Redox Flow Storage Market

HIGREEW – Workshop
16.05.23

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Global Leader in Vanadium-Redox-Flow Batteries

Long Duration Energy Storage

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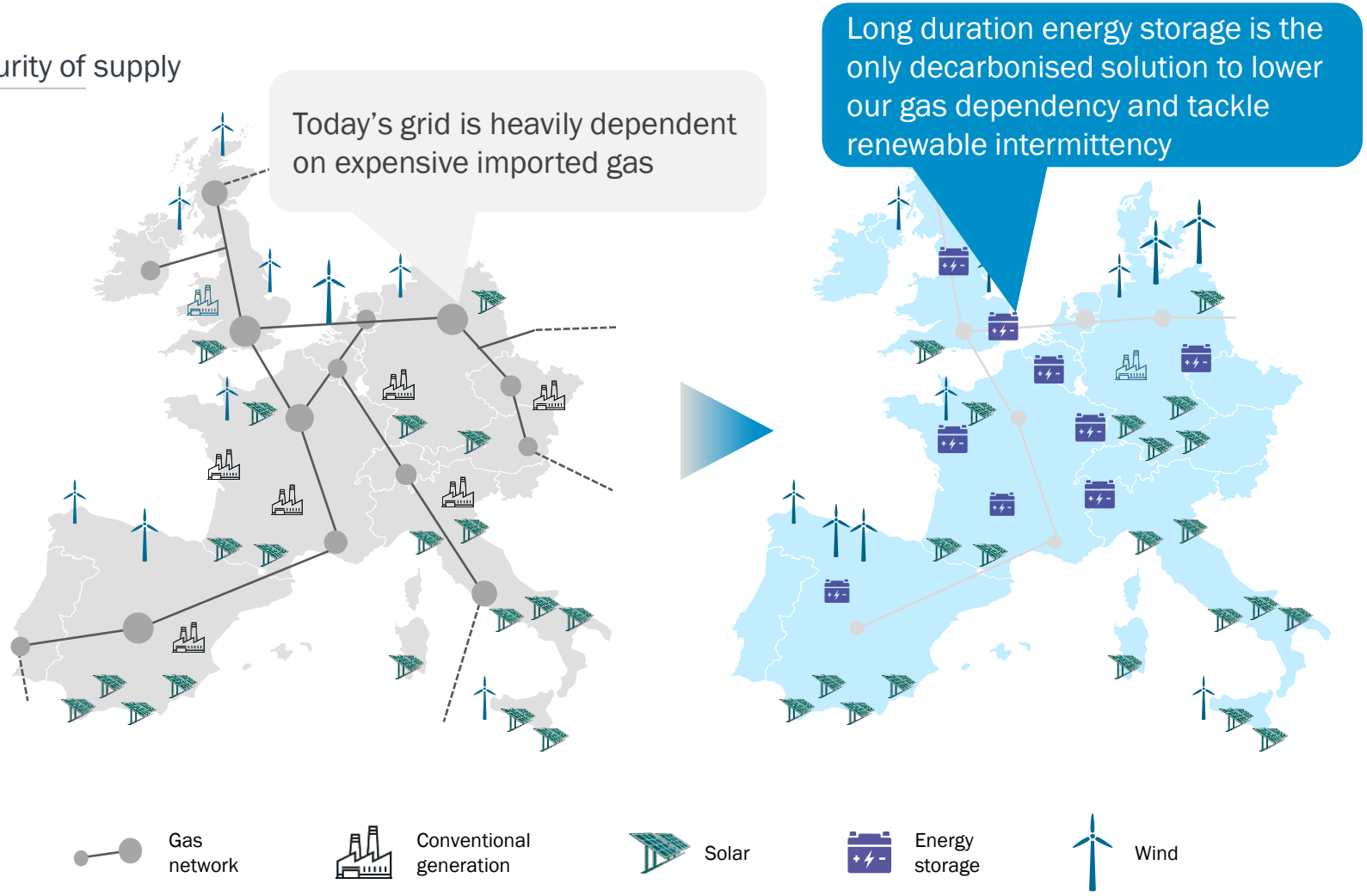
BUILDING ENERGY STORAGE INFRASTRUCTURE

Regulators' energy security focus needs to consider incentivized microgrid applications rather relying on centralized models

The introduction of LDES would contribute to security of supply

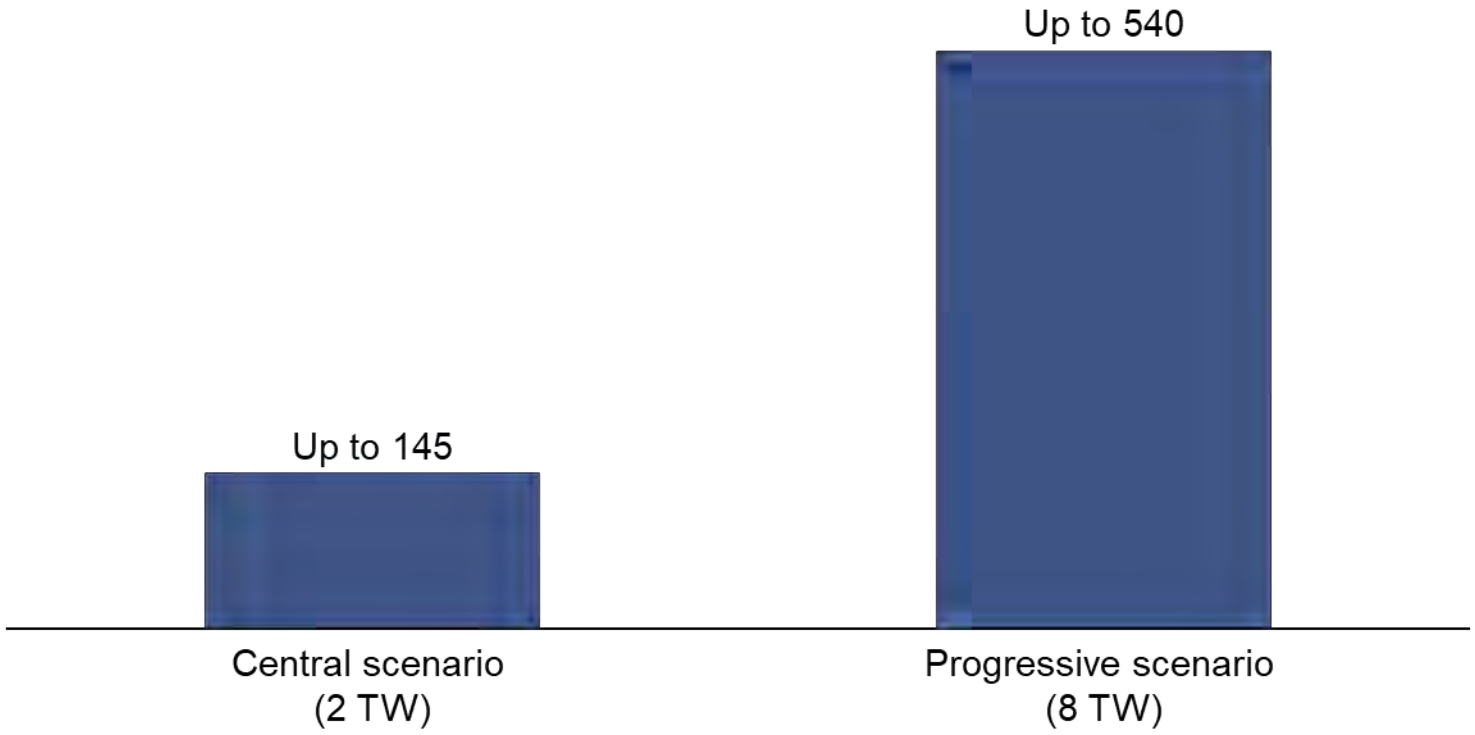
- renewable penetration results in increased flexibility demand that is largely balanced with gas assets nowadays -> problem increased
- Despite high prices – wholesale day-ahead price on 17 Sept 2022 was below 10 EUR/MWh for 3 hours due to high Solar infeed
- LDES has the capability to extend low price of renewables for a 24/7 scenario and help keep lights on Net Zero scenario, keeping energy bills as low as possible and power sector emissions down
- Combined Solar-Wind-Storage Hybrid Plants have the potential to deliver 24/7 renewable energy baseload - no intermittency, reduced risk for Dunkelflaute

European regulation needs to switch from central to decentral grid operation concept mandating LDES to any renewable installation



System integration could save up to $540 billion annually

Potential global savings generated by LDES in 2040[1]
$ billions/year



1. Savings modelled based on estimated cost savings of up to USD 70 million per GW of LDES capacity installed, including fuel savings, and better utilization of variable generation resources

The introduction of LDES provides a longer duration firming capacity and thereby **reduces the need for energy curtailment or redispatch**

The system savings coming from LDES technologies are driven mostly by **reduction of fuel costs**

This system optimization translate into potential savings of USD 145 billion in a 2 TW case and **USD 540 billion annually** by 2040 in an 8 TW case

Redox Flow Market

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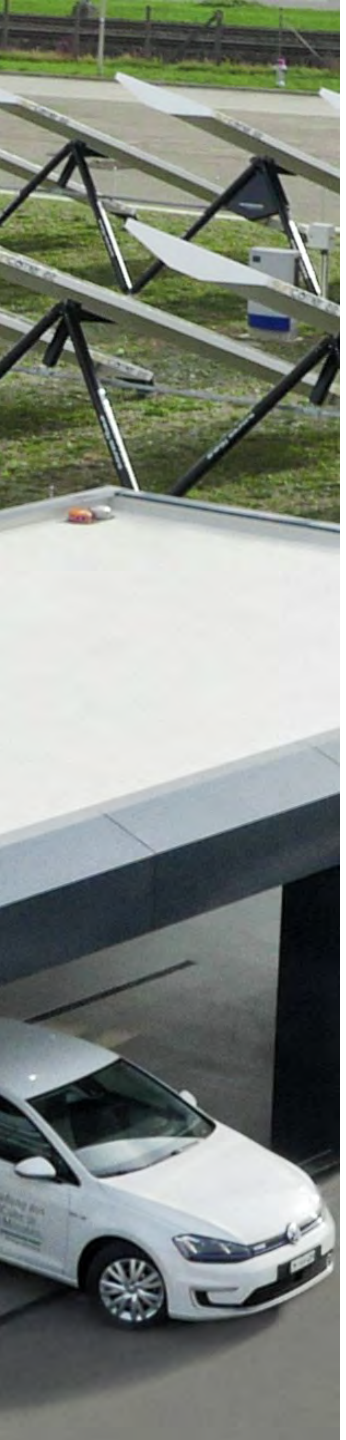
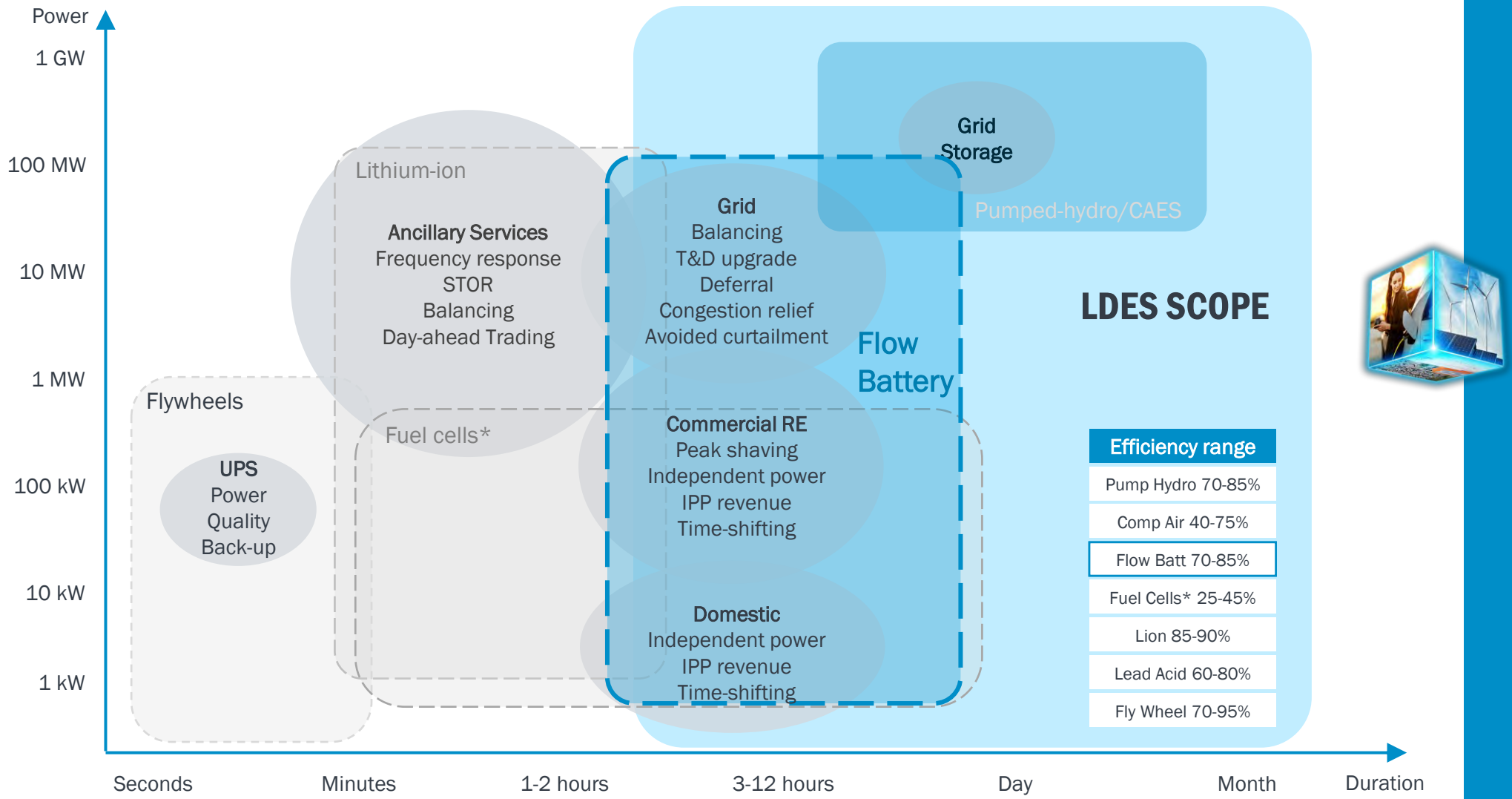


Long duration energy storage Flow Batteries solves issues that today's Li-Ion batteries cannot address



*Note: *Fuel cells fuelled by hydrogen*

Major technology providers by technology type

Thermal

Member	Sub-Archetype
Azelio, 1414 Degrees, TORC, MGA Thermal	Latent heat (solid-liquid)
Brenmiller, Echogen, Energynest, Kraft Block, Magaldi, Storworks, Electrified Thermal Solutions, Antora, Rondo	Sensible heat (solids)
Kyoto, Malta	Sensible heat (solids / liquids)
SaltX	Thermochemical (salt)

Electrochemical

Member	Sub-Archetype
redflow	Hybrid flow battery (ZnBr)
eos	Aqueous Zinc Halide
cellcube, Invinity	Aqueous (VRFB)
Enlighten	Aqueous (NaSICON membrane)
Ambri	Metal anode (Calcium)
	Metal anode (Nickel Hydrogen)
ESS Inc	Metal anode (iron flow battery)
e-zinc	Metal anode (Zn)
Form Energy	Metal anode (iron air battery)
Volt Storage	Metal anode (Iron salt)

Mechanical

Member	Sub-Archetype
Breeze	
Hydrostor, Siemens Energy	CAES
Rheenergise, Mine Storage	Gravity-based PS
Energy Vault	Gravity-based
Energy Dome	Liquified CO_2
Rye Development	Closed loop PHS and run of river
Pumped Hydro Storage, Quidnet Energy	PHS

Chemical

Member	Sub-Archetype
Ceres	Solid oxide fuel cell

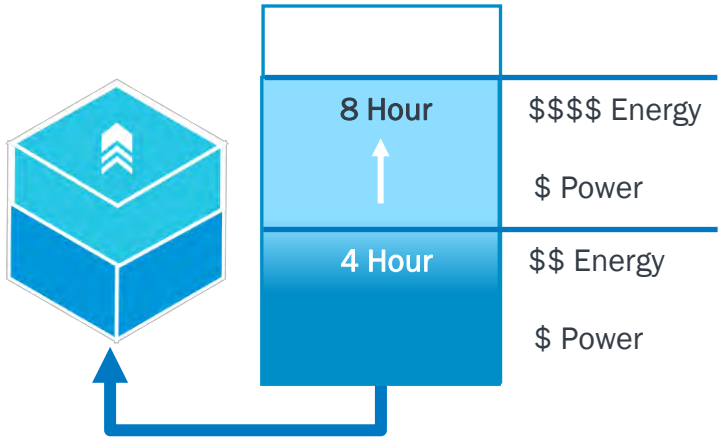
Long-duration flow batteries can be located anywhere and offers best-in-class duration at lower cost

Performance
Weakest — Best

Technology	Technology	Companies	Long duration	LCOS	Geographical limits	Scalability	Cycle life
Electrochemical	▪ Long duration flow batteries	cellcube BUILDING ENERGY STORAGE INFRASTRUCTURE; ESS INC; INVINITY ENERGY SYSTEMS	●	●	●	●	●
Electrochemical	▪ Lithium Ion	CATL; TESLA; Panasonic	◔	●	◑	◔	◔
Flywheel	▪ Flywheel	PILLER; AMBER KINETICS; Beacon POWER	○	◔	◕	◑	◑
Thermal	▪ Heat ▪ Thermo-chemical heat	OVVIO; harvest thermal; ratiotherm Smart Energy Systems	◔	◔	◕	◔	◔
Power to gas	▪ Hydrogen ▪ Syngas	Enapter; ITM POWER	●	○	◑	●	◑
Mechanical	▪ Pumped Hydro ▪ Gravity ▪ Compressed air	ENERGY VAULT; RENO ENERGY CONSULTING SERVICES; gravitricity	●	◔		◕	◕

Flow batteries have fundamentally lower cost structure at long duration

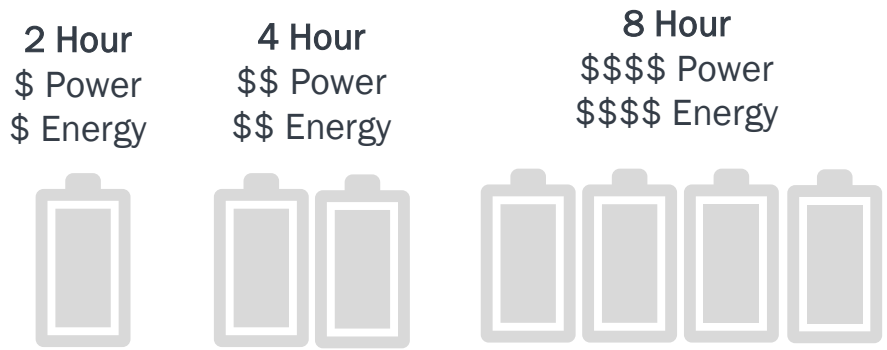
VRFB scalable architecture



Scalable System

- Power and energy are independent – so longer duration becomes increasingly economically advantaged
- Duration increased by adding electrolyte
- No additional power components needed

Li-ion closed architecture

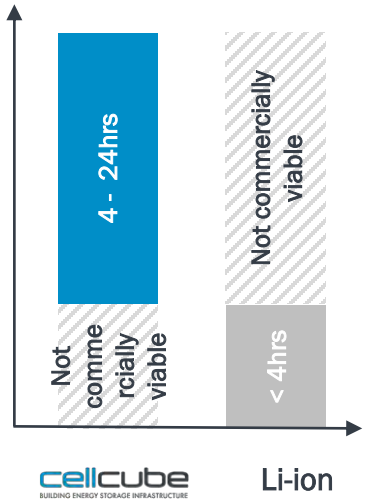


Limited scalability

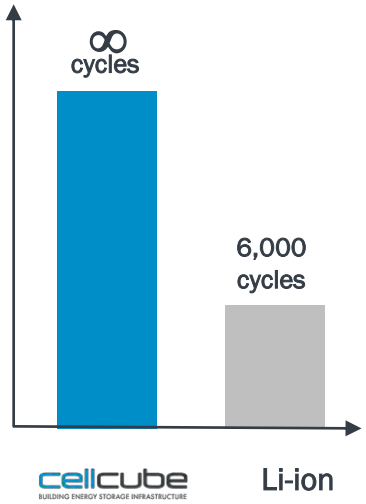
- Power and energy are dependent – longer duration costs are relatively high
- Duration increased by adding power and energy
- Power is added to achieve longer duration

Vanadium Redox Flow Batteries outperforms lithium-ion for long duration storage

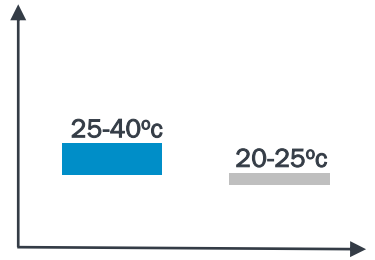
Operational feasibility



Raw material (Vanadium vs Lithium)



Optimum cell internal operating temperature

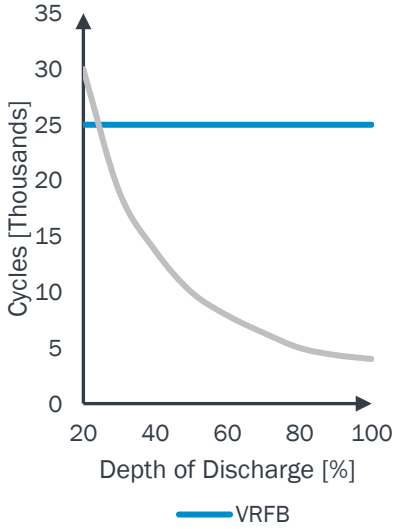


CellCube can utilise its high heat capacity and temperature level to cool without the need for a compressor support system

cellcube Li-ion

Safety

Longer asset life

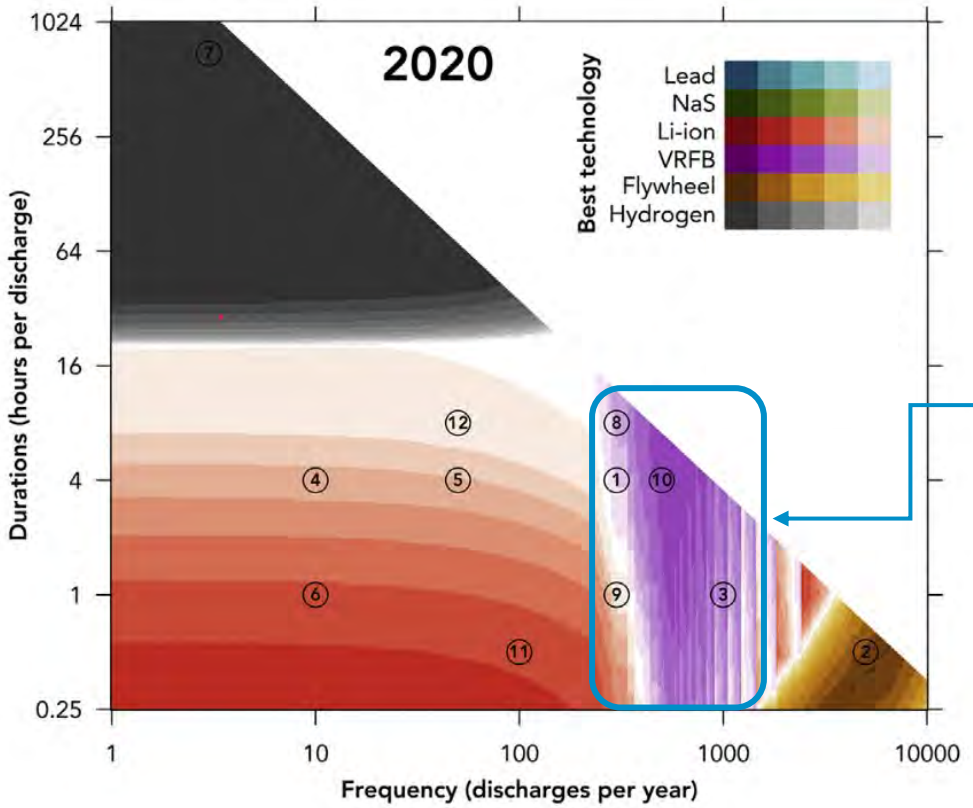


Outstanding performance

CellCube's vanadium flow technology is an ideal electricity storage system designed for continuous operation. Since lithium advantages are offset by many risks and disadvantages in the field of stationary storage systems, VRFB often presents the best option.

Vanadium Redox Flow Batteries is the most competitive option for frequent cycle and long duration applications

Best storage technologies depending on duration and frequency cycle



Use cases for VRFB

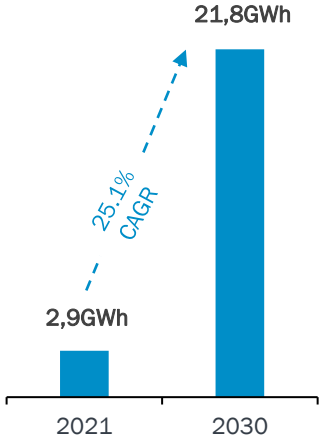
1 Energy Arbitrage
2 Primary response
3 Secondary Response
4 Tertiary response
5 Peaker replacement
6 Black start
7 Seasonal storage
8 T&D Investment Deferral
9 Congestion Management
10 Bill management
11 Power quality
12 Power reliability

Source: Schmidt, O., Melchior, S., Hawkes, A., Staffell, I., 2019. Projecting the Future Levelized Cost of Electricity Storage Technologies. Joule 3, 81–100

Flow battery storage addresses several high-growth segments

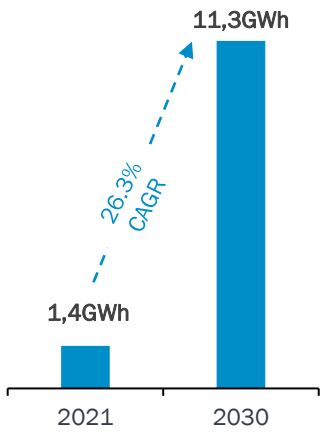
Capacity & reserves

- Enables the grid to support generation capacity requirements
- Help operators meet hour-to-hour variations in electricity supply and demand



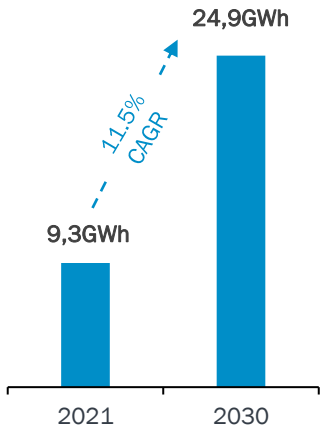
T&D asset optimization

- Ensures that lines, substations and other equipment have enough bandwidth to handle peak demand
- Enables utilities and operators to manage shifting peak demand periods



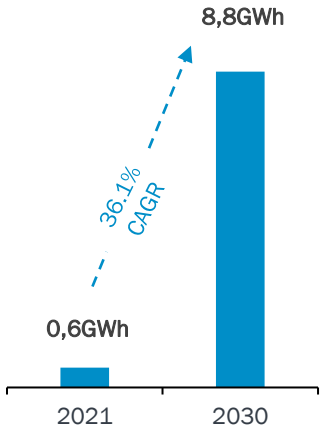
Energy shifting

- Allows for the alignment of renewable generated electricity supply and consumer demand enabling energy to be shifted from off-peak to peak demand periods



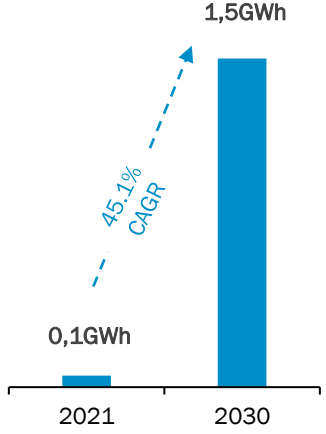
Commercial

- A commercial energy storage will allow you to expand security for most critical power loads. Other than cost-saving, it can serve as an emergency backup system.



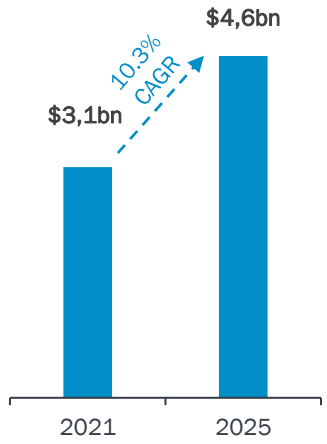
Electric Vehicles

- Distributed storage for EV charging provides very reliable electrical service in the grid. Also, batteries smooth the demand, thus reducing the utilities' overall cost-of-service.



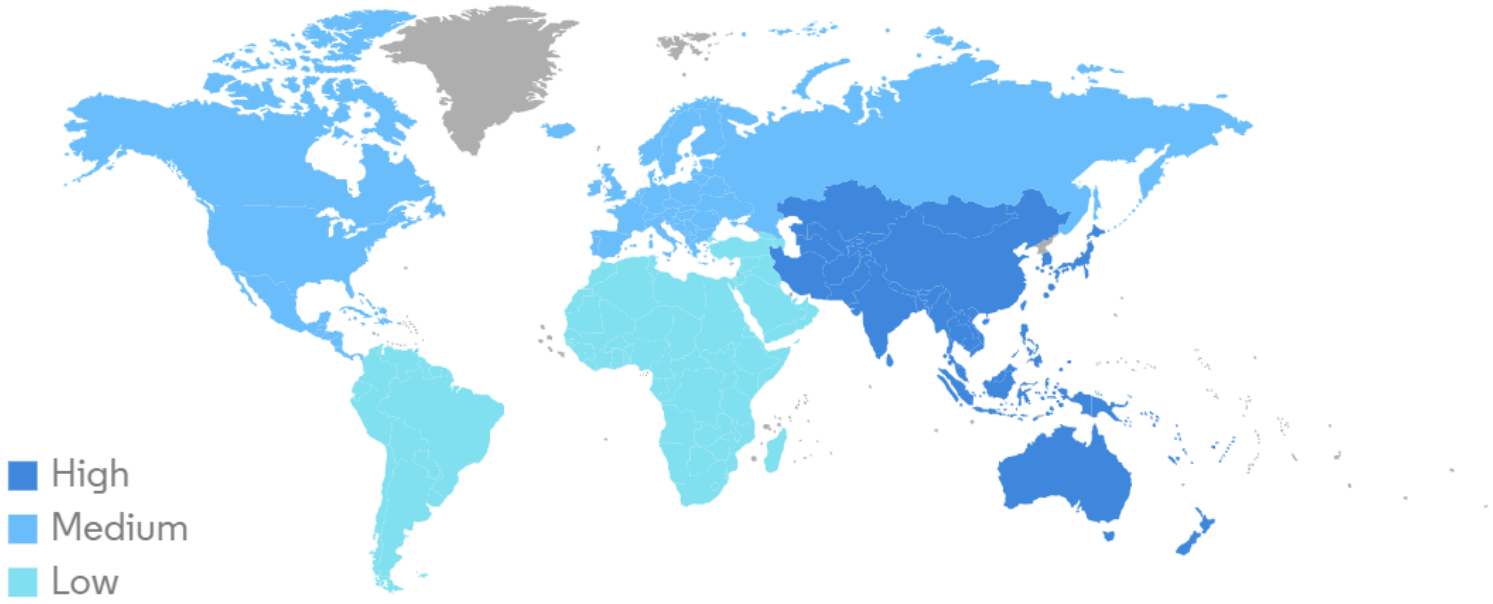
Critical infrastructure

- Critical infrastructure (military, data centres, hospitals etc..) must be protected against all possible power failures, flow batteries are the perfect power back-up to protect the infrastructure and data



Source: BNEF, research and markets 2021, 1. The global modular uninterruptible power supply (UPS) market

Flow Battery Market – Growth Rate by Region



Source: Mordor Intelligence

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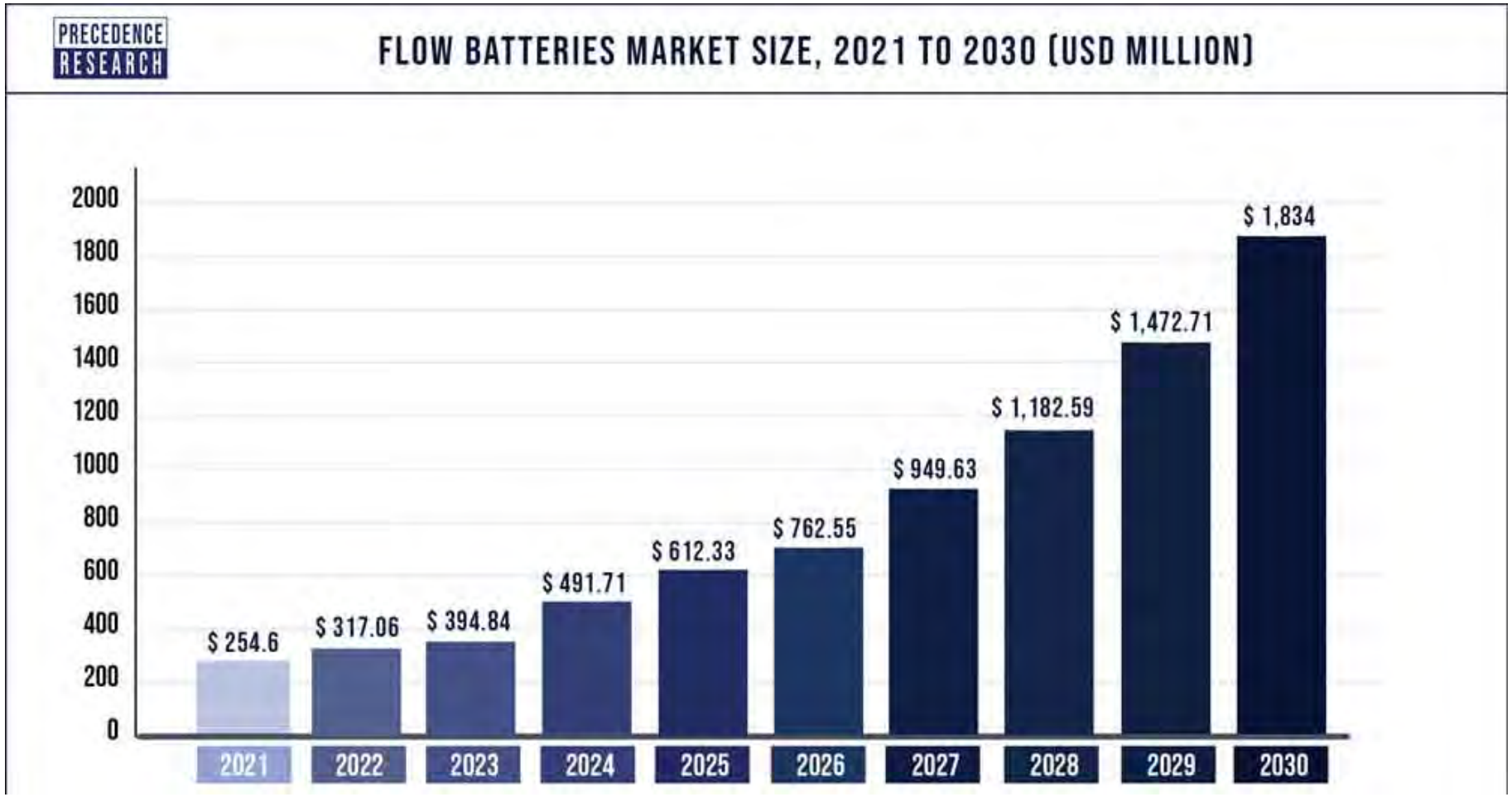
Flow Batteries Market Size 2021 to 2023



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APAC Focus

214.3 USD MILLION 2021-e

489.6 USD MILLION 2026-p

CAGR 18.0%

The global flow battery market is expected to be worth USD 489.6 million by 2026, registering a CAGR of 18.0% during the forecast period

The increasing demand for efficient energy is driving the growth of the flow battery market in APAC

The expanding industrial sector in various countries of APAC is fueling the growth of the commercial & industrial application segment

Partnerships and product launches and developments to offer lucrative opportunities for market players in the next 5 years

The flow battery market in China is expected to register a CAGR of 28.1% during the forecast period

Asia Pacific to exhibit the highest growth rate of 19.6% during the forecast period

APAC

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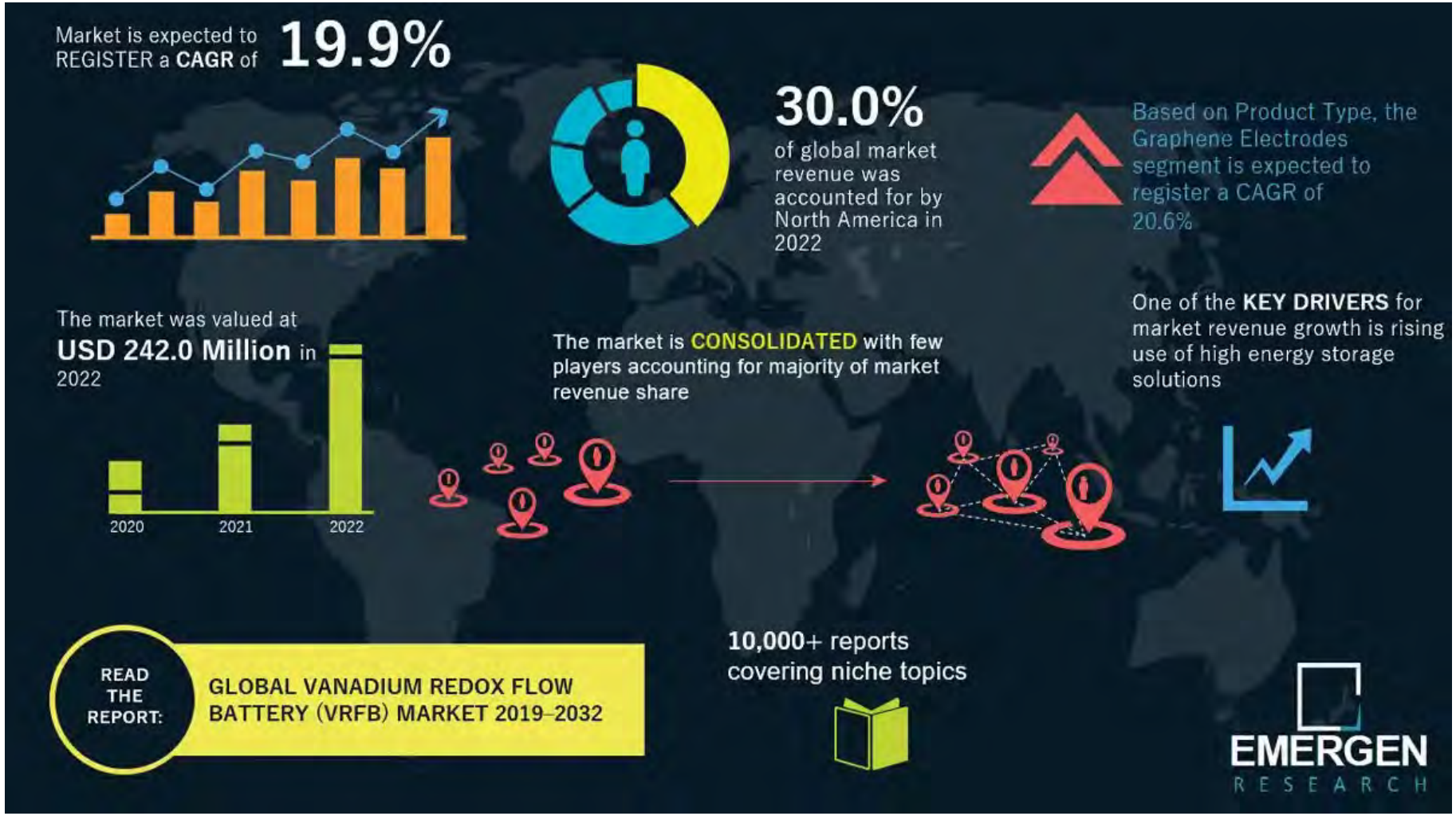
Global Focus



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Thank you!

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