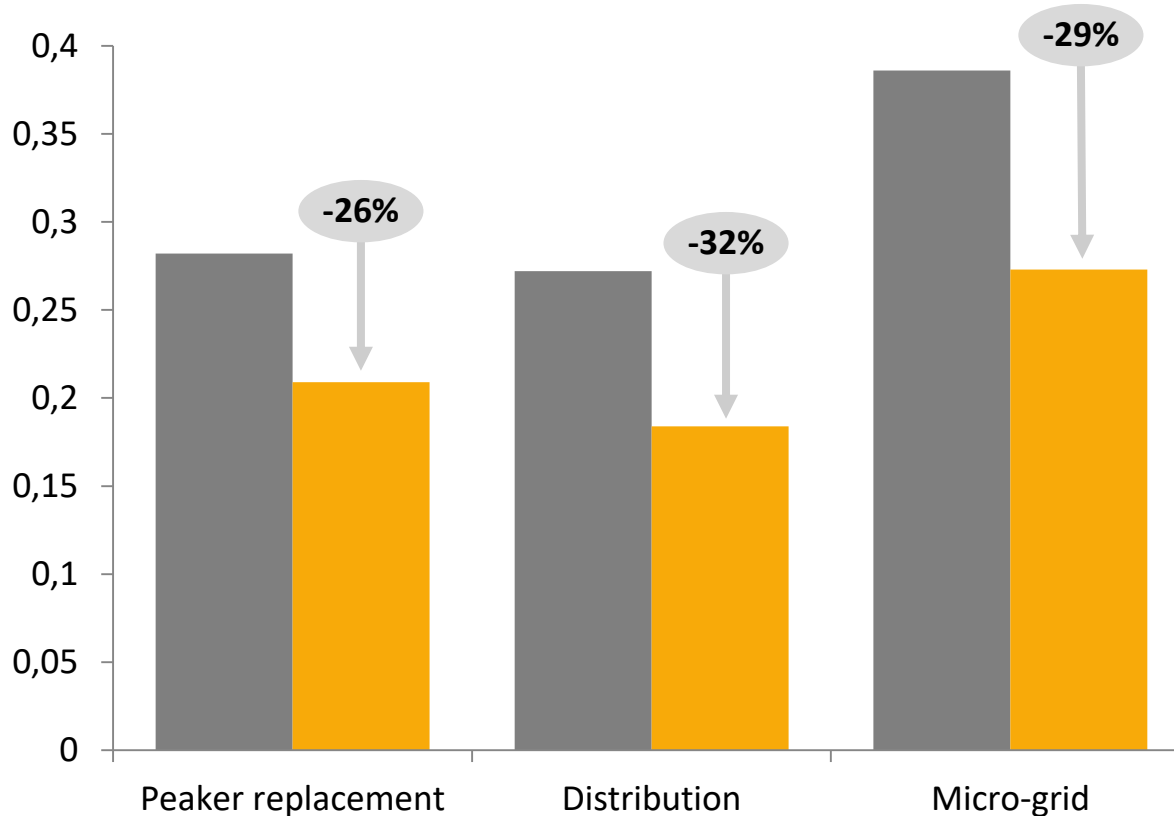
- ESJ (Energy Storage Journal) 14.11.16

VRFBs can be cheaper on life-time ownership (or levelised) cost, but costs are still high

Investment bank Lazard analysis shows that VRFBs already have the lowest costs in the industry

USD / kWh,¹ 2017, levelised costs

■ Lithium-Ion ■ VRFB

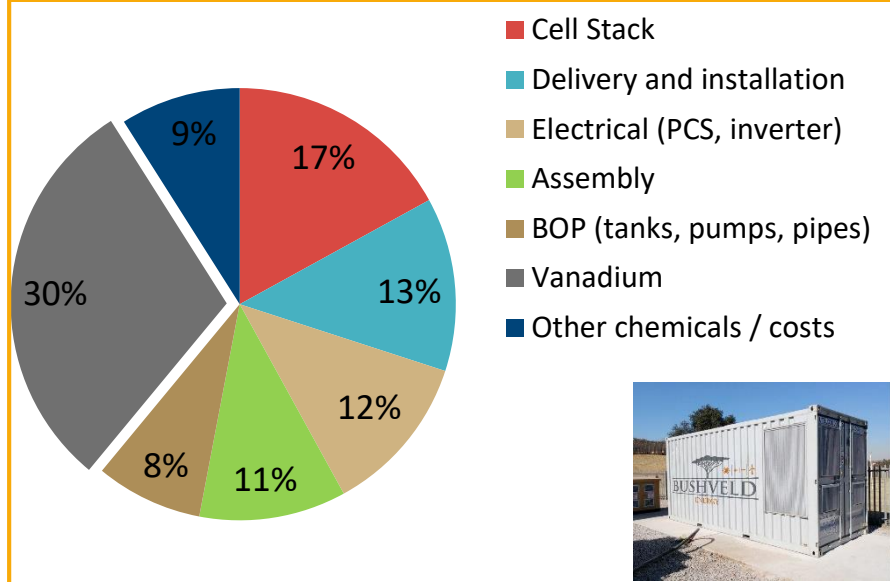


- Lithium-ion manufacturers have focused on driving down upfront costs by expanding manufacturing capacity through multi-billion dollar giga-factories and using less cobalt and lithium
- VRFB technical design offers a uniquely different means to reduce costs, even before massive capacity expansion

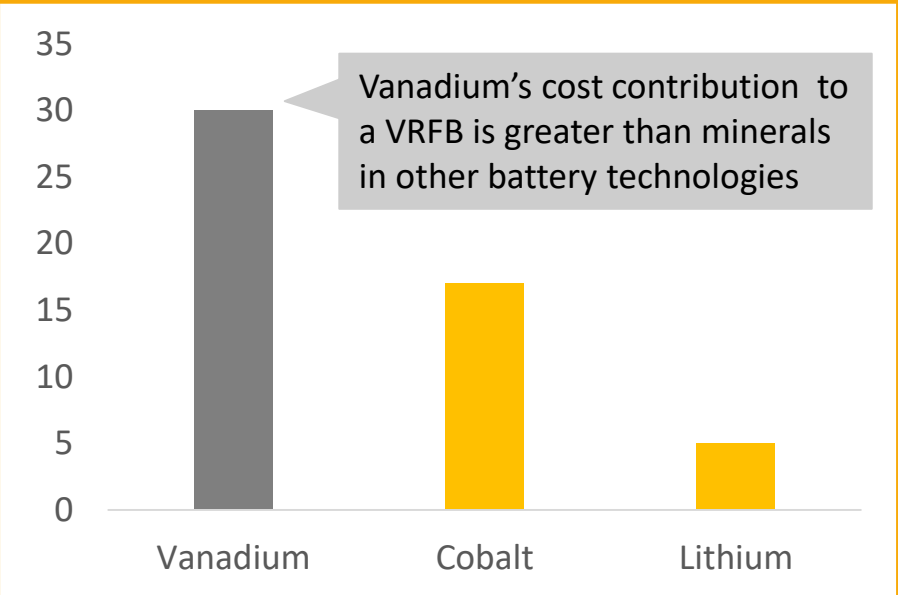
LAZARD

Vanadium is a more significant contributor to the cost of VRFBs than key minerals in comparative battery technologies

Vanadium redox flow battery's cost breakdown %



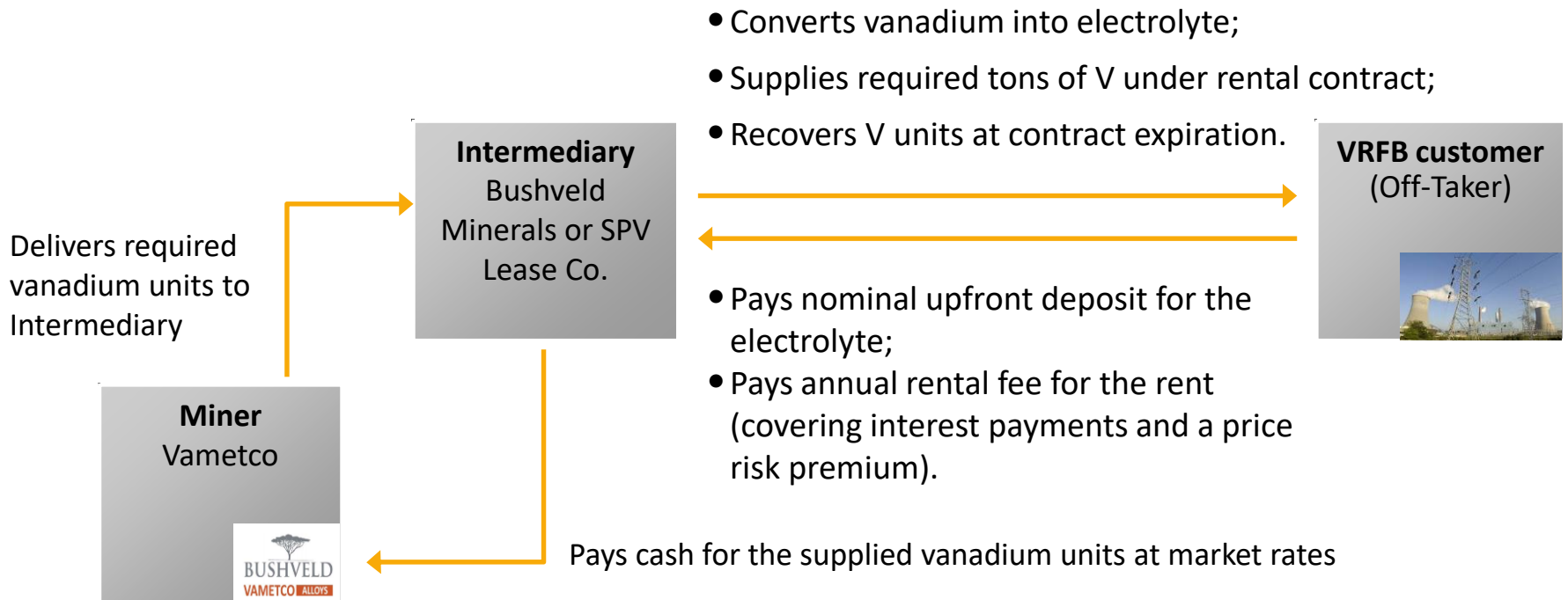
Mineral cost contribution¹ to respective battery %



- High dependence on one mineral presents a challenge for the technology but an opportunity for vanadium suppliers
- Strategies for countering high vanadium prices will be key to VRFBs' sustained success

¹ Exact cost contributions of each mineral will vary and are a function of underlying prices and other factors. Roskill utilises an average of multiple lithium ion technologies to derive a typical cost contribution for 2018

Bushveld Energy's vanadium rental product takes advantage of the unique properties of vanadium and VRFB technology

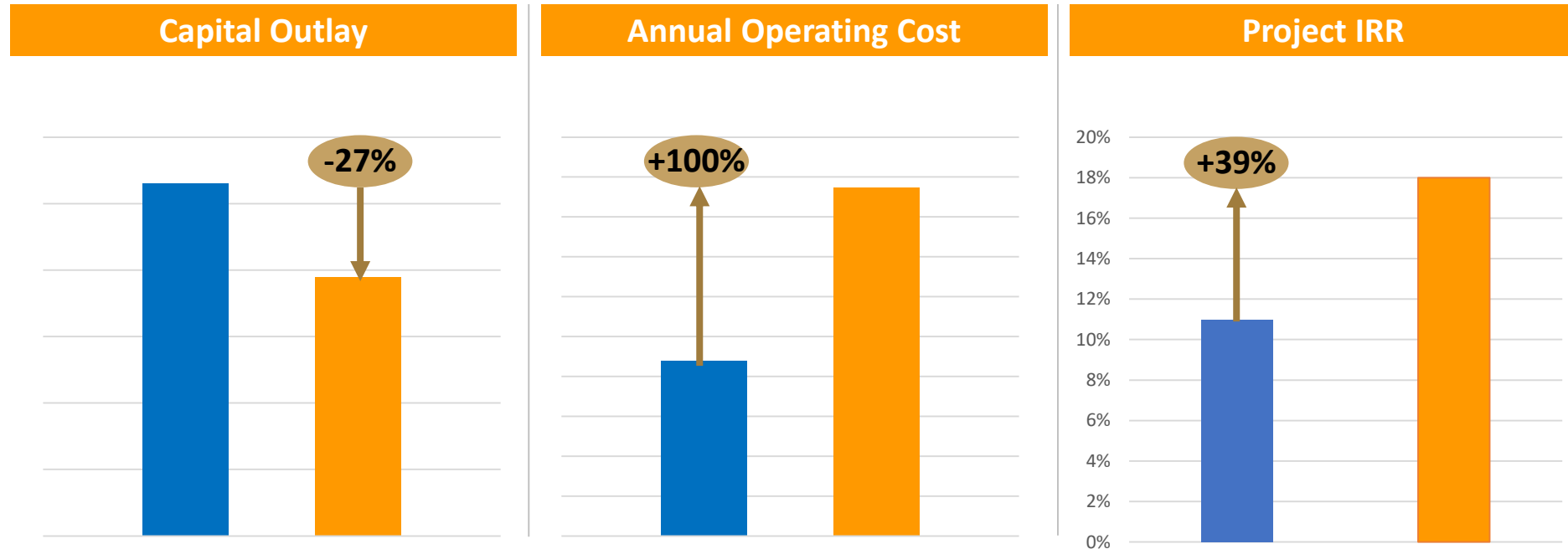


Benefits of the product to VRFB customers include:

- Significantly lower and predictable CAPEX for the battery that could make it cheaper than lithium ion
- A manageable and predictable annual fee that is added to the battery's maintenance costs
- Lower overall total cost of ownership / levelized cost for a VRFB than an outright purchase

The Vanadium Electrolyte Rental Product has significant positive impact on energy storage projects

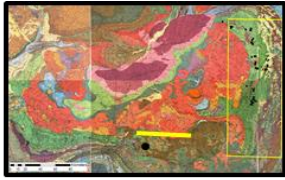
■ 100% CAPEX ■ Electrolyte rental



- Under the VRFB electrolyte rental model, the customer trades off upfront capital costs for an increase in the annual operating costs (to cover the cost of the rental payment)
- The tradeoff is a significant net gain for the end user, however, and reduces the impact of vanadium pricing in the project
- In future, as the model is proven and risk lowered, the upfront capital and/or the annual rent cost could be decreased further

This innovation is supported by the forward looking business model for the integrated vanadium-based platform

Key activities in the vanadium value chain



- Large high grade ore for primary vanadium mining
- Significant resource base in choice locations in South Africa's Bushveld complex



- Large, low cost vanadium processing
- Focus on expansion and enhancement of brownfield operations in South Africa



- Local electrolyte manufacturing for SA and export markets
- Scope to co-locate with ore processing to lower costs significantly



- VRFB assembly and manufacturing
- Research and development in cooperation with local and international institutes



- Large scale energy storage projects development
- Innovative business models and products, such as electrolyte leasing, energy storage capacity sales, ESS as a service

- **Integration over the entire vanadium value chain, positions the Bushveld group of companies uniquely to create value from vanadium resources all the way through VRFB projects**
- **The model also allows for greater beneficiation potential in South Africa for vanadium than nearly any other mineral resource**

Thank you for your attention



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