A renewable energy future driven by vanadium

World Materials Forum, June 28, 2018

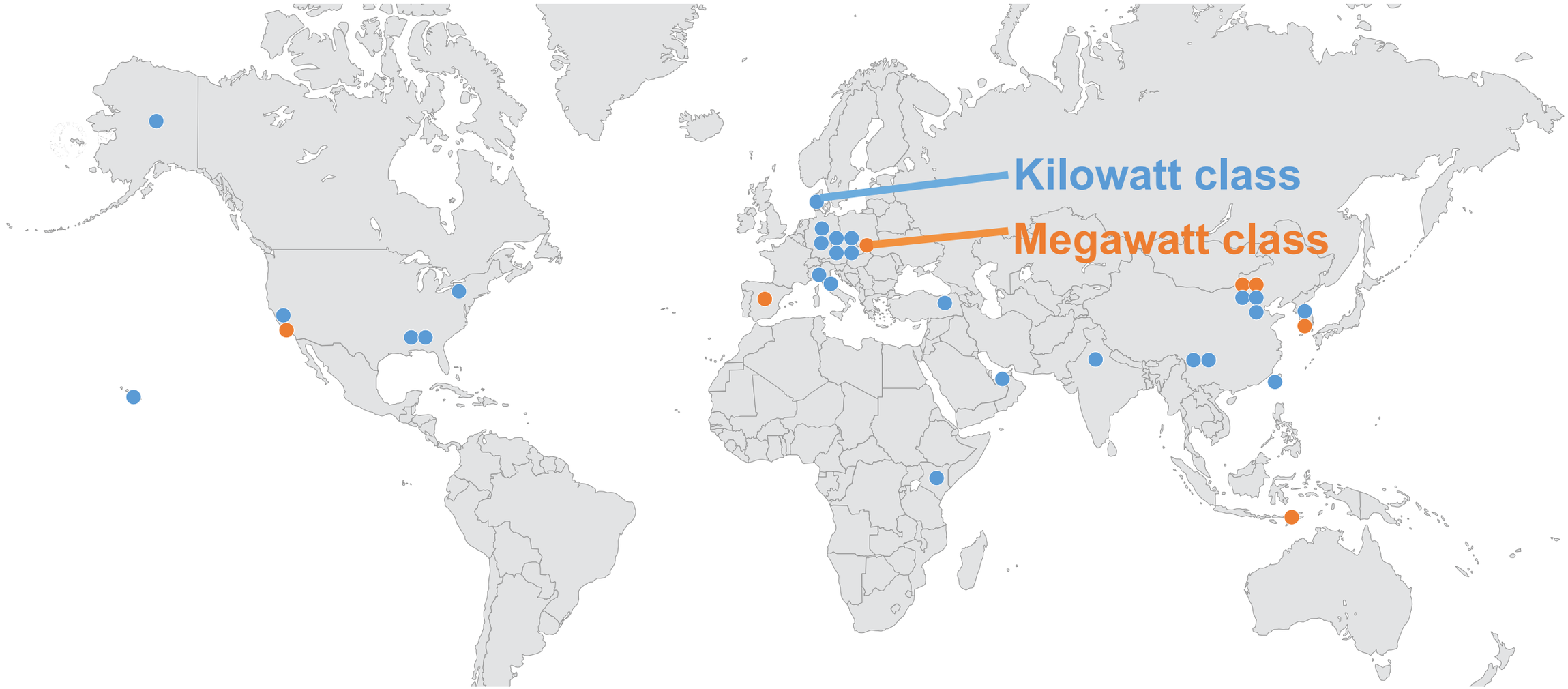
VRB Energy – Catalyst for the renewable revolution

Right technology – Vanadium redox batteries (VRB®) designed for large-scale storage, 100% utilized capacity, lowest lifecycle cost.

Proven product – 15 years and $100 million spent on R&D, 800,000 hours of operation, validated by China State Grid.

Vanadium electrolyte – Vanadium electrolyte is almost 100% recyclable, leasing unlocks massive market scale.

Offices in Mumbai, Beijing, Brisbane, Vancouver and New York, and battery installations worldwide



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A renewable energy future must have energy storage

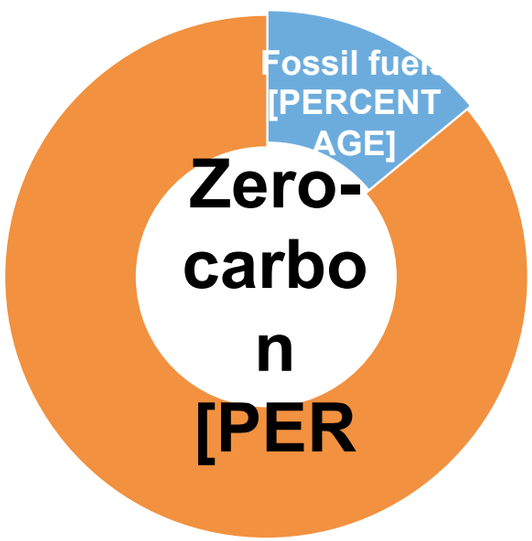
US$10.2 trillion investment in new power generation through 2040.

US$8.8 trillion will be in renewable energy.

Utilities need storage for:

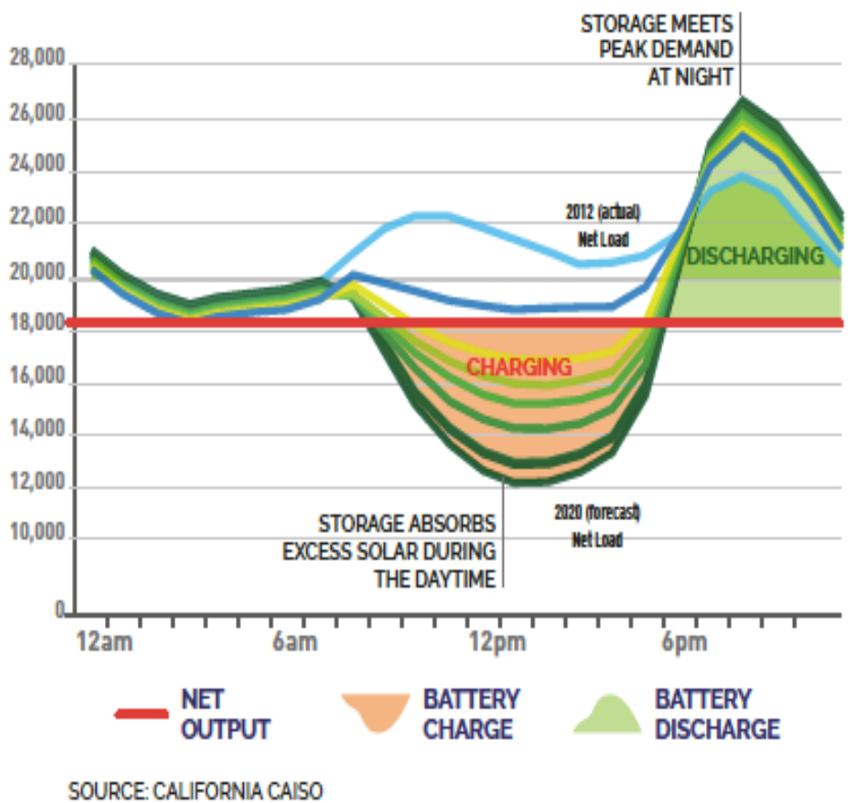
Grid security (fast response)

Reliability (energy capacity >4 hours)



Source Bloomberg New Energy Finance

Typical Spring Day, Solar Balancing in California



SOURCE: CALIFORNIA CAISO

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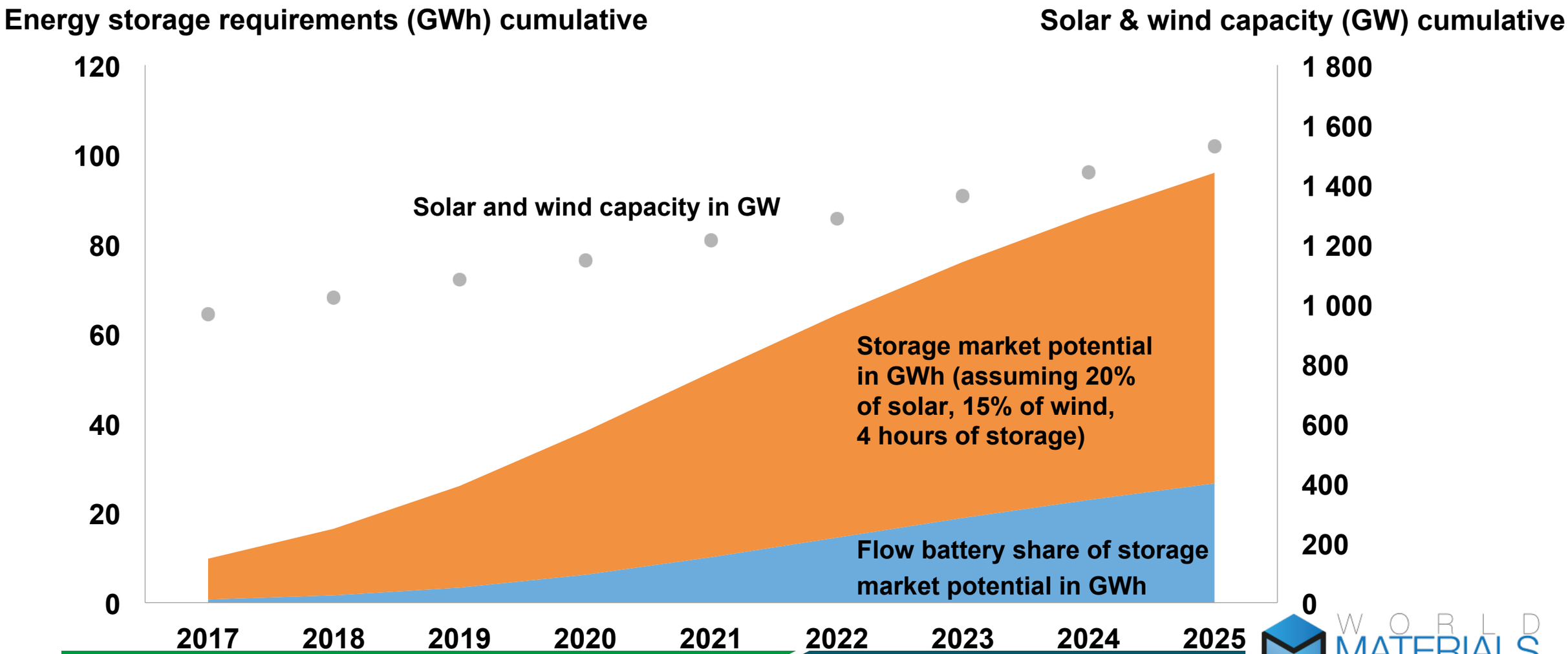
An incredible market opportunity for all storage media

>80 GWh storage with VRB Energy and our vanadium flow batteries at the center.

Conservatively assuming <30% of the storage market is served by flow batteries.



Source: WEO 2015 450ppm Scenario; internal estimates

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Vanadium flow batteries are unique:
Vanadium electrolyte never wears out

Vanadium flow batteries will require 21,000 tons of vanadium annually by 2030.

40% of costs

are stacks

and balance-of-plant

- Continuous R&D yields design and cost improvements.

60% of cost

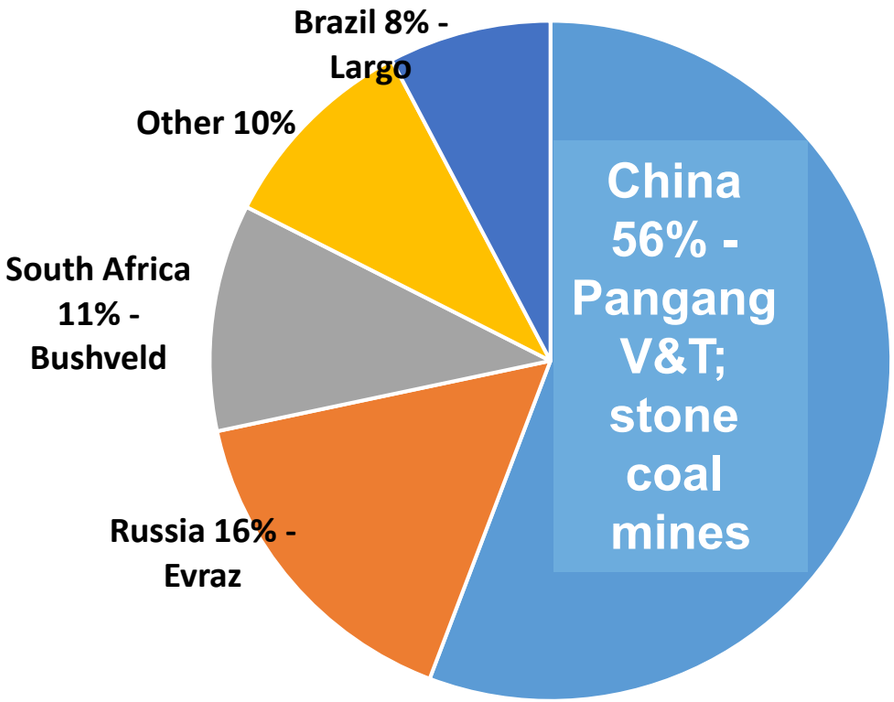
is vanadium electrolyte

- Vanadium electrolyte is 100% re-usable in another flow battery OR recovered as commodity.

Where does vanadium come from?

Multiple sources; China is a major source of vanadium.

Vanadium is not rare and is not geologically constrained.



- Steel production by-product (73%)
- Mined as a primary ore (17%)
- Recovered in power station ash, coke

Large resources in China: Approx. 118 million tonnes V_2O_5 in vanadium-rich “stone coal” deposits

Source: TTP Squared, Inc.

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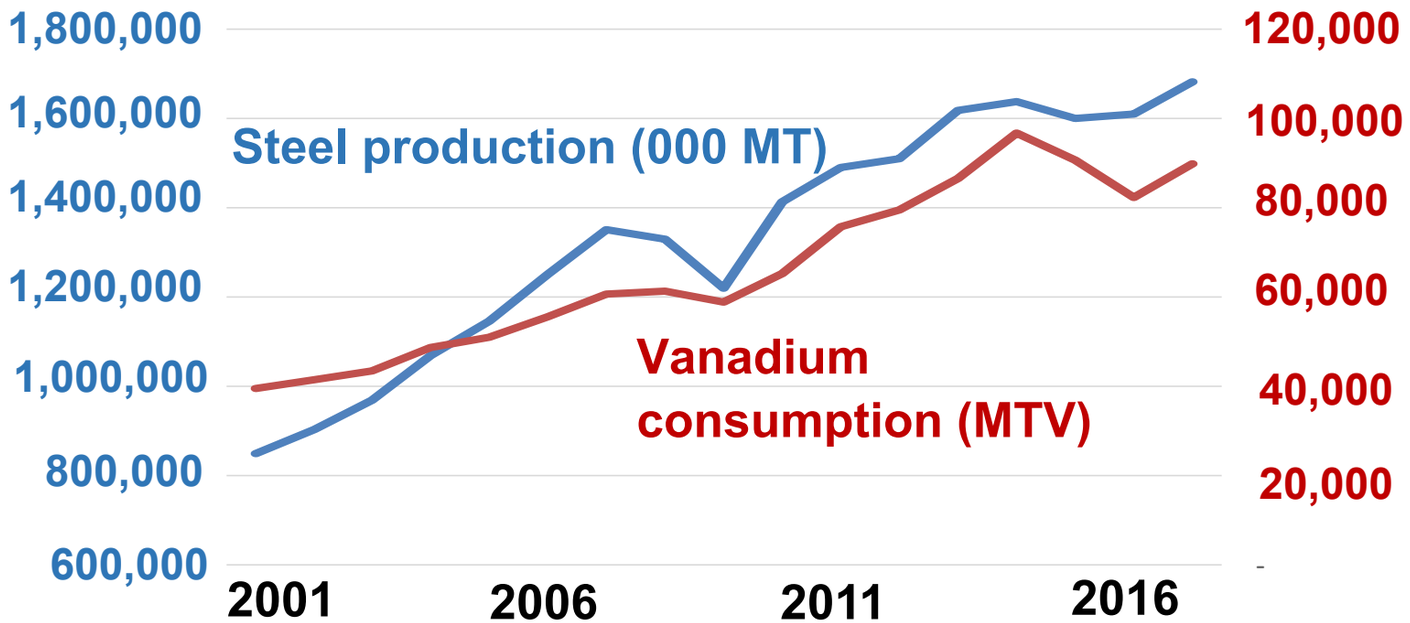
How has vanadium been used?

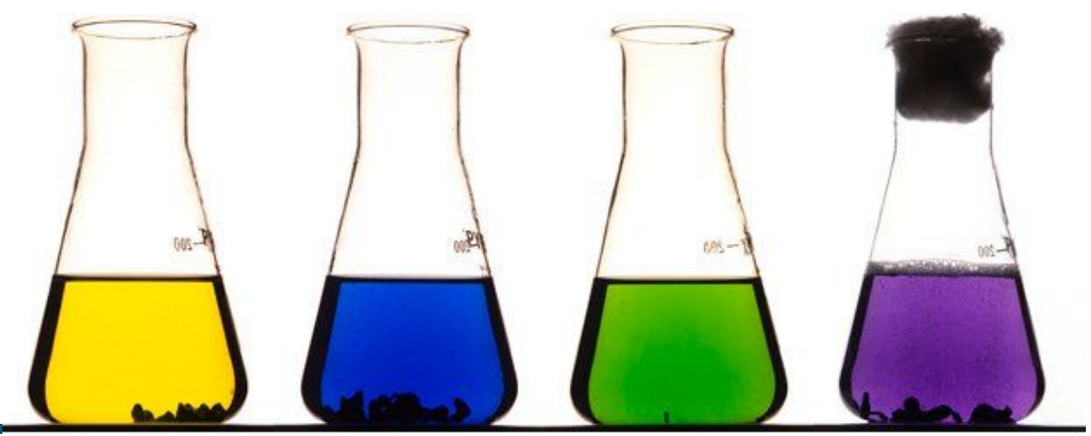
Vanadium has always been about steel, making a strong steel alloy…



…but it is perfect for energy storage

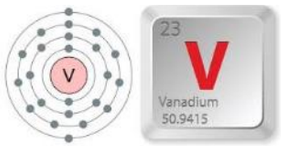
Vanadium is a transitional metal with four common oxidation states, distinguished by four different colours.

It can easily lose/gain electrons, ideal for repeated charge/discharge cycles.



Source: TTP Squared, Inc.

Vanadium vs lithium in batteries



Vanadium

- Vanadium electrolyte is the key ingredient: 60% of costs, and supply is not geologically constrained
- 100% depth-of-discharge
- Electrolyte never wears out, nearly infinitely repeatable charge/ discharge
- Inherently safe
- Nearly 100% recyclable

Lithium

- Lithium is a small fraction of the cost; nickel and cobalt are ~15%, and their supplies are much more constrained
- ~80% depth-of-discharge
- Limited lifetime, cathode and anode materials degrade over 3-5 years
- Significant safety and fire risk
- End-of-life environmental disposal cost

Spontaneous combustion of a Tesla Model S in California, belonging to the husband of actress Mary McCormack (June 15).

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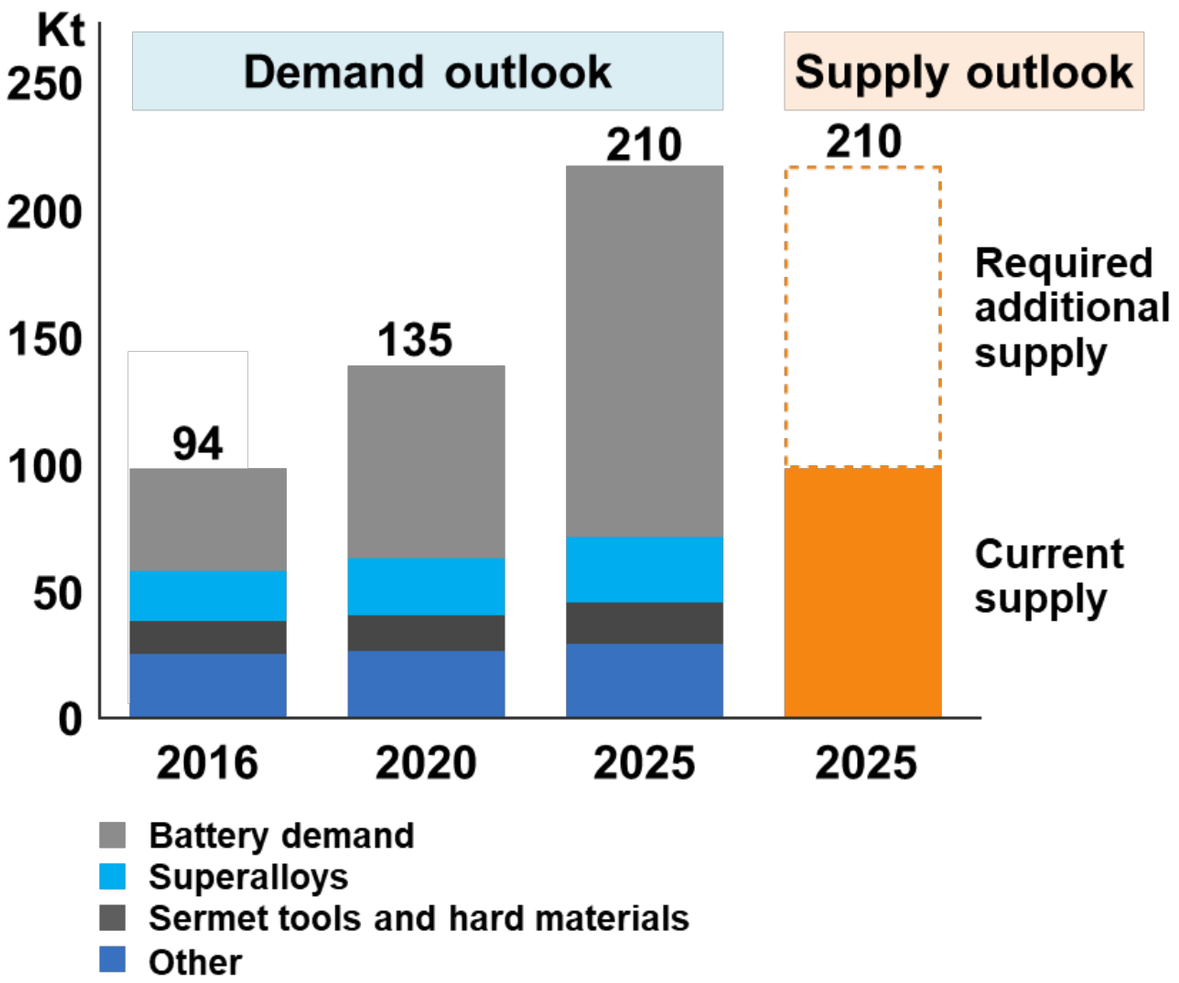
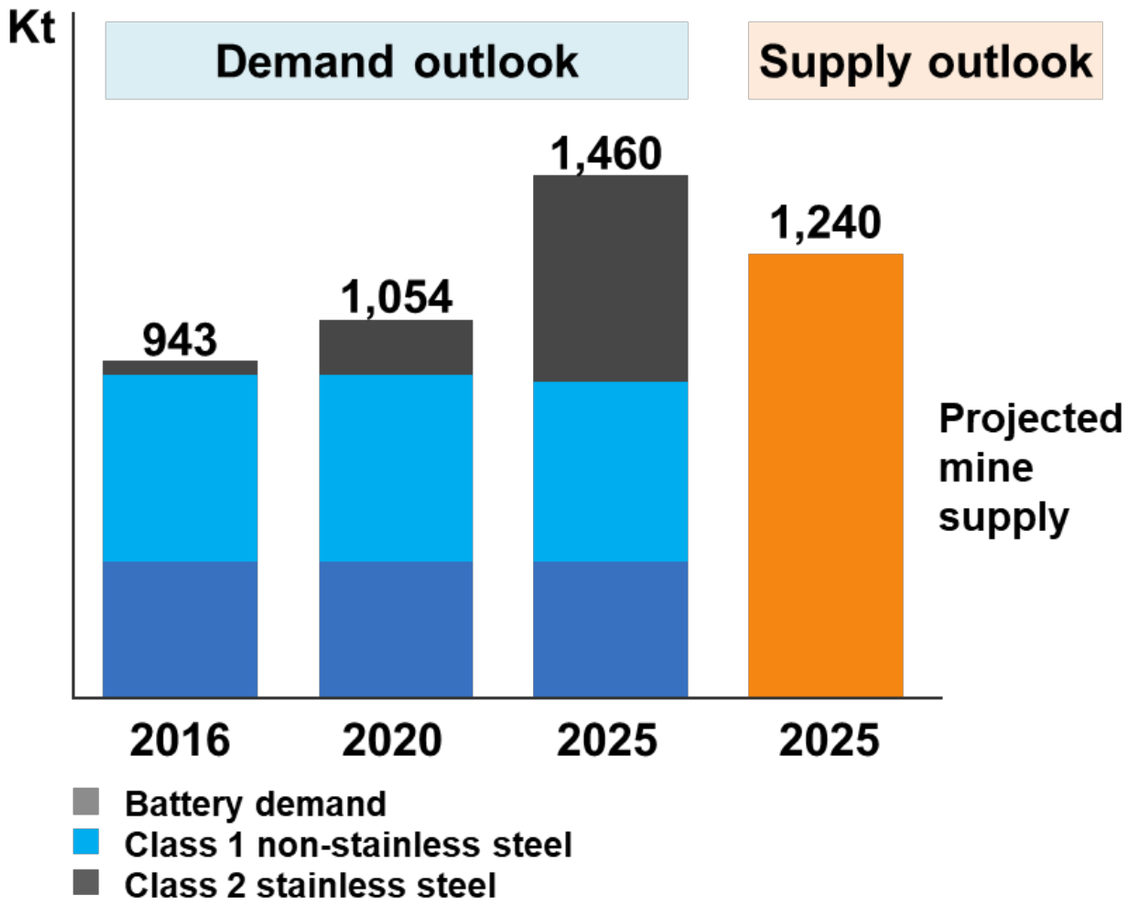
Supply constraints for cobalt and nickel are real

Cobalt supply-demand balance (Refined metal)



Class 1 nickel supply-demand balance



Source: the McKinsey Basic Material Institute

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Alternative paths to cheaper vanadium

Unconventional sources have indicative low-cost V2O5 potential.

Power plant waste

- V2O5 in power plant ash
- V2O5 in gasifier coke
- Low cost by-product

Oil sands

- Extensive Resources
- Similar process to power plant waste recovery

Spent catalysts

- Recovery and recycling of waste material

Innovation in processing technology

CLEAN TEQ
Powering innovation

- **Solvent extraction from ore**
- **Ion-exchange purification of V2O5**

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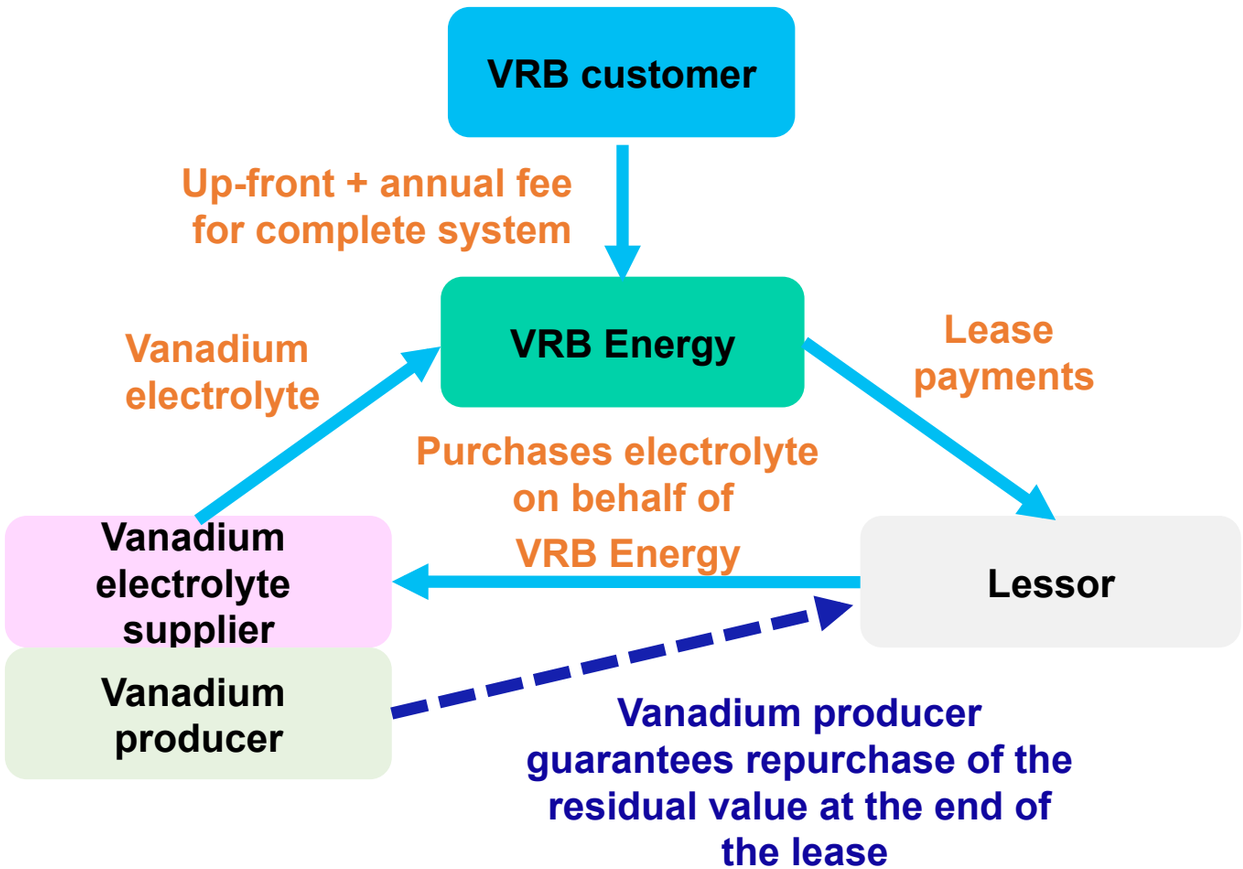
Vanadium electrolyte does not degrade

Leasing is all about the residual value: vanadium the consumable (steel production) becomes vanadium the asset (vanadium batteries).



Vanadium producer:

- Sells electrolyte to a lessor
- Agrees to buy back at 30 to 40% of the price at the end of the lease

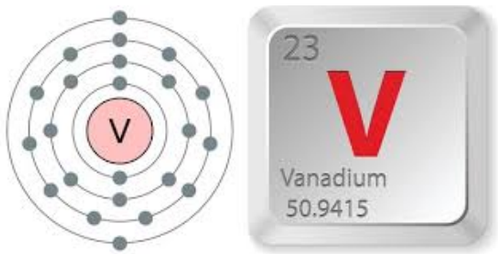
At end of lease the electrolyte can be:

- Converted and sold into the V2O5 market (commodity)
- Re-leased as electrolyte (asset)

Leasing is NOT viable for other batteries that degrade in capacity and are a cost to dispose

Vanadium producers maximize profit by selling into a leasing model, unlocking an enormous market

Past:
Electrolyte sales



Future:
Electrolyte leasing

VRB >$500/kWh

VRB <$150/kWh

Battery market expectations $500/kWh

Battery market expectations <$200/kWh

A vertically-integrated vanadium producer can choose to:

Sell once: V2O5 market (commodity)

Sell twice: Lease to VRB market (asset) and then V205 market (commodity)

Sell multiple times: Continue leasing to VRB market (asset)

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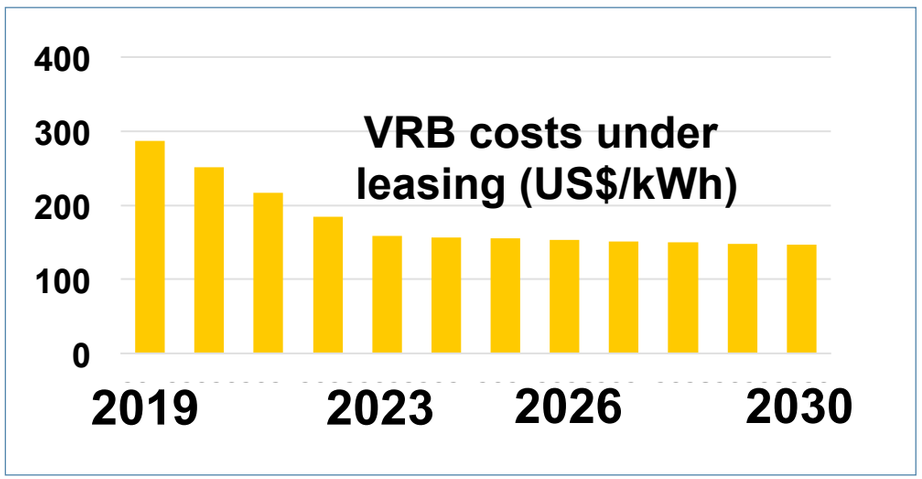
Vanadium is poised to become a major global commodity

<$250/kWh

vanadium redox batteries



Leasing, technology cost reductions, and VRB lifecycle durability deliver low-cost storage

US$8 billion

storage market

Low-cost storage creates an enormous market in support of the renewable energy revolution

405 kt **vanadium**

in evergreen circulation (commodity stockpile)

VRB added to steel demand supports investment in mining and alternative vanadium sourcing

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Vanadium electrolyte leasing:
Putting it all together – out to 2030

Vanadium flow battery manufacturers
- Low-cost entry price for customer
- Opens up VRB market

Vanadium producers
- De-risks price exposure to steel demand
- Converts a commodity to an asset

Lessors
- Financier returns with guaranteed residual value mitigating risk

43 GWh energy storage

405 kt V_2O_5, in evergreen circulation (commodity stockpile)

US$5 bln leasing market

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