

# VRFB technology attributes and applicability to developing countries



Energy Storage Partnership Presentation

18 November 2020

## Context about the presenter

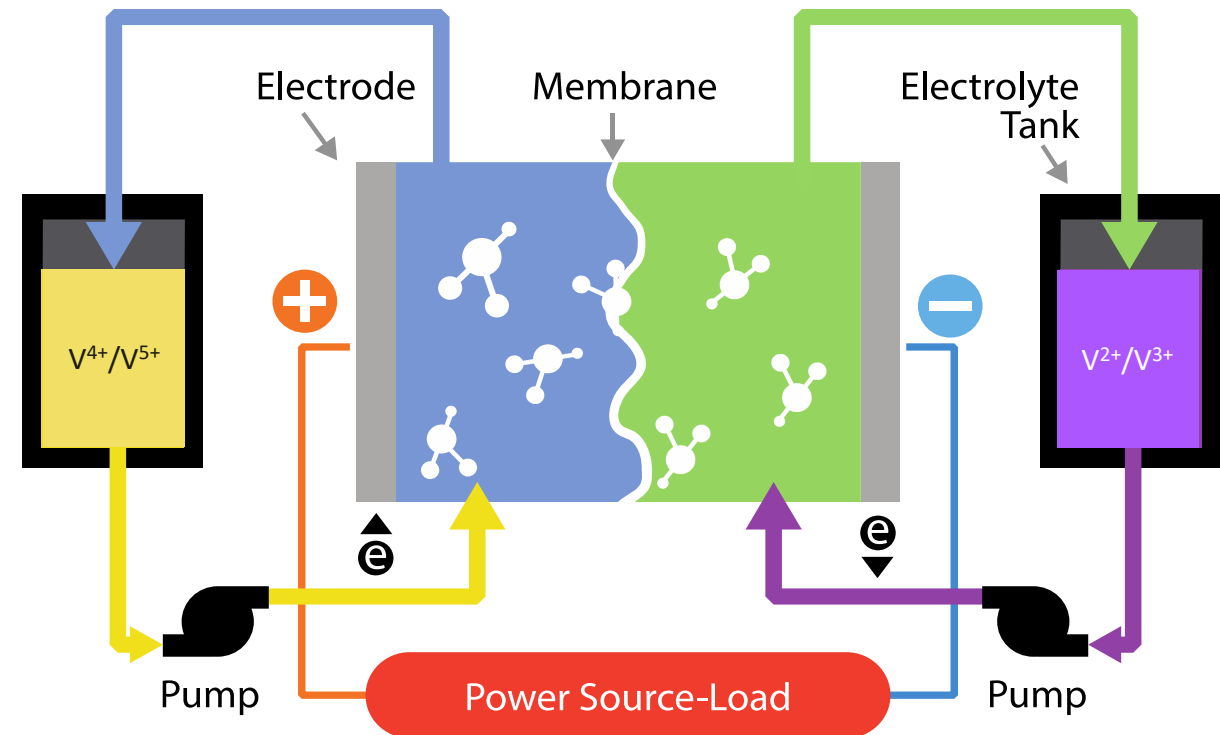


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*Bushveld Energy*

- Co-founder and Chief Executive Officer of Bushveld Energy, an energy storage solutions company, part of AIM-listed Bushveld Minerals, an integrated vanadium company
- Chairman of the South Africa Energy Storage Association (SAESA) and of the Energy Storage Committee of Vanitec, the global non-profit association of vanadium producers
- Not a representative of any specific ESS company
- Representing the vanadium-based value chain, including mining, component manufacturing, investment in BESS companies and project development across the African continent
- Based in South Africa

## The vanadium redox flow battery, or VRFB, is the simplest and most developed flow battery in mass commercial operation

- The flow battery was first developed by NASA in the 1970s and unlike conventional batteries, the liquid 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 a reversible reduction-oxidation (“redox”) electrochemical reaction takes place, charging or discharging the battery
- Vanadium can exist in four different states, allowing for a single element to be used to store energy. Vanadium was first used in flow batteries in the mid-1980’s
- In addition to vanadium, the electrolyte consists primarily of water and additives such as sulphuric acid or hydrochloric acid



## VRFB technology offers significant advantages



- **Long lifespan cycles:** ability to charge / discharge over 35,000 times for over 20 years, with minimal performance degradation
- **Separation of power and energy:** allowing for kWh and kW to be scaled independently, making the technology extremely cost effective for long duration use cases
- **100% depth of discharge:** allowing for the entire battery to be used all the time
- **Lowest cost per kWh:** when fully used at least once daily makes VRFBs today cheaper than Li-ion batteries
- **Safe:** with no fire risk from thermal runaway
- **Sustainable:** 100% of vanadium is re-usable upon decommissioning and the CO<sub>2</sub> footprint is much less than of other batteries
- **Very fast response time** of less than 70ms
- **No cross-contamination:** Only one battery element, unique among flow batteries
- **Large scale adoption in China and Japan,** including multiple 400MWh+ sites under construction in China; a 60MWh battery with 5 years performance in Japan; and many smaller systems in Europe and Americas, some operating for over 10 years

# VRFB is the only BESS technology to be proven at large scale to exhibit nearly no degradation

Most Battery Energy Storage Systems (“BESS”) technologies, such as lithium ion, rapidly degrade from use

## Phase 1 Battery Packs – SOH Estimates from Capacity Test Results

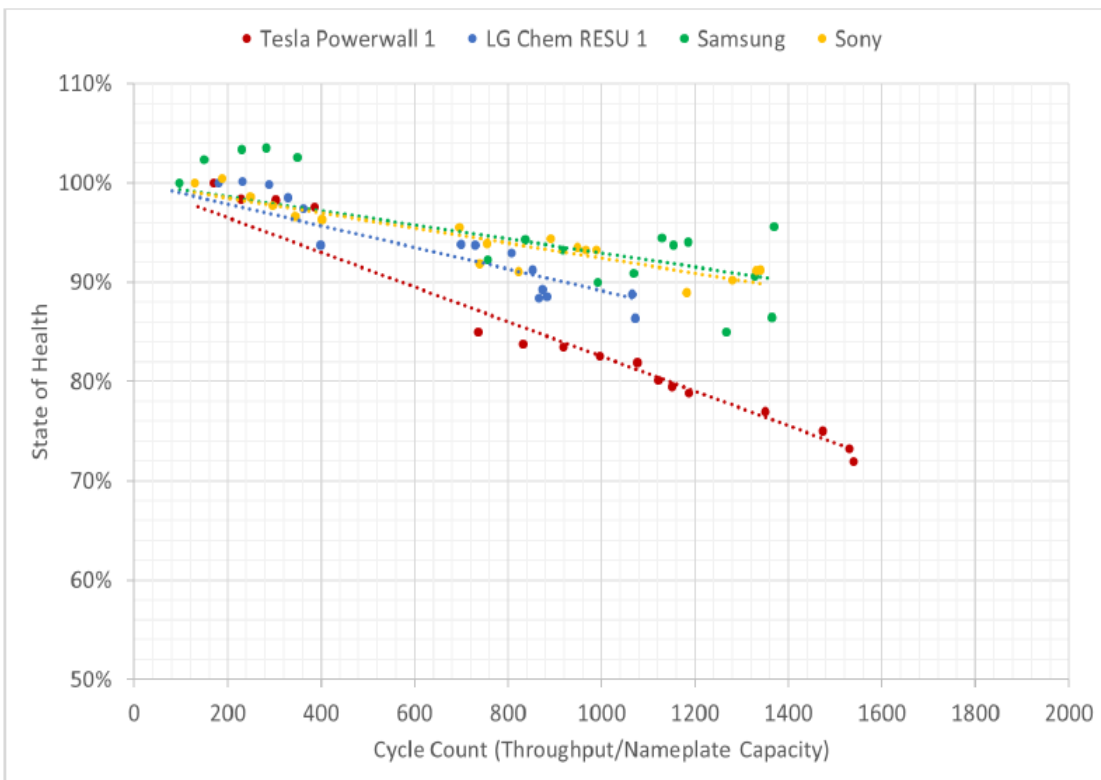
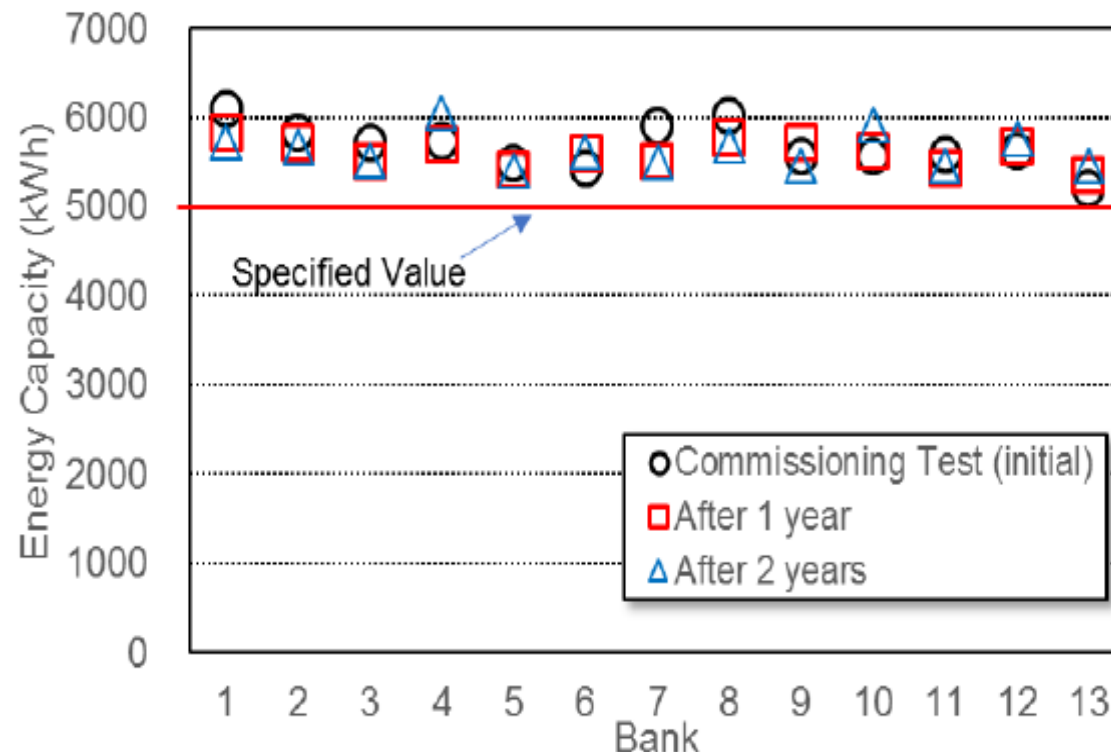


Figure 1. Capacity fade of Phase 1 battery packs based on monthly capacity tests

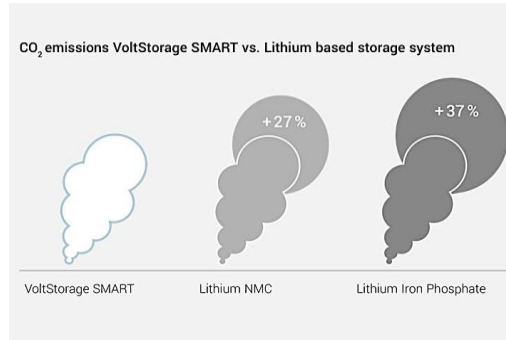
## VRFB performance has minimal performance degradation (NEPC)



Measured capacity at HEPCO’s 60MWh VRFB built by Sumitomo – data covers 2015-2018

# The strongest argument for a VRFB is the sustainability it offers because it uses vanadium

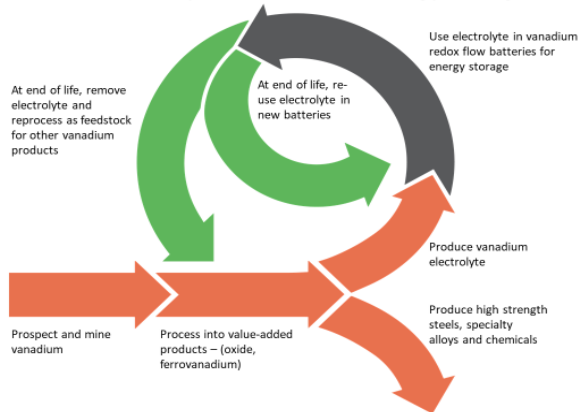
## Low carbon intensity of VRFB technology



- According to research from the Technical University of Munich, a VRFB produces less “cradle to grave” CO<sub>2</sub> emissions than other technologies;
- The savings range from 27 to 37%, when compared to multiple lithium ion technologies

## Circularity of vanadium in energy storage

### Circular economy of vanadium in energy storage



- Vanadium is not consumed and does not degrade during operation in a VRFB
- After the battery’s end of life the vanadium electrolyte can be fully redeployed into another VRFB or converted into ferrovandium for use in steel alloys
- Conversion costs a fraction of the vanadium’s market value

Source: Vanitec, Bushveld Energy, Technical University of Munich, Volterion, RMI

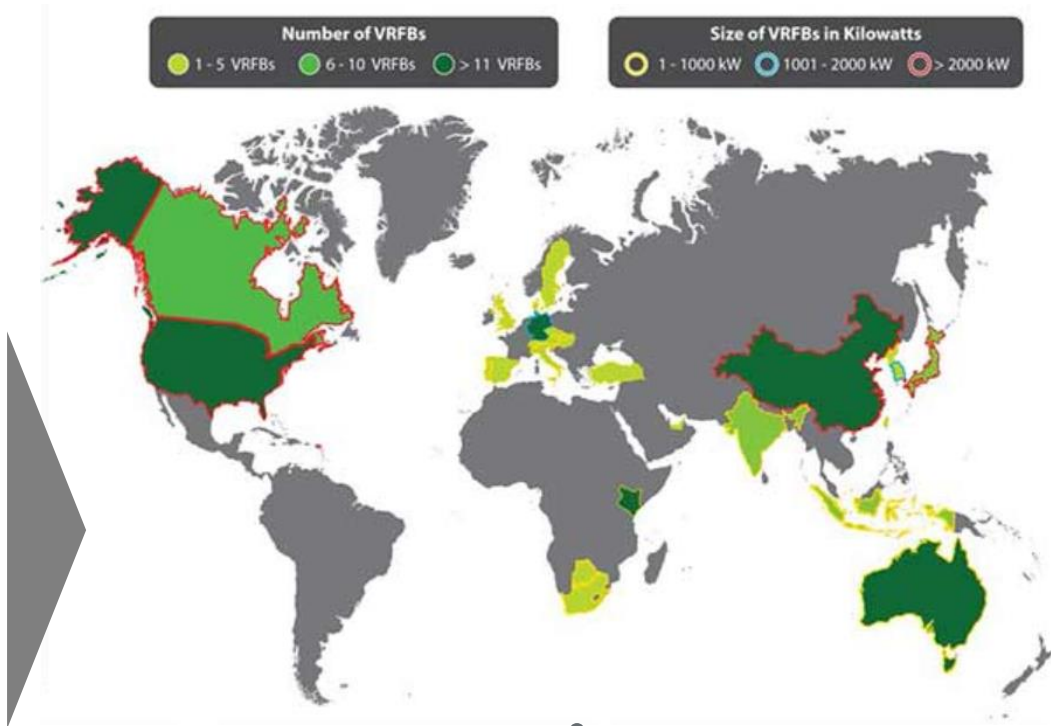
## An entire new paradigm of mineral finance is possible

- Because the vanadium in VRFBs does not degrade, the **vanadium electrolyte can be rented** or leased to the VRFB customer rather than sold. A special purpose vehicle is used as a financial intermediary between the miner and VRFB customer.
- For energy or VRFB customers, this **reduces the upfront costs** of the battery as well as its levelized costs.
- For investors, it creates **direct exposure to the vanadium commodity**, without the management or inventory costs of most commodity funds.
- For all of us, it guarantees that the **chemistry in the battery will be recycled** and introduces a **new model for mineral wealth exploitation** and transferring mineral wealth across generations
- The model can eventually be applied to other products and other commodities, creating a new paradigm where mineral wealth has economic value both below and above ground

95% of vanadium is mined in BRICS countries, making it especially attractive for these developing countries



Not surprisingly, there are over two dozen VRFB manufacturers and hundreds of operating systems globally



In China alone, we are tracking ~2GWh of VRFBs currently under construction

Source: Vanitec, company websites

# 2020 has been an especially good year for VRFB momentum

## China



Shanghai Electric announced plans for another **100MW / 400MWh** VRFB in Yancheng, China



Rongke Power's **200 MW/800 MWh** is due for initial commissioning this year

Sichuan Xuteng Battery Energy Co., Ltd. is a newly introduced enterprise in Panzhihua successfully signed the R & D and industrial park projects of VRFB energy storage.



Jiangxi Yinhui New Energy Co., Ltd. plans to build a new project with an annual output of **66,000 cubic meters** of vanadium electrolyte in Yichun

Yichun Jin Kong Group issued) to support the demonstration production base project of vanadium battery industrialization

## Rest of the world



Nusaned Investment

A SABIC initiative to support local investment



Joint venture established to build a VRFB facility “an annual production capacity of **3 GWh**”

**51MWh** VRFB system awarded to Sumitomo for a wind farm in Hokkaido, Japan



M&A activity is picking up, including a “**\$70 million merger of vanadium redox flow battery start-ups**”. The new company just announced **7.8MWh** of orders from the California Energy Commission in the USA

Developer and maker of home VRFB energy storage systems, raised **€6 million (US\$7.1 million)** in July 2020.



Large, multinational power companies are deploying VRFB technology, including **ENEL in Majorca, Spain** and **EDF in Oxford, UK**

**Increased deployment of VRFBs and demand is likely to rise as governments focus on accelerating the transition to a zero-carbon energy future**



## Closing thoughts on test beds

- Need to reduce duplication to maximise use of resource - how can existing test beds be incorporated into the WB ESP programme (e.g. Eskom's site)?
- Significant flexibility is needed from the “test bed” team, as it is impossible to future proof for possible issues and being overly prescriptive will make it less attractive.
- Need to make test beds more attractive for OEMs
  - Create a WBG-backed technology risk guarantee facility for vetted products
  - Offer partial grants, possibly success based (e.g. paying for certification)
  - Provide a path to global certification from test bed results (local is not enough)
  - Consider other services or benefits
- Important to not only test technical performance but ESS use cases – who is doing pro forma validation for new ESS use cases?