

**BUSHVELD**  
ENERGY

## **Update on Vanadium Flow Battery market, supply chain and policy developments**

Energy Storage Partnership Meeting

7 November 2023 - Pretoria, South Africa

## Context about the speaker

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**Mikhail Nikomarov**  
*Chief Executive Officer*  
*Bushveld Energy*

- Since 2015, Co-founder and Chief Executive Officer of Bushveld Energy
  - Investment in BESS supply chain, including SA manufacturing and international BESS OEMs
  - Developer of projects requiring long duration energy storage solutions
  - Part of London-listed Bushveld Minerals, an integrated vanadium company
- Chairman of the South Africa Energy Storage Association (SAESA)
- Chair of the Energy Storage Committee of Vanitec, the global association of vanadium producers
- Previously a consultant in Russia and South Africa, focusing on the power sector (strategy and plant operations) and economic development



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Today's presentation will cover three topics

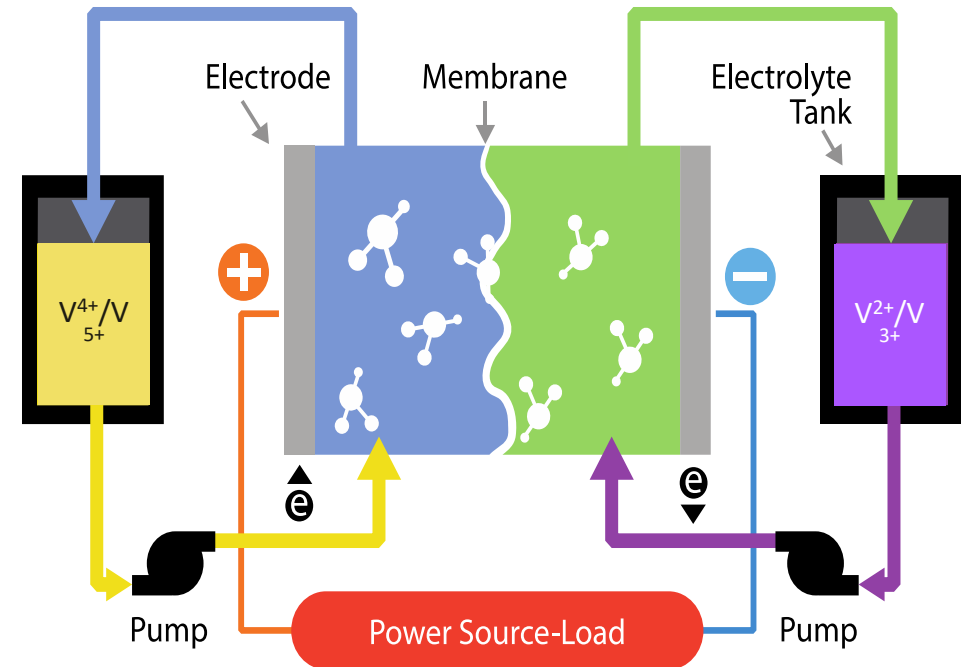
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- 1. Provide an update on the vanadium flow battery market**
- 2. Provide an update on the VFB supply chain**
- 3. Share some thoughts on the impact of regulation**



# 1. The Vanadium Flow Battery (“VFB”) is the simplest and most developed flow battery in mass commercial operation for long duration energy storage

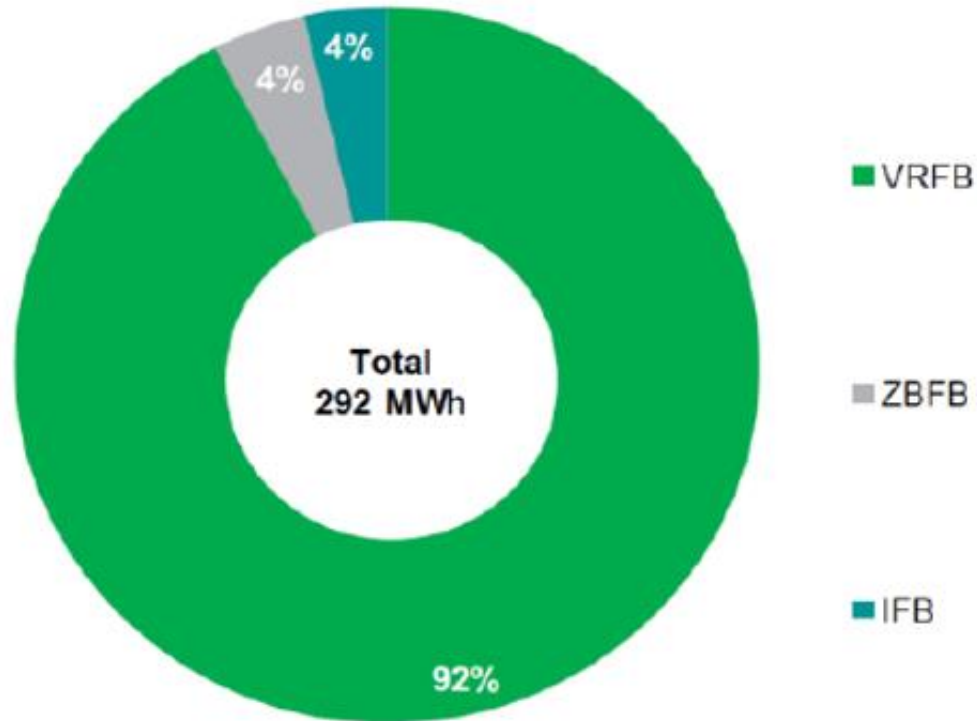
- The flow battery was first developed by NASA in the 1970s and unlike conventional batteries, the liquid electrolytes are stored in separated storage tanks, not in the power cell of the battery
- During operation these electrolytes are pumped through a stack of power cells, or membrane, where a reduction oxidation (“redox”) electrochemical reaction takes place, charging or discharging the battery
- Vanadium can exist in multiple oxidation states, allowing for a single element to be used to store energy.
- In addition to vanadium, the electrolyte consists primarily of water and chemical additive acids, such as sulphuric acid or hydrochloric acid



Source: IEEE Spectrum: “It’s Big and Long-Lived, and It Won’t Catch Fire: The Vanadium Redox-Flow Battery”, 26 October 2017; company websites

# 1. Vanadium is the dominant flow battery technology

Installed based by flow battery technology, MWh, 2020

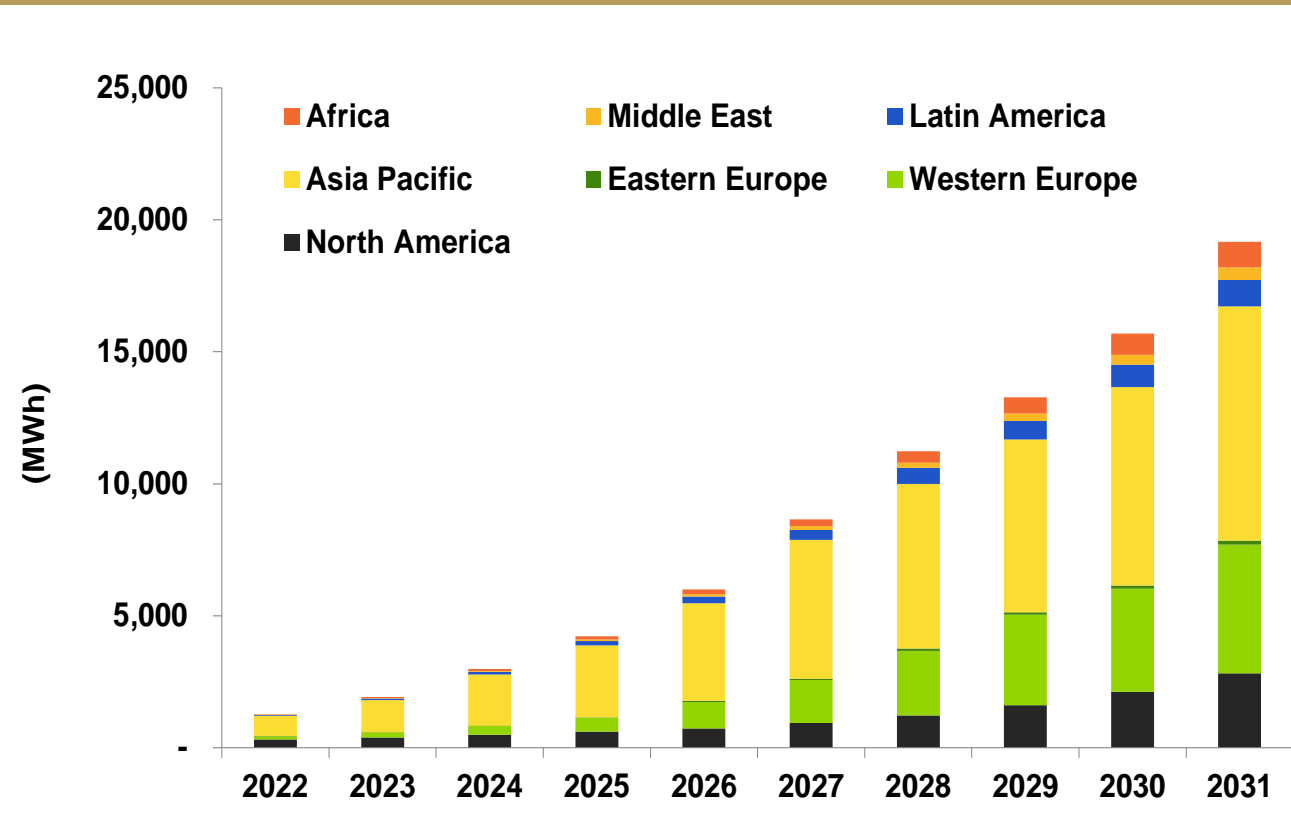


Note: Data based on project information listed in the IHS Market Energy Storage Project Database, second quarter 2020, excludes telecoms applications  
Source: IHS Market © 2020 IHS Market

- In the last few years, other flow battery chemistries to gain traction include iron, iron-chrome and zinc-bromine. Some are even looking at vanadium and either iron or chrome flow batteries
- Still, VFBs have a massive head start
  - ~50 VFB companies globally
  - Growing supply chain of stack and electrolyte producers
  - Dedicated technology-based policy in China
  - Adoption by large Western power equipment manufacturers (e.g. Siemens Gamesa, Voith)

# 1. Going forward, the market for vanadium flow batteries (VFBs) is forecasted to grow exponentially, creating significant new vanadium demand

Annual Installed VFB Battery Deployment Energy Capacity by Region, Application Segments, World Markets: 2022-2031 All



- Guidehouse forecasts that VFB's will account for 32,800 MWh by 2031, a market share of **~20% of the stationary storage market.**
- Over the **next 5 years**, the vast majority of that is forecast to be **in China**, with faster growth in other regions in the second half of this decade.
- The annual **growth rate of over 40%** has massive implications for VFB OEMs and companies in the battery supply chain.
- The implication for vanadium producers is also significant, as based on Vanitec calculations, this VFB market would **require between 127,500 and 173,800 tons of additional annual vanadium** production. That is over twice current production.
- According to Texas A&M, the **2022 forecast for Asia Pacific was 97% accurate**, but **actual deployments in other regions were ~15%**

# 1. The contribution of energy storage to vanadium demand is increasing rapidly

## Breakdown of global vanadium consumption

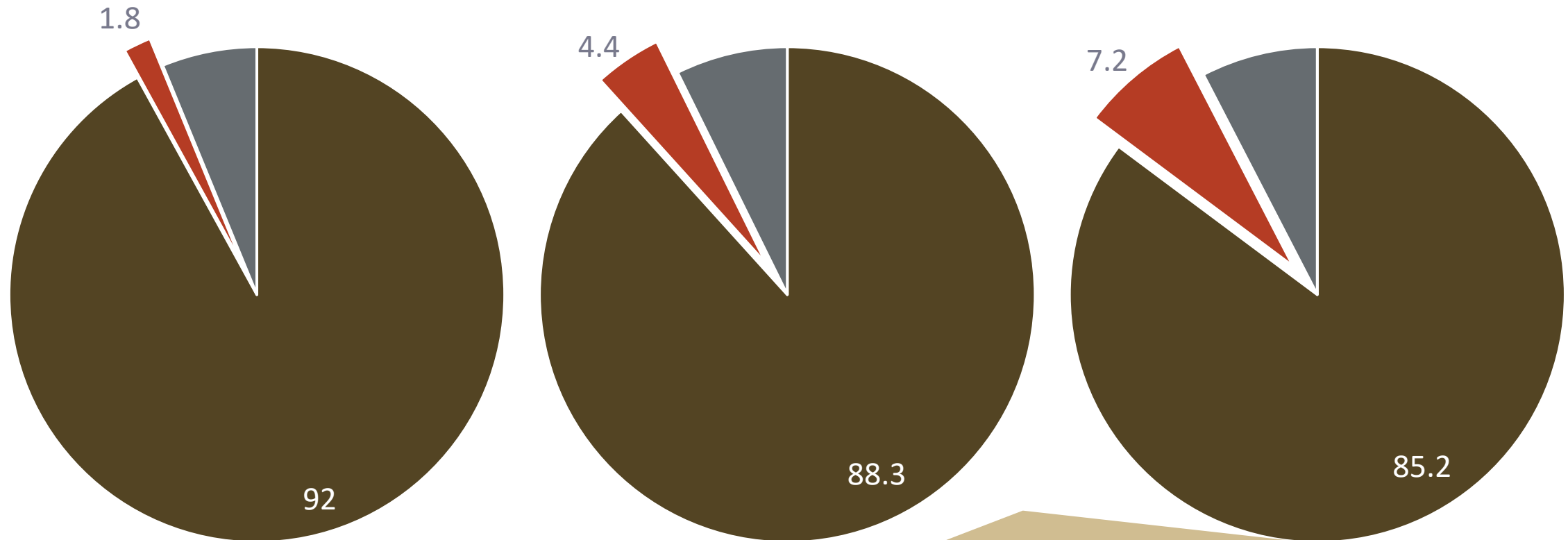
%

2018-2021

2022

H1 2023

Steel alloys  
Electrolyte  
Other uses<sup>1</sup>



- Vanadium demand may be decoupling from steel demand
- China dominates and accounts for 85% of the global vanadium used in electrolyte
- Non-Chinese vanadium demand in electrolyte is growing very fast at 300% from 2021 to 2022, from a small base

# 1. China is leading on VFB deployments



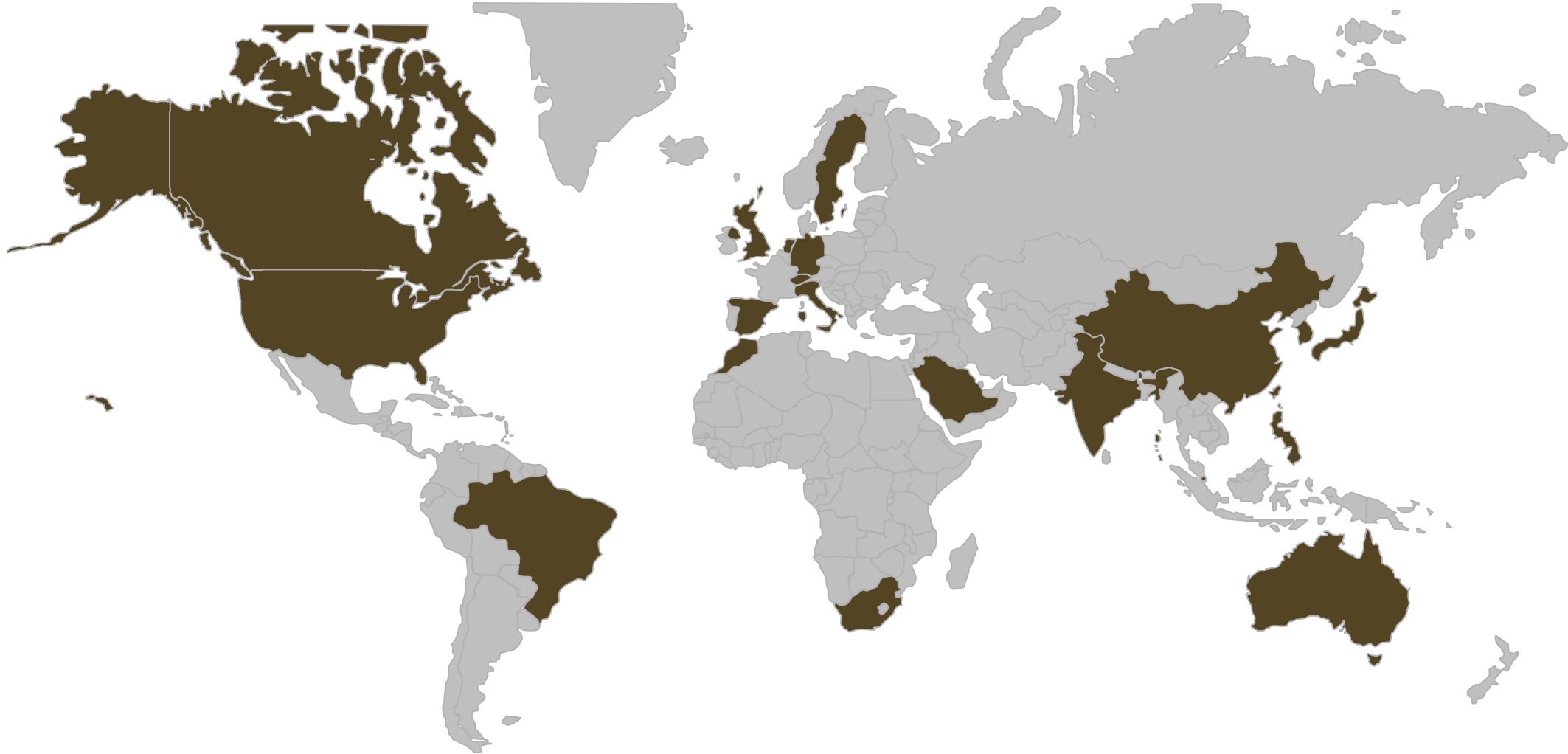
In China, we have observed at least 13 new announced projects for nearly 4.5GWh in VFB capacity

Project Name	Power/Capacity	VFB Manufacturer/ Project Contractor	Construction Location
Zhejiang 0.5MW/5MWh VRFB energy storage project	0.5MW/5MWh	Zhejiang Dayou Industry	Hangzhou Qiantang District
Ganzi Prefecture Zhengdou Photovoltaic Demonstration Experimental 250kW/1MWh VRFB Energy Storage Project	250kW/1MWh	Beijing Puneng Century Technology Co., Ltd.	Zhengdou Township, Xiangcheng County, Ganzi Prefecture, Sichuan Province
Liangshanzhou power grid side 100 MW VRFB energy storage demonstration project		Shanghai Electric (Anhui) Energy Storage Technology Co., Ltd.	Xichang City, Liangshan Prefecture, Sichuan
200MW/800MWh vanadium liquid flow shared energy storage project in Urad Zhongqi, Inner Mongolia	200MW/800MWh	Linyuan Group	Urad Middle Banner, Bayannur City, Inner Mongolia Autonomous Region
VRFB energy storage project in Longdanping Town, Changyang Tujia Autonomous County	70MW/280MWh	SPIC Hubei Changyuan New Energy Co., Ltd.	Longdanping Town, Changyang Tujia Autonomous County
CECEP Honghu Caoshi Town VRFB Energy Storage Power Station Project	100MW/200MWh	State Grid Electric Power Research Institute Wuhan Nari Co., Ltd.	Honghu Caoshi Town
Zaoyang VRFB new energy storage power station	100MW/200MW	Dali Zaoyang New Energy Open Co., Ltd.	Zaoyang
Pilot demonstration project of new hybrid VRFB + lithium titanate energy storage power station in Zaoyang City, Hubei Zhongfan	100MW/215MWh	Beijing Ruineng Century Technology Co., Ltd.	Zaoyang
Jilin Baicheng VRFB energy storage power station project	100MW/600MWh	China Vanadium Energy Storage/Shanghai Electric	Baicheng, Jilin Province
Linyuan Group - vanadium redox flow battery energy storage power station project landed in Shapotou District	50MW/300MWh	Jiangsu Linyuan Group	Ningxia Shapotou District
Neijiang 100MW/400MWh VRFB energy storage demonstration power station project	100MW/400MWh	SPIC Sichuan Electric Power Co., Ltd.	Neijiang Economic Development Zone
Gansu Qingyang Shared VRFB Energy Storage Power Station Project	240MW/960MWh	Wontai Power	Qingyang, Gansu
The largest VRFB energy storage demonstration project in Southwest China	100MW/500MWh	Panzhuhua China Power Investment New Energy Co., Ltd.	Panzhuhua Vanadium Titanium High-tech Zone
	<b>Total 4460MWh</b>		

- In 2022, we tracked ~2GWh in newly announced VFB projects across 12 sites
- It is possible that not all of these will be delivered; however, it is also possible that we have not captured every project in China



# 1. Overview and examples of recent VFB projects and installations outside of China (1/2)



# 1. Overview and examples of VFB projects and installations outside of China (2/2)

	<ul style="list-style-type: none"> <li>▪ Invinity will supply an 8.4MWh VFB to a solar-plus-storage project in Alberta, Canada. It will be paired with a 21MW solar PV plant.</li> </ul>
	<ul style="list-style-type: none"> <li>▪ Sumitomo installed a 51MWh VFB in Hokkaido. This was a follow-on installation after Sumitomo previously installed a 60MWh system on the island in 2015.</li> </ul>
	<ul style="list-style-type: none"> <li>▪ E22 commissioned a 250kWh battery for Bharat Heavy Electricals Limited (BHEL) in Hyderabad</li> <li>▪ Local manufacturer Delectrik has delivered VFBs locally and started to deliver for export, as well.</li> </ul>
	<ul style="list-style-type: none"> <li>▪ Bushveld Energy achieved financial close and has installed a minigrid featuring 3.5MW of solar PV and a 4MWh VFB from CellCube. The minigrid is an IPP that sells energy to a mine. The VFB used vanadium mined by Bushveld in South Africa.</li> </ul>
	<ul style="list-style-type: none"> <li>▪ Largo Clean Energy announced the start of manufacturing of a 6.1MWh VFB to be installed in Spain with Enel Green Power. The battery will be coupled with a 1MW PV plant to shift excess solar generation from day to evening.</li> </ul>
	<ul style="list-style-type: none"> <li>▪ Invinity installed a 1.8MWh battery at the European Marine Energy Centre (EMEC) hydrogen facility, as part of a tidal power-to-green hydrogen research project</li> <li>▪ Sold a VFB and announced an MoU to rent VFBs with Dawsongroup, assessing a 50MWh opportunity in the UK</li> </ul>
	<ul style="list-style-type: none"> <li>▪ Invinity won a tender to supply 84MWh to Indian Energy under the US DOE LDES program</li> <li>▪ CellCube installed an 8MWh system in Illinois, as part of a multi technology minigrid with G&amp;W Electric</li> <li>▪ H2 announced a 20MWh in California to be completed in 2023/2024</li> </ul>

## 2. China is also leading on the VFB supply chain (1/2)

**In China, we have observed 7 new announced vanadium electrolyte projects (some are integrated with other production plants)**

Project Name	Power/Capacity	Construction Location
The production base project of the whole industry chain of vanadium redox flow battery settled in Chongqing		chongqing
Xingxin Vanadium's 3500m <sup>3</sup> vanadium electrolyte project	3500m <sup>3</sup> /year	Sichuan Weiyuan Lianjie New District
Century Ronghua vanadium redox flow battery energy storage equipment industrialization project (vanadium electrolyte, energy storage equipment manufacturing)	12GWh	Lusigang, Qidong City, Jiangsu Province
Gansu Qingyang Vanadium Electrolyte Production Line	20000 cubic meters/year	Qingyang, Gansu
Jianlong Group 70,000 cubic meters/Year of vanadium electrolyte processing base	70000 cubic meters/year	Yingshouyingzi Mining Area, Chengde City
Dalian vanadium redox flow battery electrolyte production line		Dalian
Yongfu Energy Storage's annual production of 2,000 cubic meters of VRFB electrolyte project	2000 cubic meters	Ya'an city

- Not all the announcements have disclosed volumes
- Of those disclosed, the capacities range from small (2 ML) to very large (70 ML)

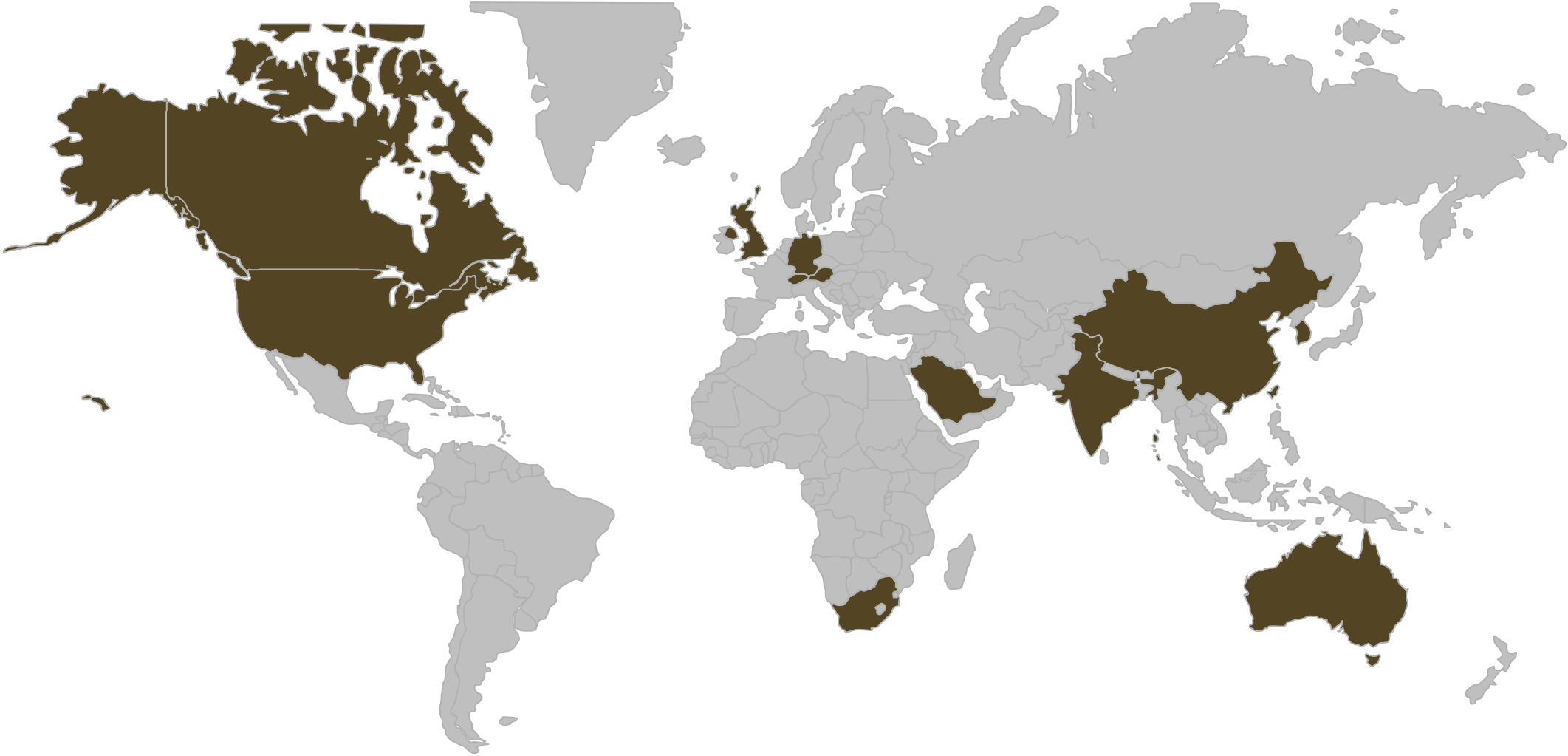
## 2. China is also leading on the VFB supply chain (2/2)

### In China, we have observed over 30 newly announced VFB manufacturing factories

Project Name	Power/Capacity	Construction Location
Anchao Economic Development Zone Energy Storage Flow Battery Production Line Project	1GWh	Anhui Chaohu Economic Development Zone
1GW production of VRFB and shared energy storage power station project in Fengning County, Hebei Province	1GWh	Fengning County
Gansu Jiuquan 2GWH VRFB energy storage equipment production project	2GWh	Jiuquan
VRFB Manufacturing project in Kazuo County, Chaoyang	1GWh	Kazuo County, Chaoyang City, Liaoning Province
4GWh VRFB manufacturing project in Urad Zhongqi, Inner Mongolia	4GWh	Urad Middle Banner, Bayannur City, Inner Mongolia Autonomous Region
Yunnan Qujing VRFB industrial base (phase I) project	500MWh/year	Zhanyi District, Qujing City
Flow battery energy storage and hydrogen energy technology innovation and industrialization base project in Yijinhuoluo Banner, Ordos City		Ejin Horo Banner, Ordos City
Annual output of 1GWh vanadium flow energy storage battery project in Wuhu City	1GWh/year	Jiujiang District, Wuhu City
The production base project of the whole industry chain of vanadium redox flow battery settled in Chongqing		chongqing
Hubei Xiaochang 3GW/12GWh VRFB energy storage equipment intelligent production base	3GW/12GWh	Xiaochang County, Hubei Province
Jinchang 500MWh vanadium energy storage battery industry project	500MWh	Jinchuan District, Jinchang City, Gansu Province
Ningxia Zhongning vanadium redox flow battery energy storage equipment manufacturing project	200MW	Zhongning County, Ningxia
Lixin Guoke vanadium redox flow battery equipment manufacturing project officially started		Wangjiang County
Linyuan Group - vanadium flow energy storage battery production project landed in Shapotou District	1.2GWh	Ningxia Shapotou District
Century Ronghua vanadium redox flow battery energy storage equipment industrialization project (vanadium electrolyte, energy storage equipment manufacturing)	12GWh	Lusigang, Qidong City, Jiangsu Province
China Vanadium Energy Storage - vanadium redox flow battery energy storage equipment manufacturing project	1GW/year	Baicheng, Jilin Province
Weili Energy - Vanadium Battery Industrial Park		Leshan, Sichuan
EVERFLOW - 5GW flow battery whole industry chain project	5GW	Jiuyuan District, Baotou City
Tongchang Energy Fuping Vanadium Redox Flow Battery Energy Storage Industrialization Project	500MW	Fuping County, Baoding City, Hebei Province
Linyuan Group - 5GWh vanadium flow battery manufacturing project	5GWh	Yancheng
Sichuan Chemical Industry Group - annual production of 100MWh vanadium redox flow battery system project	100MWh	Ya'an city
Star New Energy - Vanadium Redox Flow Battery gigawatt factory	3GW	Changzhou Wujin National High-tech Industrial Development Zone
Vanadium redox flow battery production line project in Kaiweichang County		Kaiweichang County, Hebei Province
SCEGC New Energy - annual output of 3GW vanadium battery production project	3GW	Dingbian County, Yulin City
Detai Energy - 1000MW vanadium redox flow battery manufacturing base project	1000MW	Zhangjiagang
Xinjiang vanadium/iron-chromium flow battery production project	2GWh	Baijiantan District (Karamay High-tech Zone)
Shaanxi Construction Engineering vanadium battery production project	1GW	Golmud
Dalian vanadium redox flow battery electrolyte production line		Dalian
Haiyue Energy VRFB Energy Storage Industrial Park Project		Shangnan County, Shangluo City, Shaanxi Province
Saihan Green Energy VRFB GW-level production line project		Weichang Manchu and Mongolian Autonomous County, Chengde City, Hebei Province
Dehai Aiko VRFB intelligent production project	300MW/year	Tangqi Town, Linping District, Hangzhou City, Zhejiang Province

- The sizes are all at least 100MW per annum (400-500MWh)
- The largest is a 5GW gigafactory
- There may be duplication, as some plants may do assembly while others do stacks or precursor components

## 2. Overview and examples of VFB supply chain activities outside of China (1/2)





## 2. Overview and examples of VFB supply chain activities outside of China (2/2)



- Vecco announced the start of construction of a 9 million liter electrolyte plant in Townsville
- North Harbour and CellCube started a feasibility study for manufacturing VFBs in Australia, aiming at a minimum 40MW and up to 1000MW in annual production
- Numerous vanadium prospecting companies intending to start vanadium production of oxide for VFB electrolyte, such as LE Systems and TMG, who are testing an electrolyte production process



- AMG announced construction of a 6 million litre vanadium electrolyte plant in Germany



- AMG announced a multi-project initiative with Shell and UCI that includes a ~\$200m gasification ash project to produce high purity vanadium oxide and vanadium electrolyte
- Tdafoq Energy Partners and Delectrik Systems signed a distribution and manufacturing agreement for VFBs. Tdafoq will set up a VFB manufacturing plant in Saudi Arabia, which will be scaled to a GWh capacity by 2025.
- Schmid and Nusaned set up a JV to build a VFB facility “an annual production capacity of 3 GWh”



- Bushveld Electrolyte Company completed construction of and started commissioning an 8 million litre vanadium electrolyte plant
- Bushveld Minerals completed partial refurbishment of its Vanchem plant, which produces high purity pentoxide. Capacity increased from ~1,100 to ~2,500 mtV per annum
- Bushveld Energy and the Industrial Development Corporation started a study of local VFB manufacturing



- Sumitomo is to invest an initial US\$7.6 million into US production and installation facilities, based on the expectation of rising demand for the energy storage technology
- US Vanadium expanded its electrolyte production capacity to 4 million litres per annum
- Largo launched the Largo Physical Vanadium fund to own vanadium and vanadium electrolyte (listed in Canada)

### 3. These developments come from policy and regulation that supporting vanadium-based energy storage



- VFB-specific battery procurement of multiple 100MW+ systems
- Provincial requirements for all new renewable energy generation to include 5-15% of long duration storage
- Low cost, concessional debt for new vanadium battery and supply chain manufacturing



- Government grants for construction of a 30MWh vanadium electrolyte manufacturing
- Government grants of over AUD\$75m for new vanadium mining and exploration



- CAD \$7m grant for R&D in vanadium electrolyte manufacturing under Emissions Reduction Alberta (ERA)
- Subsidized renewable energy with VFB storage procurement (also under ERA)
- Grants for vanadium mining exploration companies in Quebec



- Designation of vanadium as a critical material
- Long duration battery procurement that excludes lithium ion (in California)
- Additional grants and tax incentives expected for long duration technologies in the newly announced Inflation Reduction Act

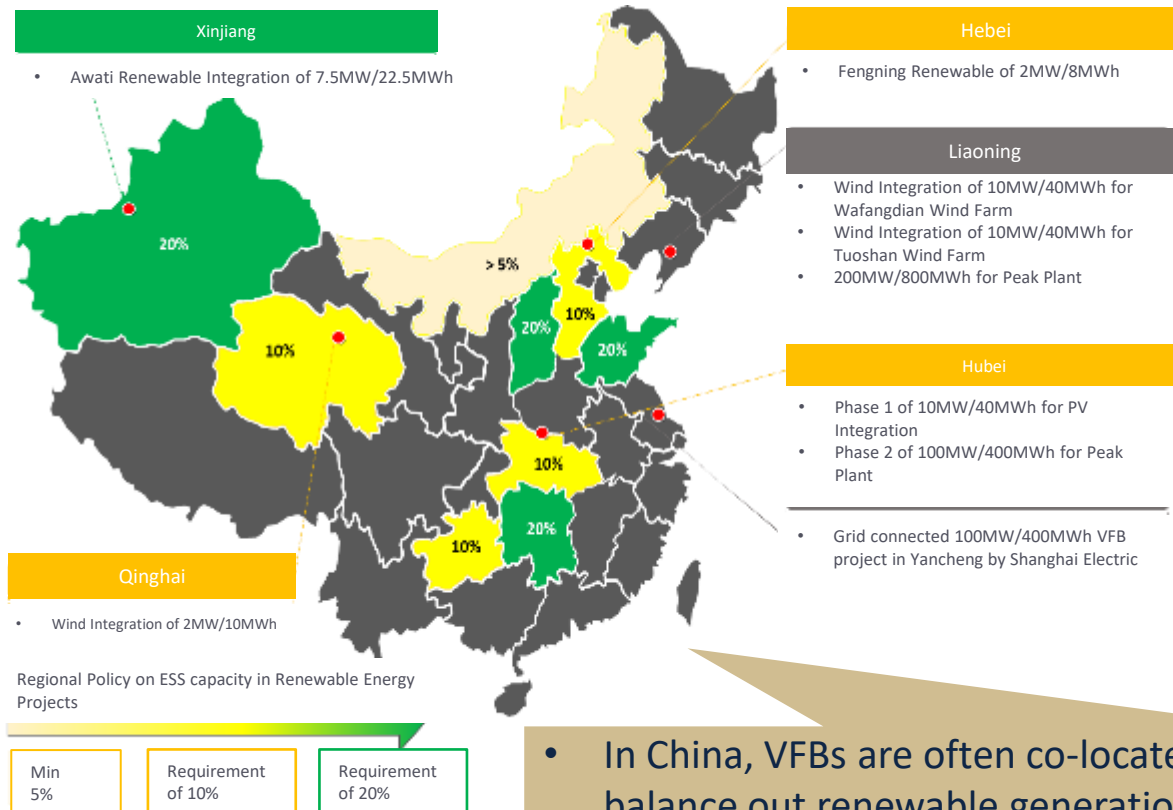


- No formal policies yet; however, it is developing a Green Deal Industrial Plan as a response to the USA's IRA and may include support for long duration storage / VFBs
- Establishment of Flow Batteries Europe, an industry association representing the voice of flow battery stakeholders

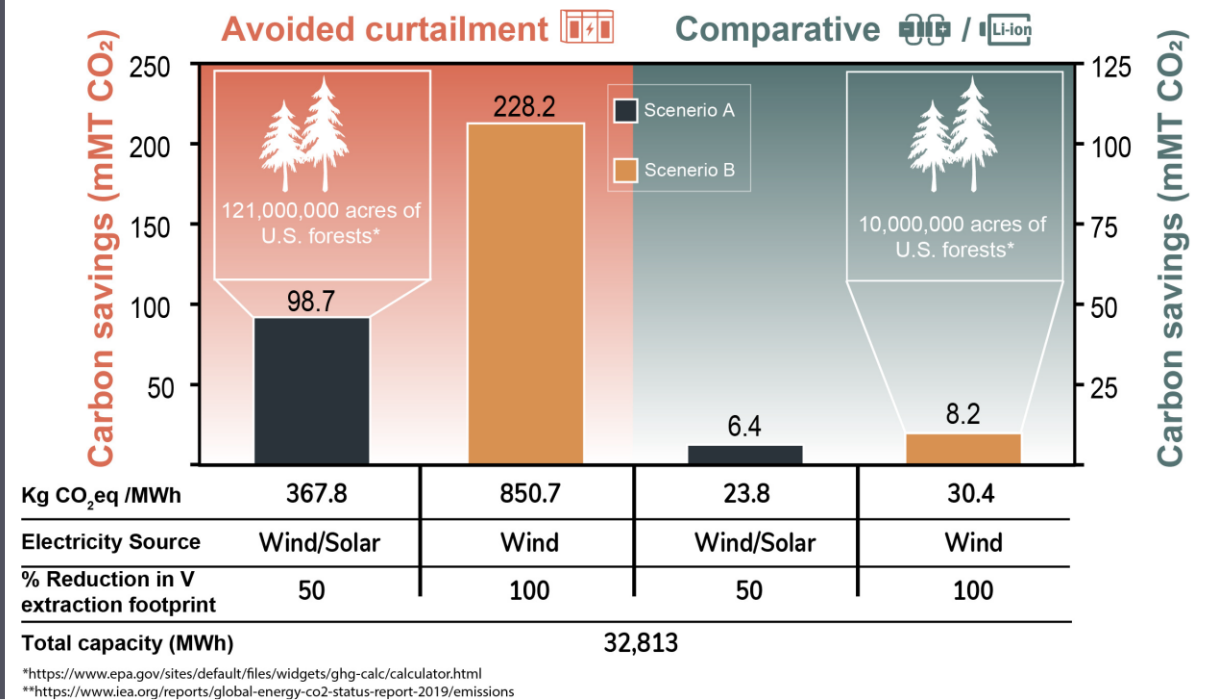
- What are the policy levers available to developing countries?
- How to make governments aware of the benefits from policy action?

### 3. These policies are part of larger effort by governments to accelerate the energy transition to a low-carbon energy

#### In China, VFBs are being deployed primarily in provinces with high renewable energy resources



#### Texas A&M University assessed the CO<sub>2</sub> savings from deployment of VFBs and their benefits over lithium ion batteries



- In China, VFBs are often co-located with renewable energy generation or located on networks to balance out renewable generation to reduce curtailment and network congestion
- This use case is relevant to South Africa due to grid constraints but great solar and wind resources
- In countries with limited grids, long duration storage coupled with solar can provide off-grid generation and reduce diesel or HFO consumption

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