Energy Storage

Matt Harper, Co-Founder and Chief Commercial Officer
Carleton Sustainable Energy Seminar Series
March 22nd 2021

Agenda

- The case for energy storage
- A view of the storage landscape
- Invinity and our products
- Reflections

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The Case for Energy Storage

Humanity's Resources

	Water	Liquid Fuels	Electricity
In Time →			?
…and in Space →			

Clockwise from top left: © 2010 Daily Mail; © 2007 Emanuele / Wikimedia Commons; Author; CC / No Attribution.

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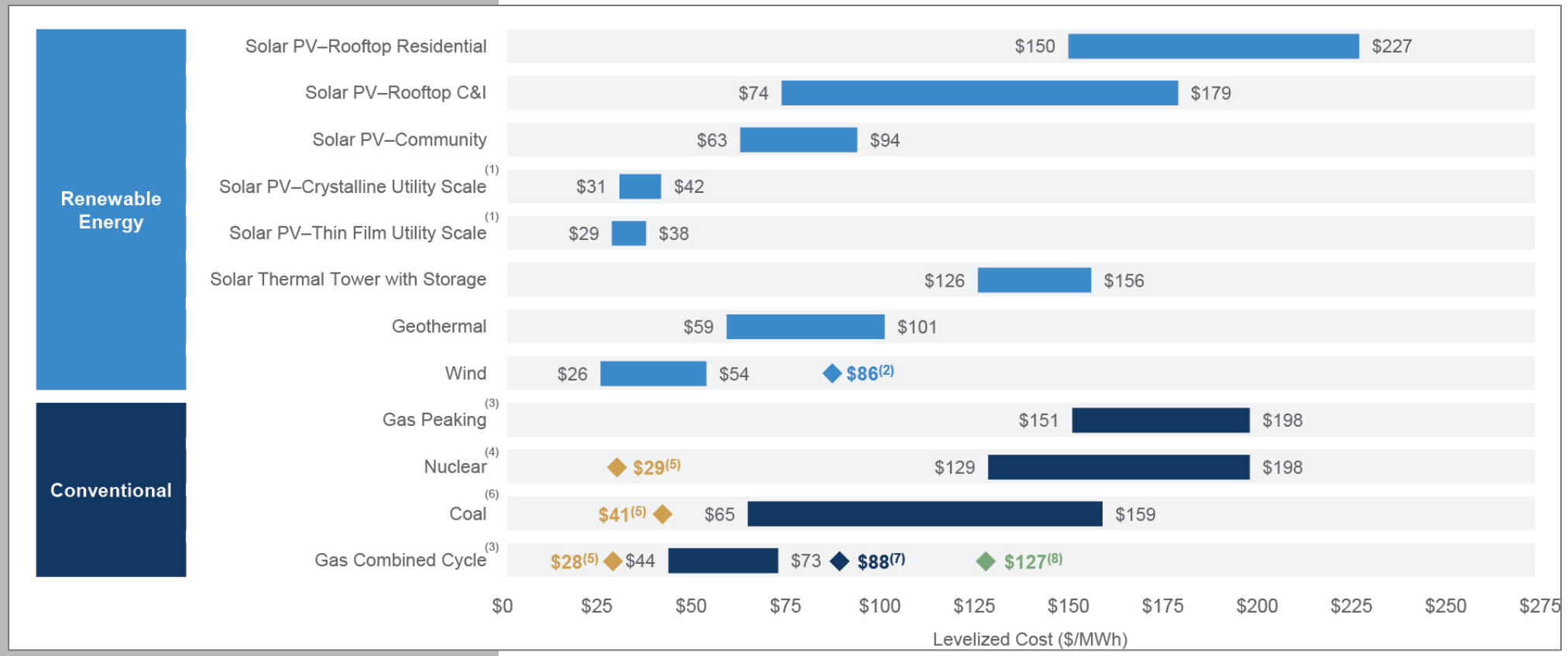
What's Driving Renewables?

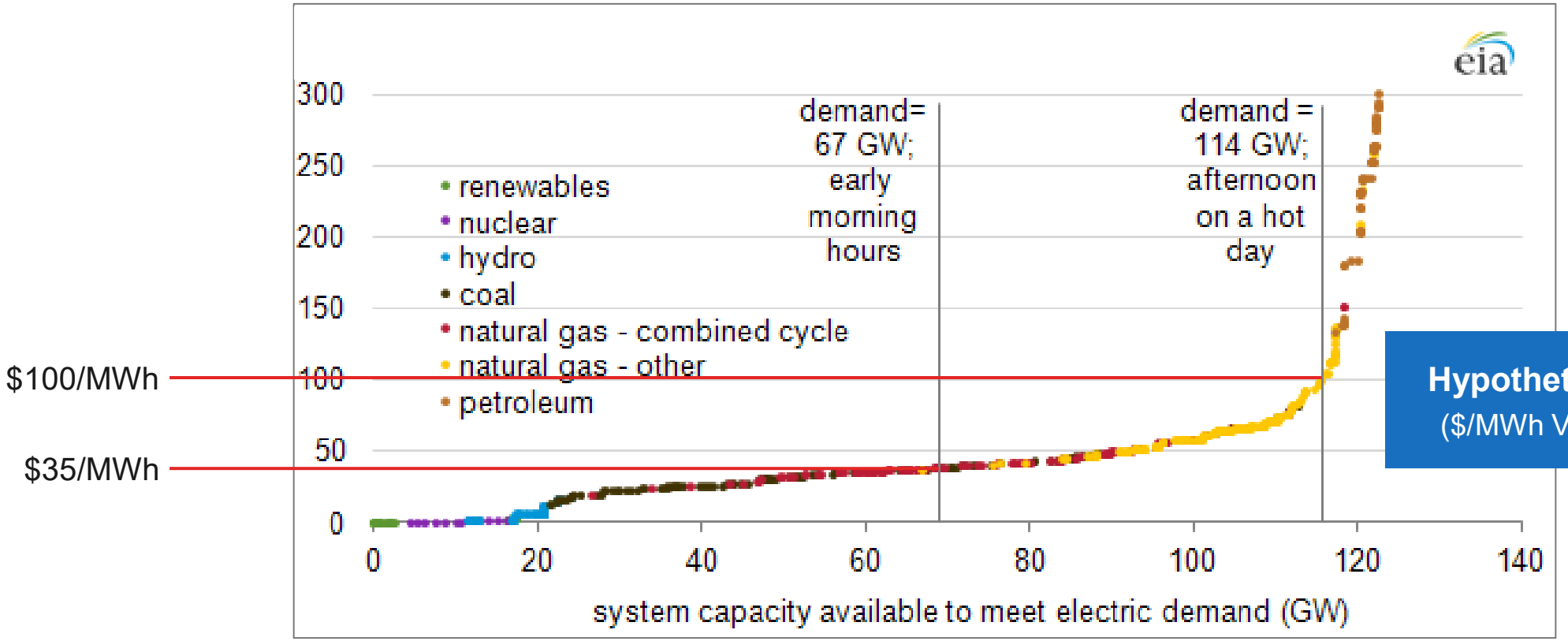
Low levelized costs = rapidly expanding market share



Source: Lazard LCOE 2020. https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/

Why Intermittency Matters

Variable low marginal cost resources = price fluctuations.



Hypothetical Dispatch Curve
($/MWh Variable Operating Cost)

Source: US EIA https://www.eia.gov/todayinenergy/detail.php?id=7590

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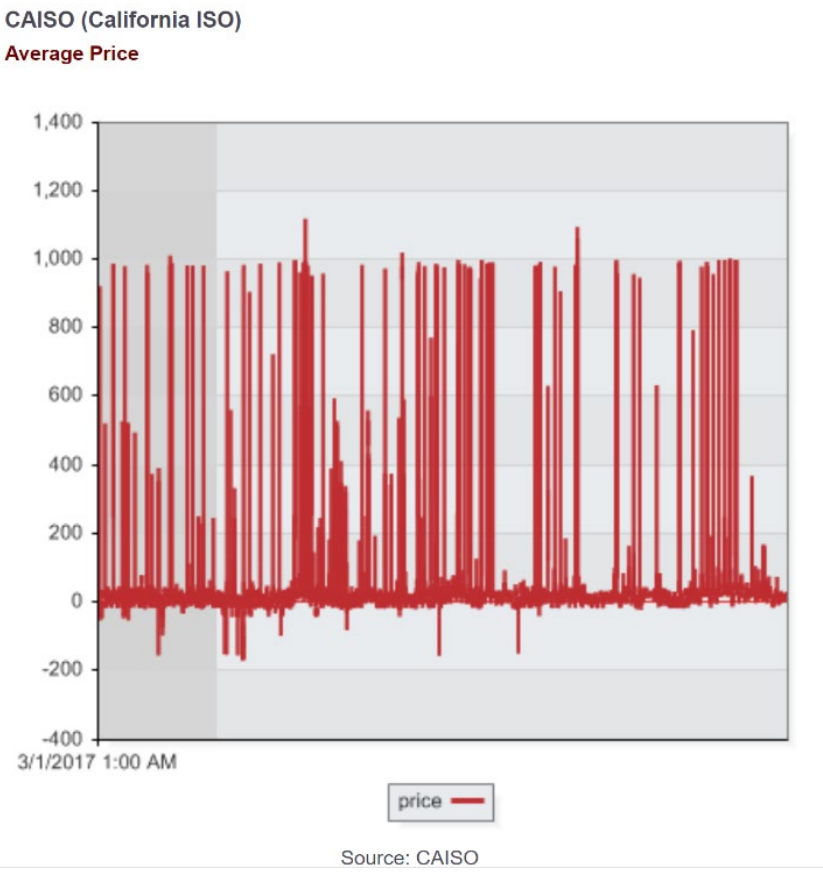
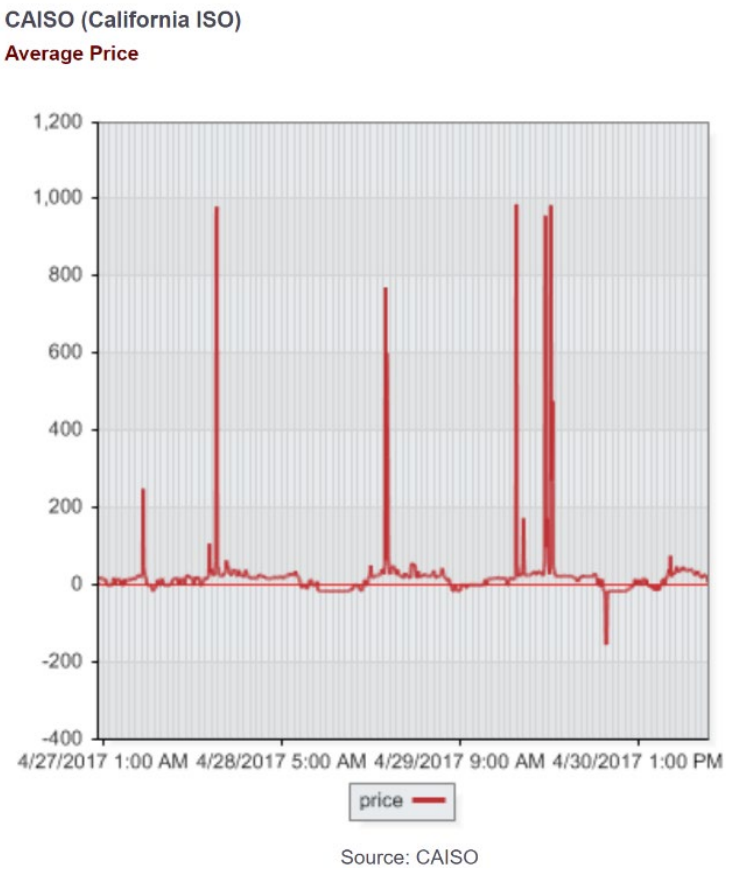
Markets Subject to Intermittency



Source: CAISO



Source: CAISO

← Prices at 50x average

← Negative prices

Source: LCG Consulting / EnergyOnline

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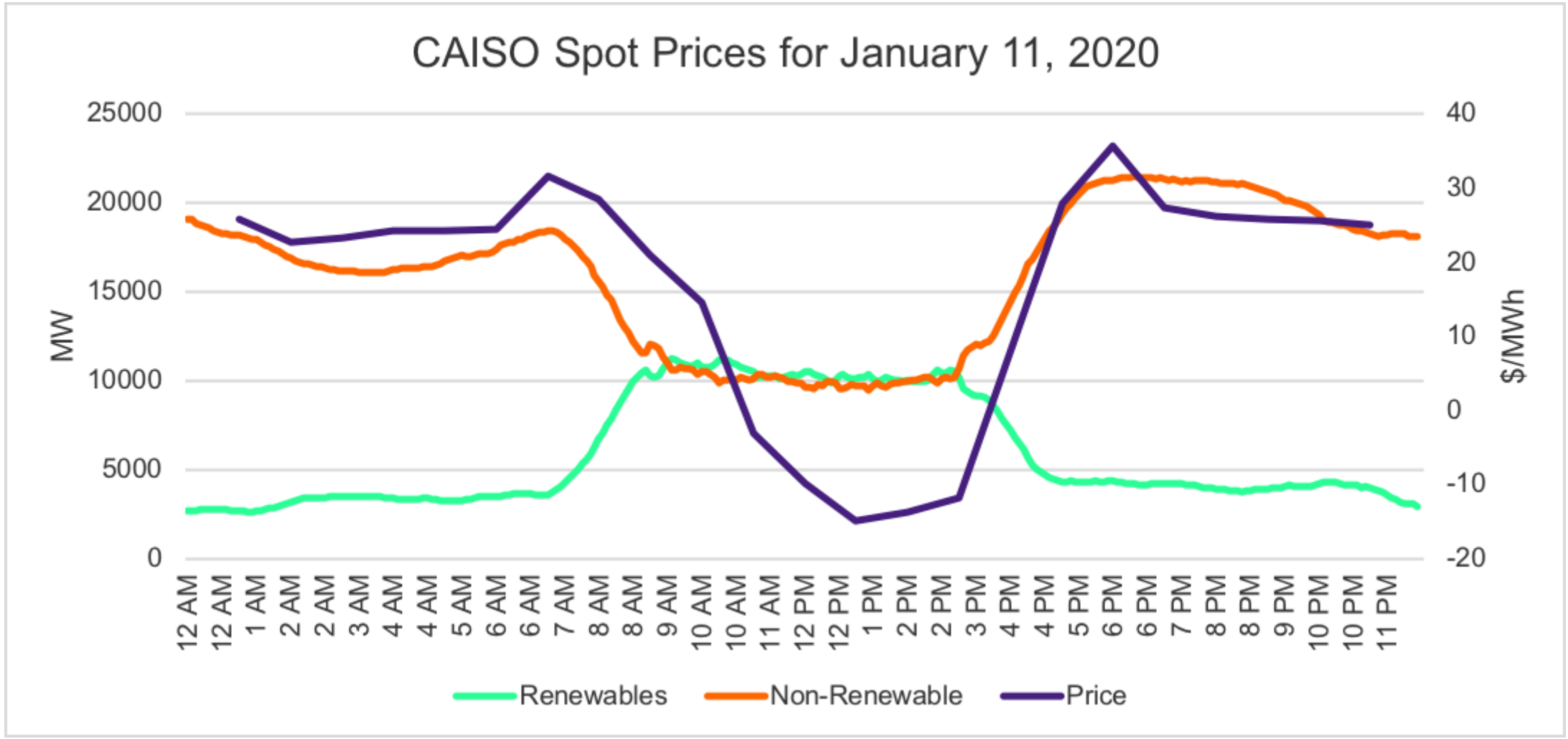
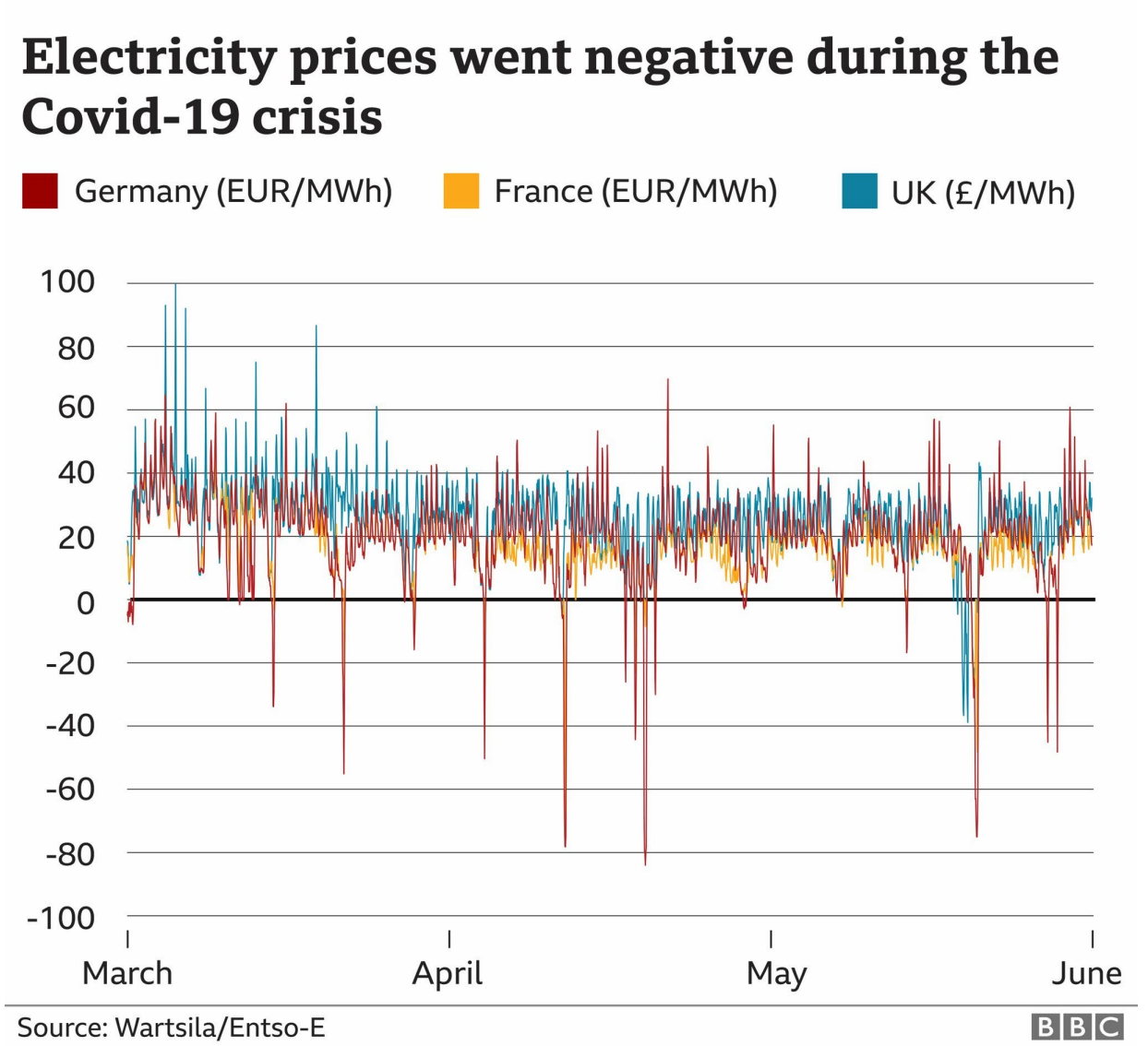
Negative Pricing: California



Reference: https://www.enelx.com/n-a/en/stories/energy-efficiency-management/why-electricity-prices-oil-prices-sometimes-go-negative

Negative Pricing: Europe



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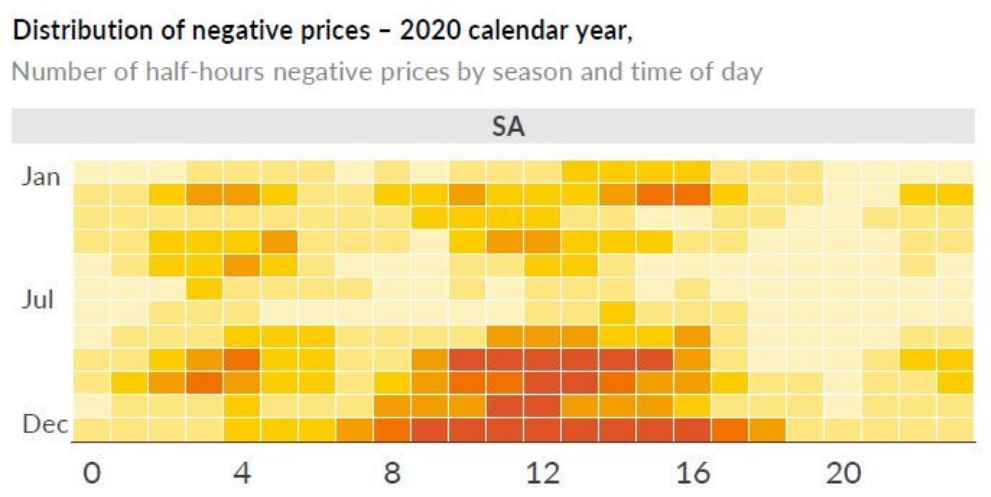
Negative Pricing: Australia

…and where storage can help!



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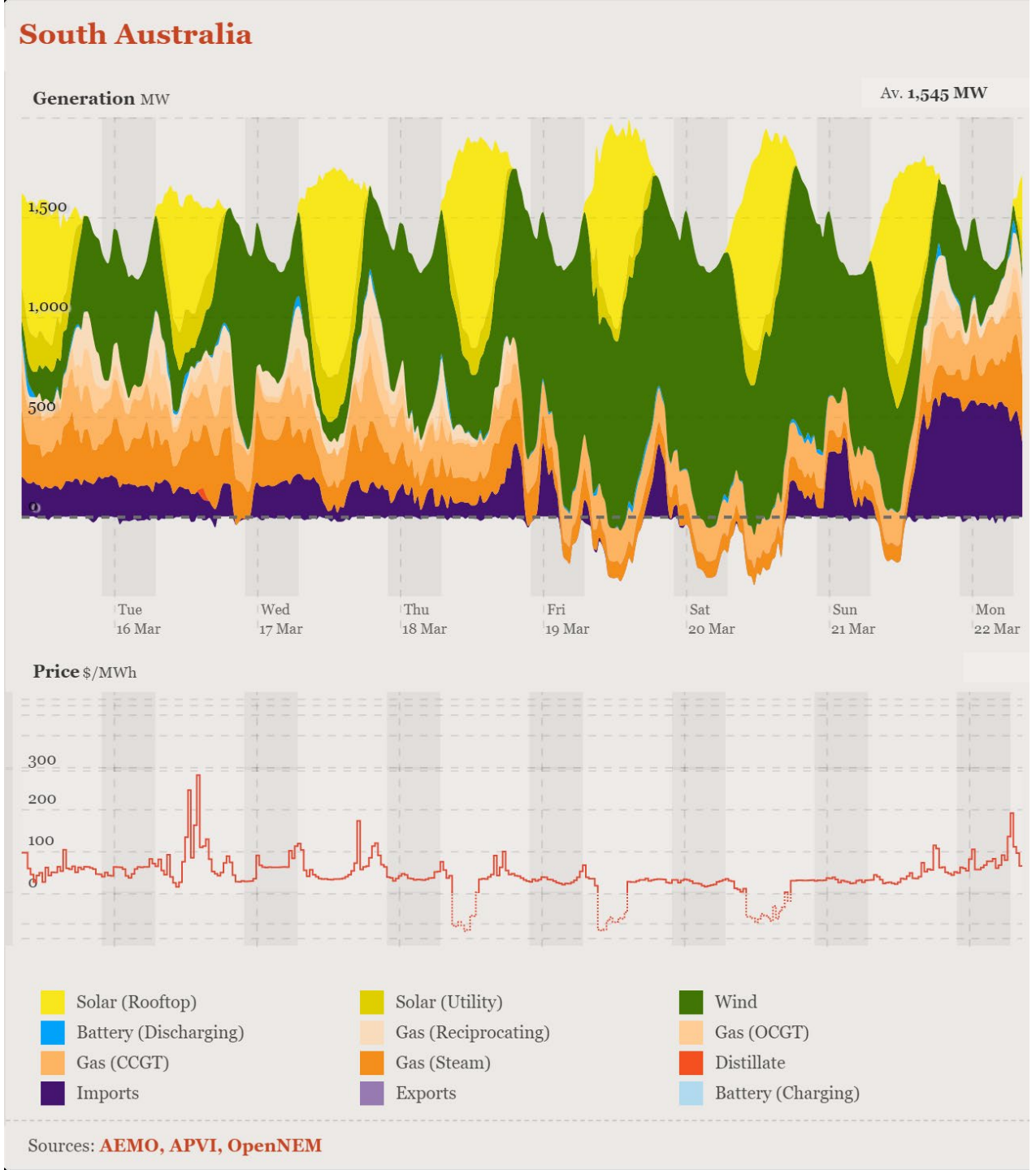
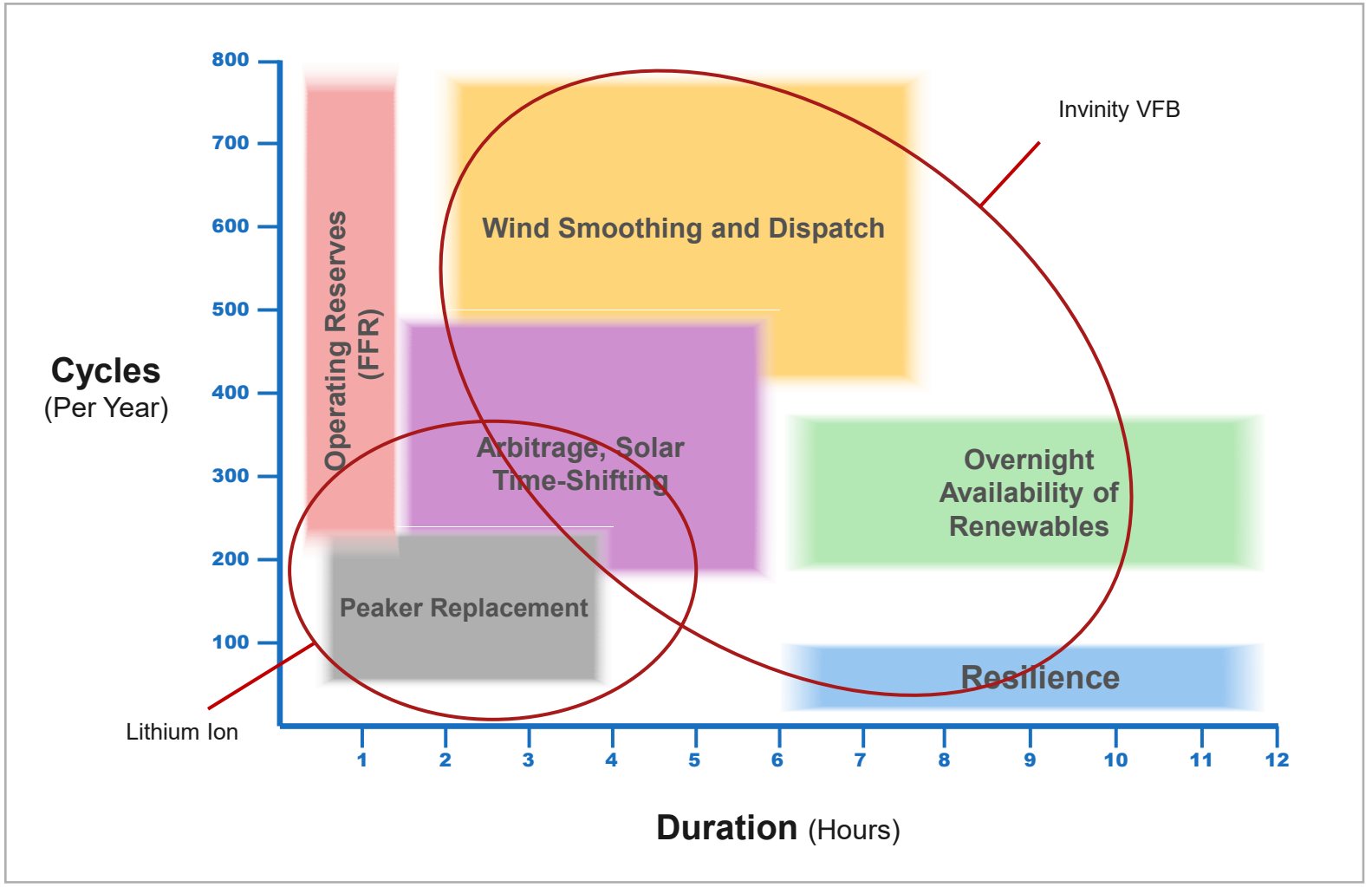


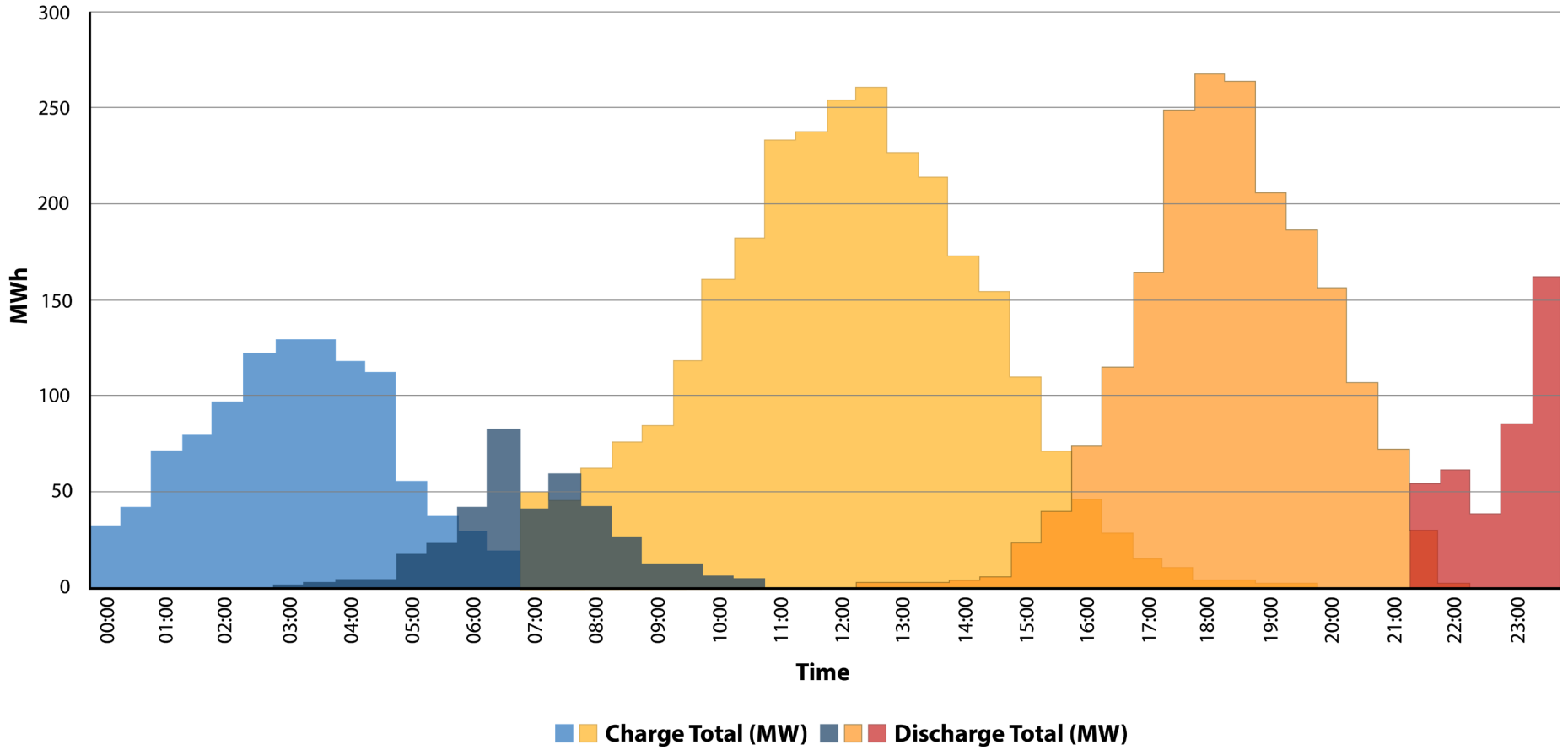
The Storage Landscape

Use Case: Invinity versus Lithium



‘Stacking’ Cycles for Maximum Benefit

- Gird-connected solar-plus-storage: 2+ cycles per day, 24/7 battery utilization
  - Cycle 1: Charge from low-cost excess solar during day. Discharge into evening peak
  - Cycle 2: Charge from low-cost overnight power. Discharge into morning peak
  - Cycle 2+ Performing ancillary services



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Vanadium flow batteries

Lithium vs Vanadium Flow

Both are excellent, products - but they do different jobs.

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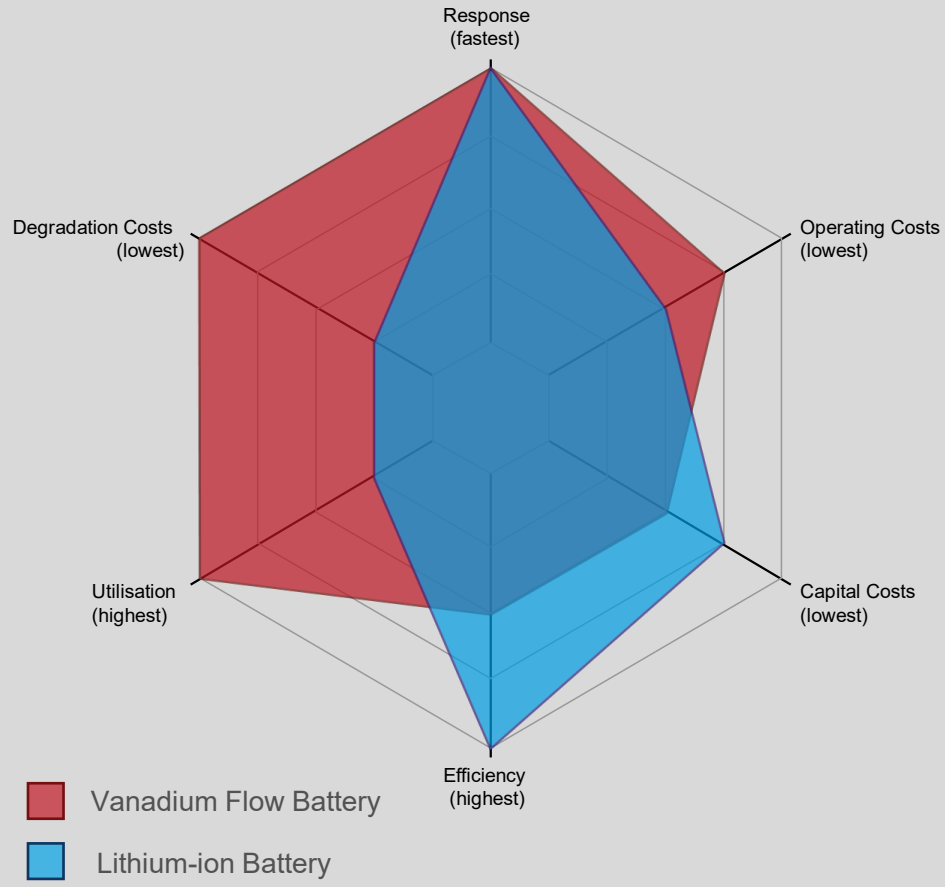
Vanadium Flow Advantages

- **No Degradation** – Does not degrade with cycle life
- **High Utilization** – Multiple cycles per day at 100% DoD
- **Compelling Economics** – Lower total cost of ownership
- **Fast Response** – sub-second response times
- **Sustainable Materials** – Readily sourced, easily recyclable
- **Factory Built** – Low cost, repeatable quality

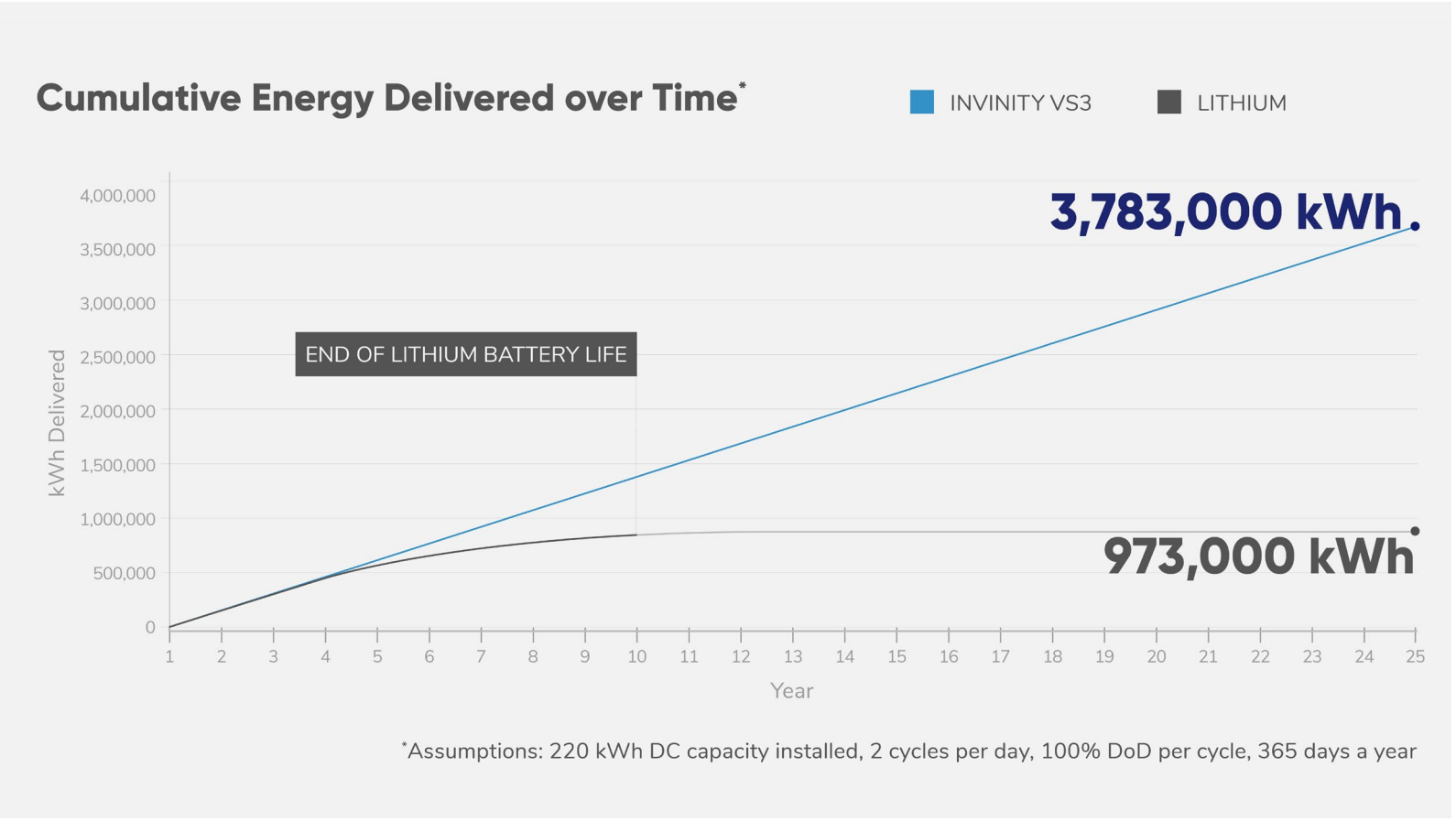
Flow vs Li-ion



The Result – Significant advantages over lithium for serving the electric grid

High Throughput: 20+ Year Lifetime With No Limit on Cycles

Key Differentiator: Low Cost—Low Degradation in Heavy-Use Applications



Ultra low capacity degradation allows for more energy throughput and higher value

- True liquid-liquid flow battery chemistry without electrode plating reactions
- Stable, low-emission electrolyte

Effective measures are in place to prevent downtimes and faster degradation

- BMS with proprietary state of health (SOH) metrics predict service needs before downtime
- Proprietary specs and 100% factory built and tested product ensure highest quality control

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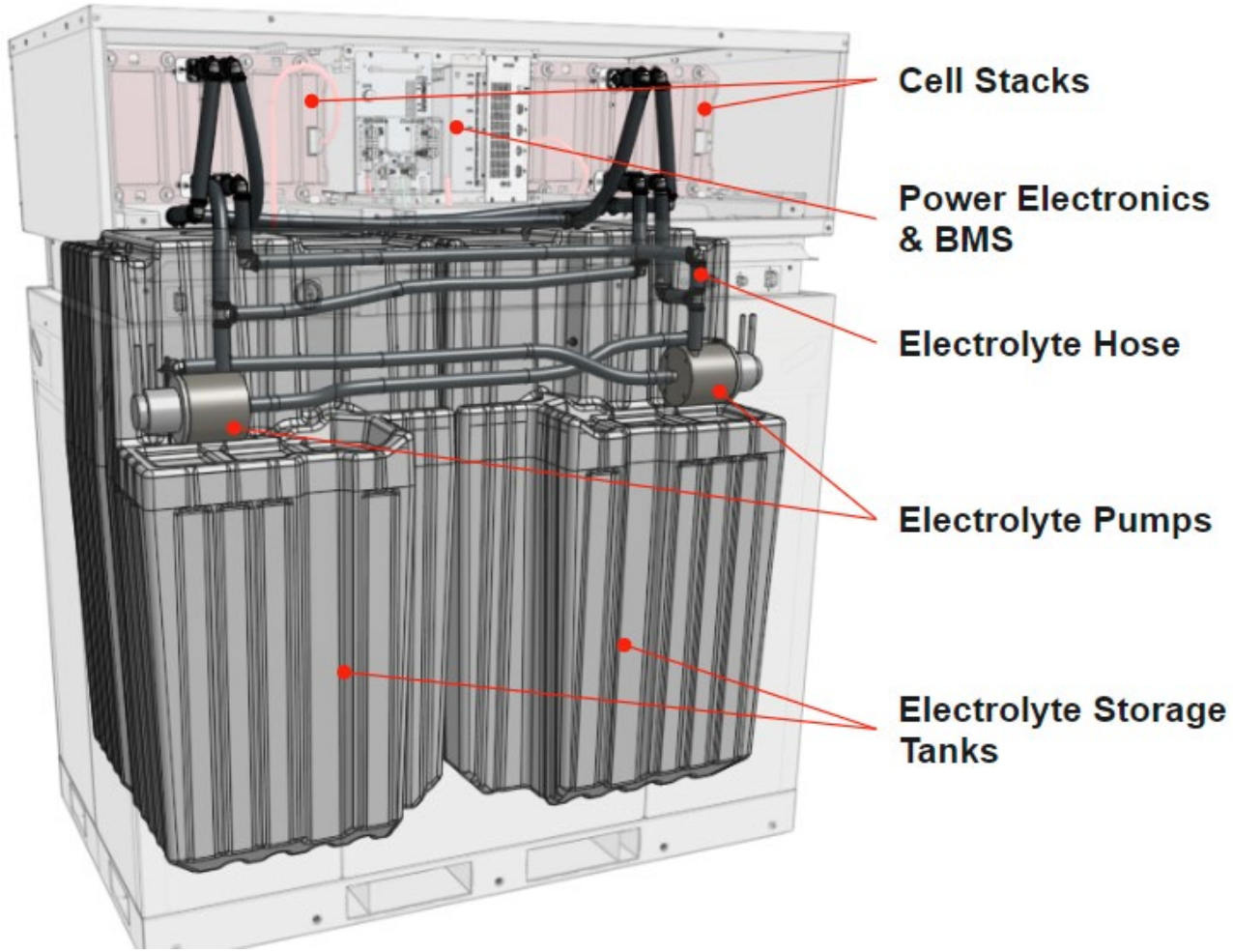
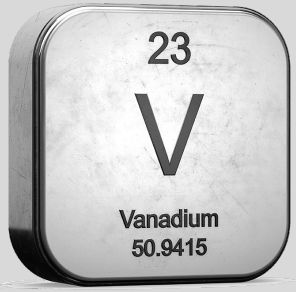
Inside Vanadium Flow

Durable • Reliable • Economical • Proven



Vanadium



- **Available –** Element 23, readily available and more abundant in the Earth's crust than copper. Accessible reserves in Australia, South Africa, United States, Canada, Russia.
- **Reusable –** Virtually unlimited working life. 97% proven recovery rate from used electrolyte.
- **Safe –** Electrolyte is ~70% water, non-flammable with no risk of thermal runaway

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About Invinity

The renewable shift will stall without energy storage.

Lithium will not meet all future energy storage needs.

Invinity delivers the flow battery alternative.

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Established 2020 (AIM:IES)

Merger of redT energy and Avalon Battery

14 Years of R&D Investment

Over £40 million spent on development to date

102 Employees

We believe to be the most experienced team in flow batteries

50 Projects

Over 25 MWh installed or signed on five continents

73 Patents

Granted or pending, plus trade secrets and know how

Worldwide Presence

Canada (technology, NA hub), UK (technology, sales), US (sales), China (manufacturing)

Invinity's Global Operations

Vancouver, Canada
- Design & Manufacturing

Bay Area, USA
- Sales & Support

Johannesburg, SA
- Sales & Support

Bathgate, UK
- Design & Manufacturing

London, UK
- Sales & IR

Suzhou, China
- Manufacturing

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Invinity's VFB Product

Invinity VS3

	Battery	Project
Rated Power, Continuous:	**78 kW**	**Up to 10 MW**
Energy Storage, Nominal:	**220 kWh**	**Up to 24 MWh**
Energy Storage, Duration:	**2 – 12 hours**	
Form Factor:	**20' container size, handling**	
Lifetime:	**25 years**	
Recommended depth of Discharge:	**100%**	
Cycle Life:	**Unlimited**	

Rather than typical flow battery custom production, Invinity's flow batteries are mass produced in a dedicated factory.

VS3 Modules for Energy Superhub Oxford in production at Invinity's dedicated facility in Suzhou, China

Invinity's Customers

Grid Services Providers

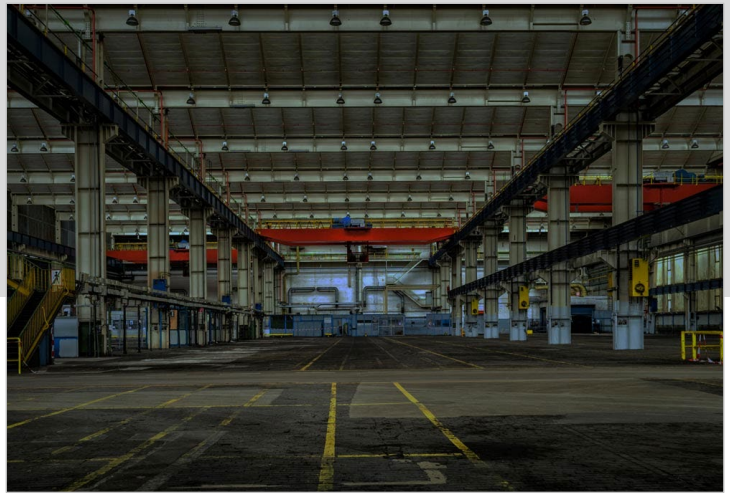
- T&D cost deferral/avoidance
- Balancing & ancillary services
- Wholesale market trading

Commercial and Industrial

- Energy cost reduction
- Carbon reduction
- Improved resiliency

Off-Grid

- Secure 24/7 renewable power
- Fuel cost reduction
- Carbon emissions reduction



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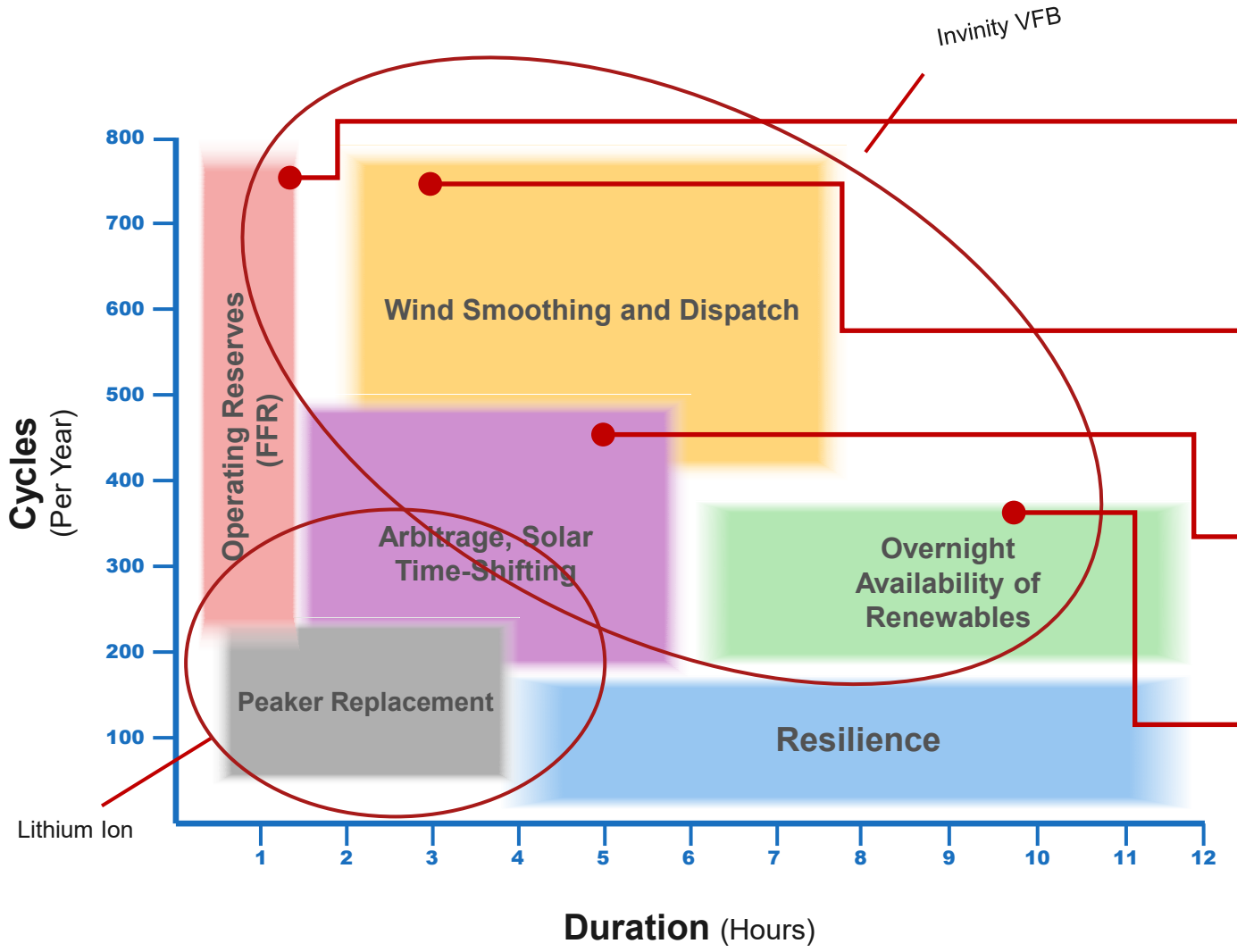
Flow Battery Use Cases



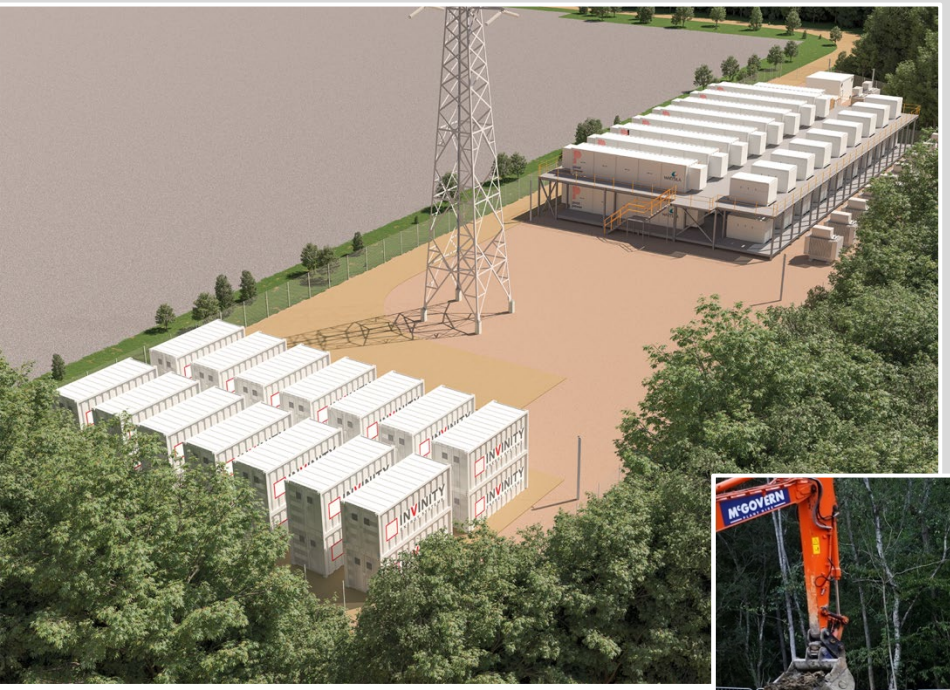
Energy Superhub Oxford
- Heavy cycling grid services

European Marine Energy Ctr.
- Tidal + hydrogen electrolyser

Yadlamalka Energy
- Dispatchable solar + storage

Soboba Fire Station
- Infrastructure resiliency

Energy Superhub Oxford



Invinity Is Providing UK's largest flow battery

- Supporting Oxford's decarbonization
- 2 MW / 5 MWh flow battery system
- Flow batteries provide heavy cycling capability
- Order to be fulfilled with 27 Invinity VS3 batteries
- Construction / manufacturing currently underway
- **First modules shipped – completion first half 2021**

Energy Superhub Oxford

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OXFORD CITY COUNCIL

UNIVERSITY OF OXFORD

HABITAT ENERGY

pivot power

EDF renewables

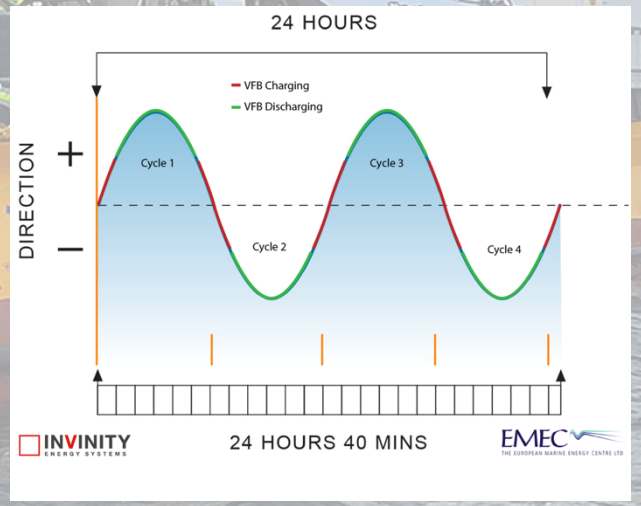
Kensa Contracting

European Marine Energy Centre

Invinity To Deliver 1.8 MWh Battery System

- Announced November 9th 2020
- Tidal power → Invinity energy storage → Hydrogen electrolyser
- To be installed at EMEC in Orkney, Scotland
- Eight Invinity VS3s
- **Delivery 1st half 2021**

Cutaway rendering of installation.



"Hydrogen and systems integration with renewables will be a key part of our energy transition pathways"

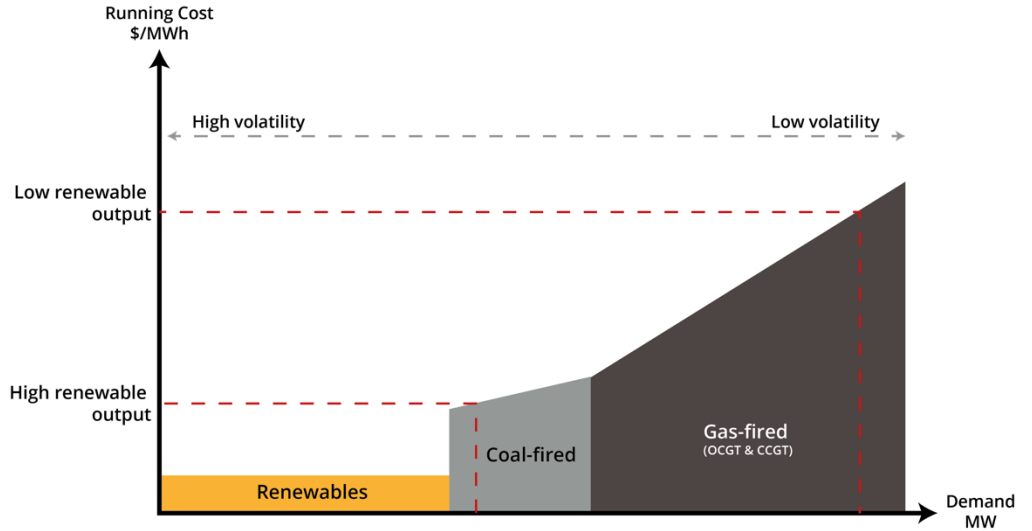
- Paul Wheelhouse, Scottish Energy Minister

Yadlamalka Solar + Storage

World's Largest Solar-Powered Vanadium Flow Battery

- 8 MWh Invinity Battery System + 6 MWp Solar PV
- Manufacturing starting H1 2021
- 41 Invinity VS3s
- Australia's largest flow battery
- **Delivery H2 2021**

Dispatchable Solar to Displace Thermal Generation



Soboba Fire Station

California Energy Commission-Funded Project

- Delivering clean power to critical infrastructure
- 0.5 MWh flow battery system integrated with onsite solar PV
- 10-hours storage duration, supplying resiliency in a region heavily affected by wildfires
- **Project to go live in 2021**

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Reflections

The Invinity Journey

VRB Power delivers 2 MWh flow battery to Pacificorp, Utah, USA

VRB Power deploys flow battery fleet to Kenyan telecoms

Prudent delivers 3.6 MWh flow battery at Oxnard, USA

First AFB2 delivered Pomona, USA

First AFB1 delivered Fremont, USA

LADWP: 1 MWh Los Angeles, USA

Ideal Energy: 1 MWh Iowa, USA

SPIC: 2 MWh Qinghai, China

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

VRB Power acquires Regenesys technology from RWE

MH @ VFB

Prudent Energy's VRB Power acquisition

Avalon Founded

Avalon foundational patents filed

Avalon first generation delivered

Avalon second generation delivered

Avalon and redT merge to form Invinity.

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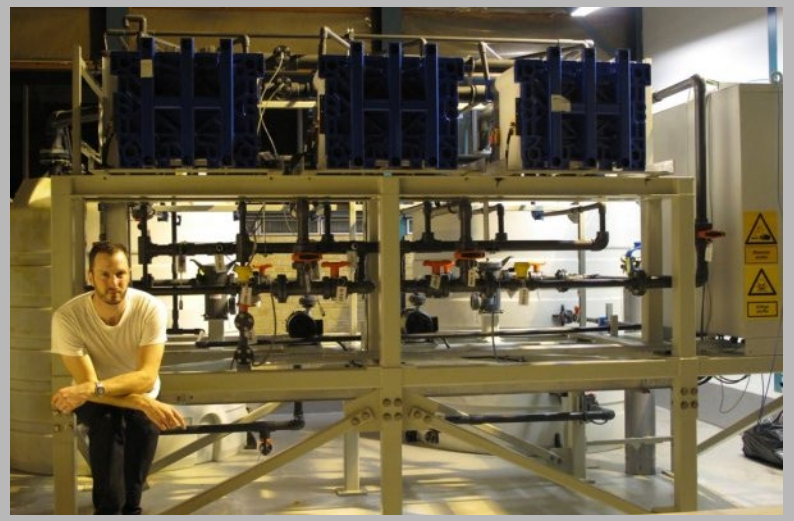
Reflections



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A brief twenty-five year journey…

- Cleantech is a long road
- It's all about the people
- Market and commercial innovation is as important as technology.
- Canada is a great place for innovation, but we can be great for commercialization too.

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