



“A next-generation smart grid without energy storage is like a computer without a hard drive: severely limited.”

- Katie Fehrenbacher, gigaom.com

Energy Storage
The Future Starts Now!



CREAMER MEDIA'S ENGINEERING NEWS

INSIGHT Net jobs gain... despite fall in coal jobs *Page 9*

NEWS FOCUS Study outlines... of a fully local government fleet *Page 23*

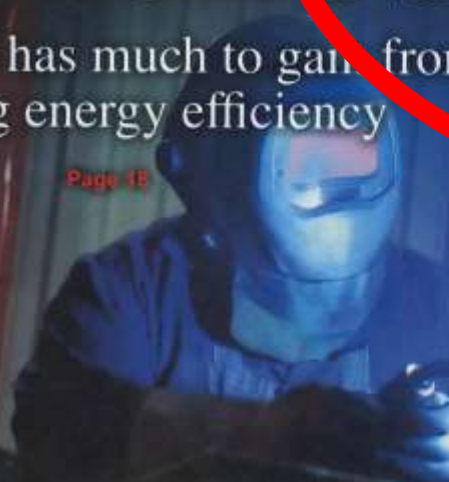
FEATURES Energy Efficiency & Management *Page 42*

& Bushes *Page 50*

EFFICIENCY STIMULUS

SA lags, but has much to gain from
boosting energy efficiency

Page 48



OPINION & ANALYSIS

ELECTRICALLY SPEAKING

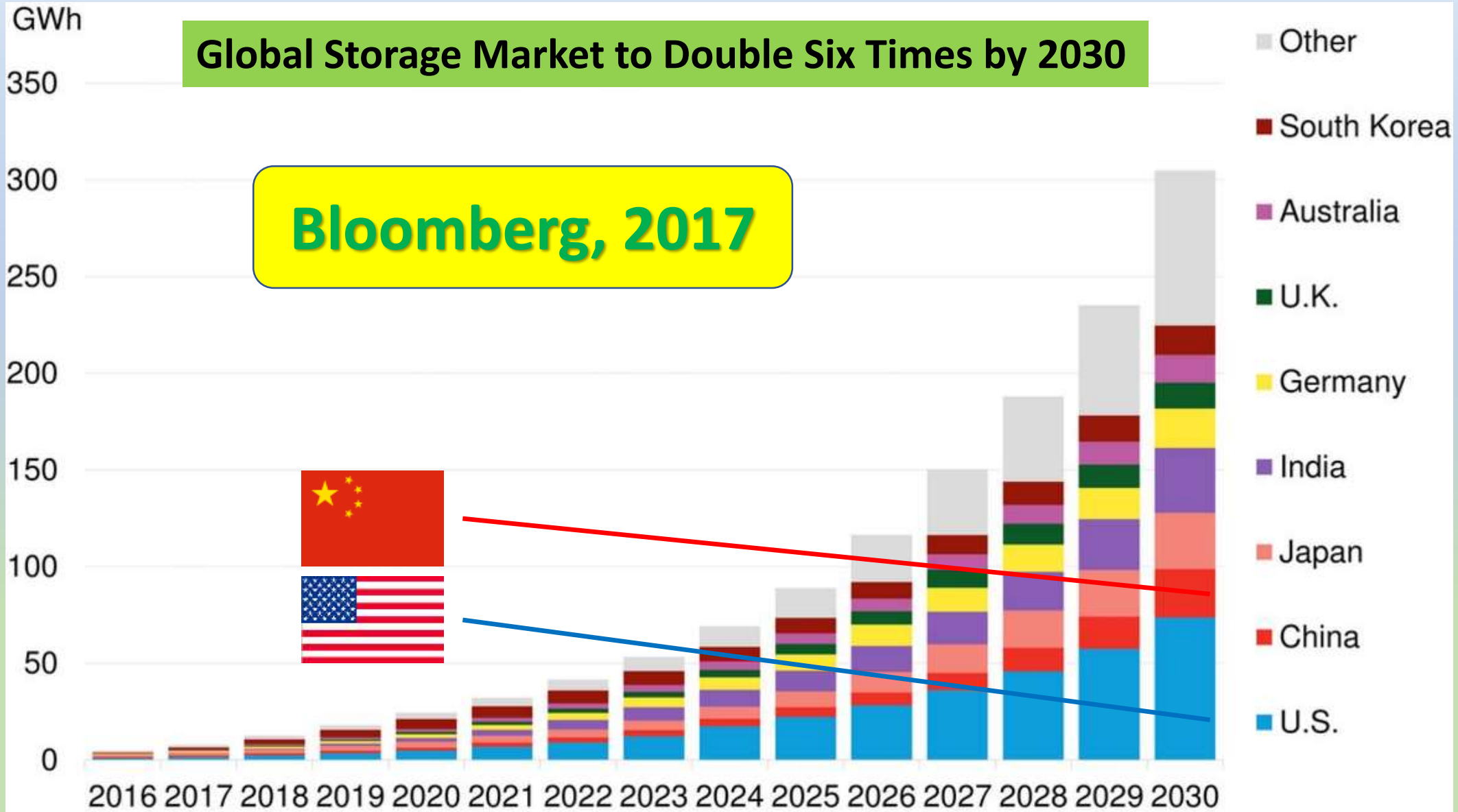
My Mini Budget speech

Of more interest is “new electricity infrastructure to distribute electricity from independent power producers”. Why would one want to do this? Why would a Finance Minister think this is a good idea? Does he know that solar power goes off at night and the wind does not always blow? Does he grasp that renewable energy in South Africa is about 4 000 MW, which is about a tenth of conventional generation?

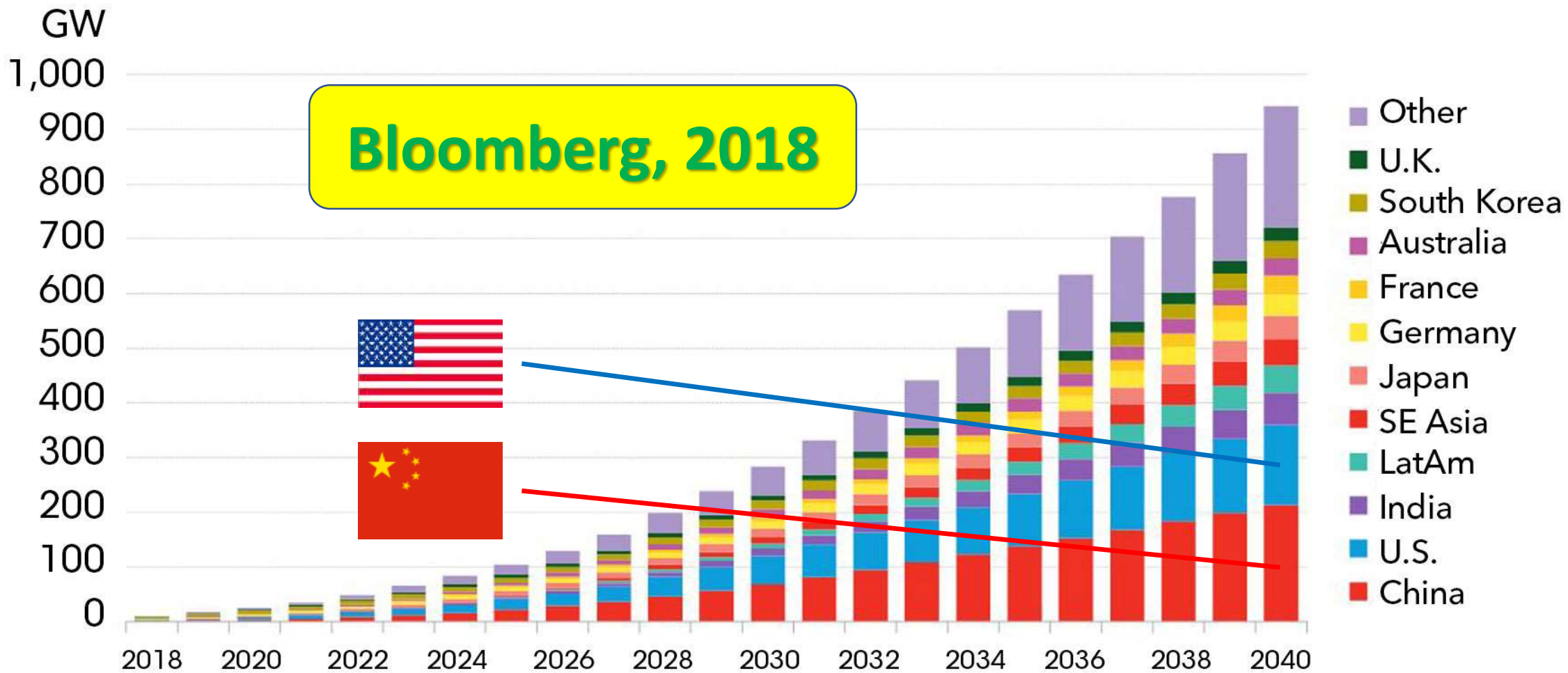
Local sceptic:
or (hopefully) tongue-in-cheek?

Global Storage Market to Double Six Times by 2030

Bloomberg, 2017



Energy Storage is a \$620 Billion Investment Opportunity to 2040



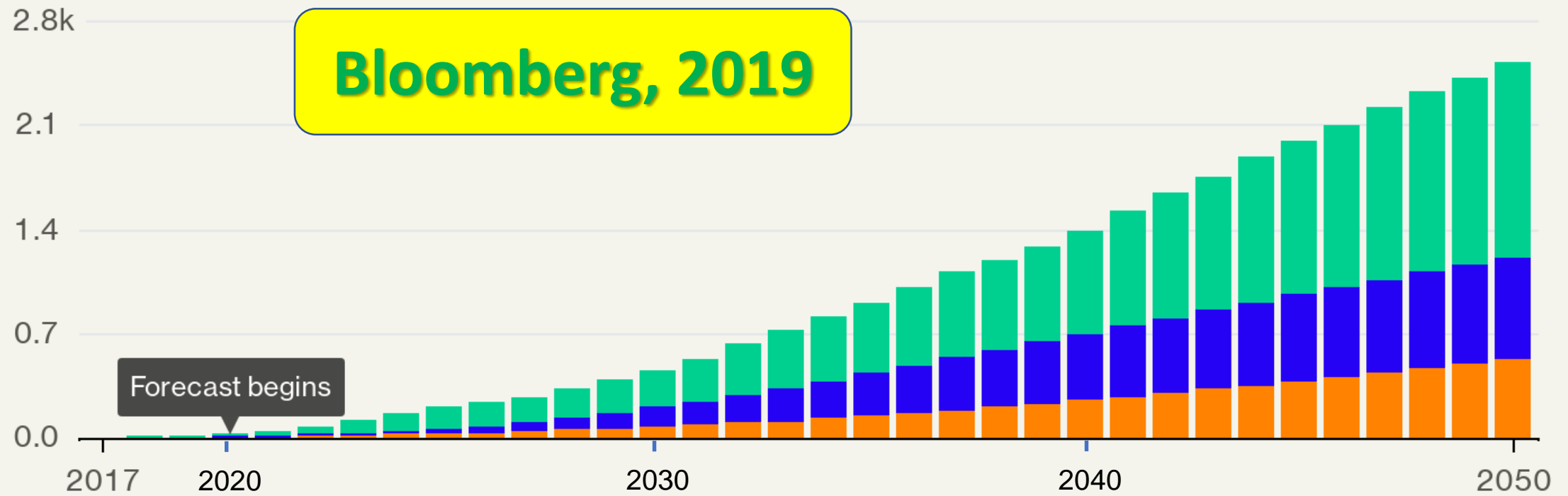
Source: BloombergNEF

Bloomberg, November 20, 2018

Storage Room

Cumulative global installed battery capacity, in gigawatt-hours

Residential small-scale Commercial small-scale Utility-scale



Source: BloombergNEF

Bloomberg

Article: August 1, 2019

Energy storage installations around the world will multiply exponentially, from a modest 9GW/**17GWh** deployed as of 2018 to 1,095GW/**2,850GWh** by 2040.

BNEF's Energy Storage Outlook 2019 predicts a further halving of lithium-ion battery costs per kilowatt-hour by 2030, as demand takes off in two different markets – stationary storage and electric vehicles.

The total demand for batteries from the stationary storage and electric transport sectors is forecast to be **4,584GWh** by 2040, providing a major opportunity for battery makers and miners of component metals such as lithium, cobalt and nickel.

Least-cost integrated resource planning and cost-optimal climate change mitigation policy: Alternatives for the South African electricity system

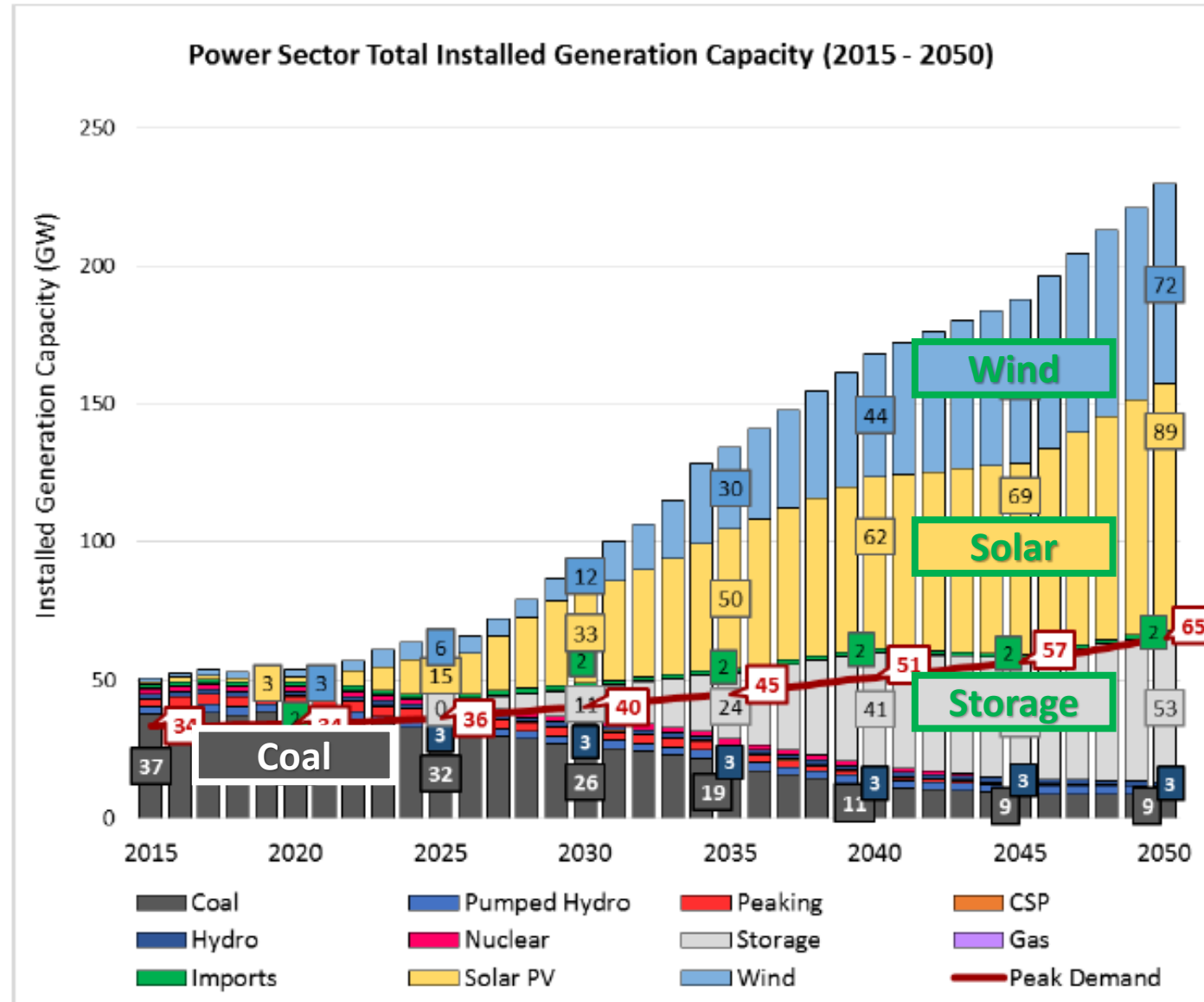


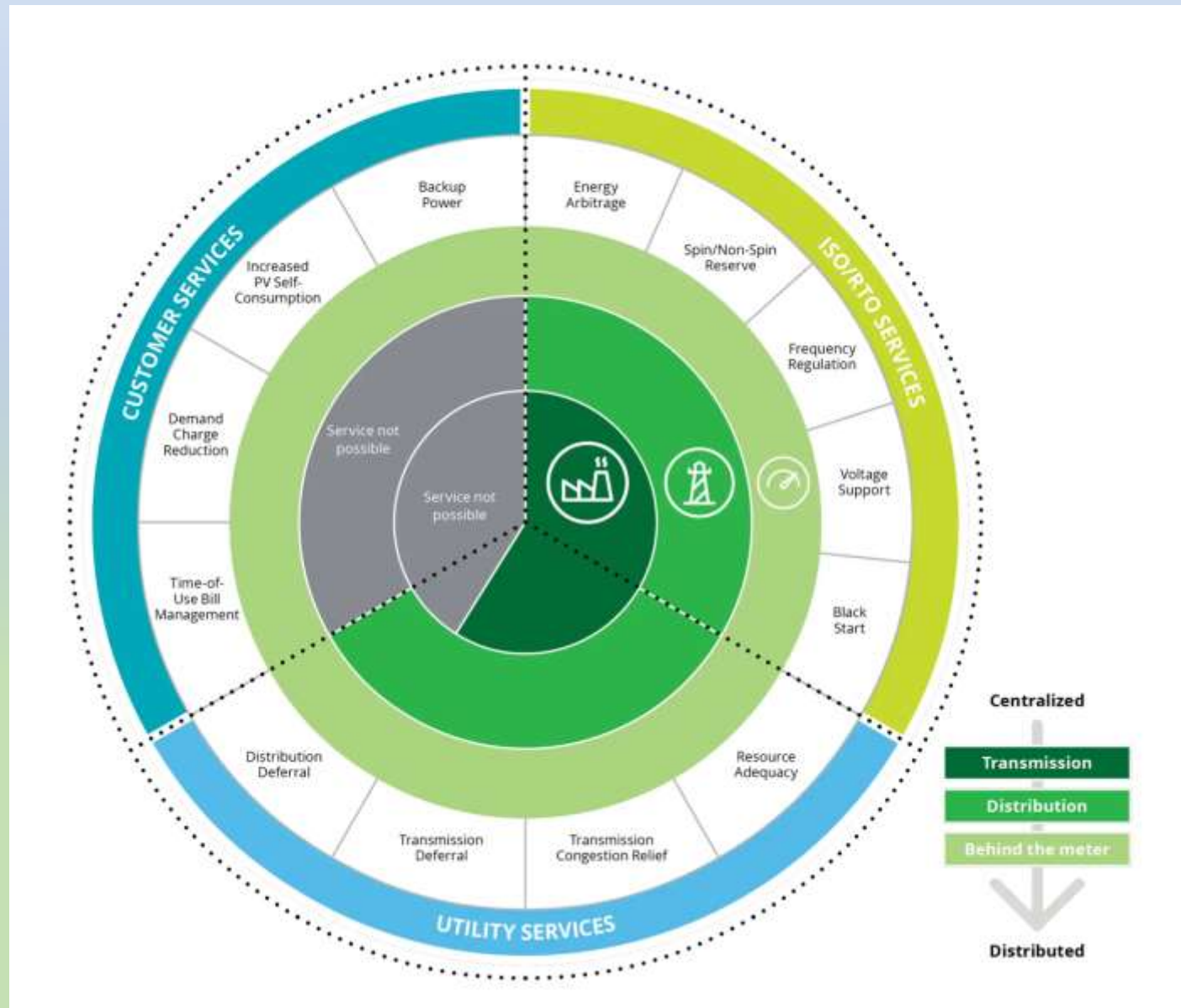
Figure 10: Installed generation capacity, reference case 2015–2050 (GW)

**BRYCE MCCALL
JESSE BURTO
ANDREW
MARQUARD
FAAIQA HARTLEY
FADIEL AHJUM
GREGORY
IRELAND
BRUNO MERVEN**

Batteries boom enables world to get half of electricity from wind and solar by 2050

- Backup Power
- Increased PV Self-consumption
- Demand Charge Reduction
- TOU Bill Management

- Distribution Deferral
- Transmission Deferral
- Transmission Congestion Relief
- Resource Adequacy



- Energy Arbitrage
- Spin/non-spin Reserves
- Frequency Regulation
- Voltage Support
- Black Start

ISO: Independent System Operator
RTO: Regional Transmission Organisation

Energy Storage Technologies



Pumped Hydro



Lithium & Other



Flow Batteries



Compressed Air & H₂



Thermal Energy
Storage (TES)



Super Capacitor

Pumped Hydro

SA Large Storage Systems in GW range:

- Drakensberg 1GW (Average production: 2GWh)
- Ingula 1,3GW (Max storage capacity: 21 GWh)

Smaller:

- Steenbras - 180MW
- Palmiet - 400MW

Limited potential in South Africa due to the geography

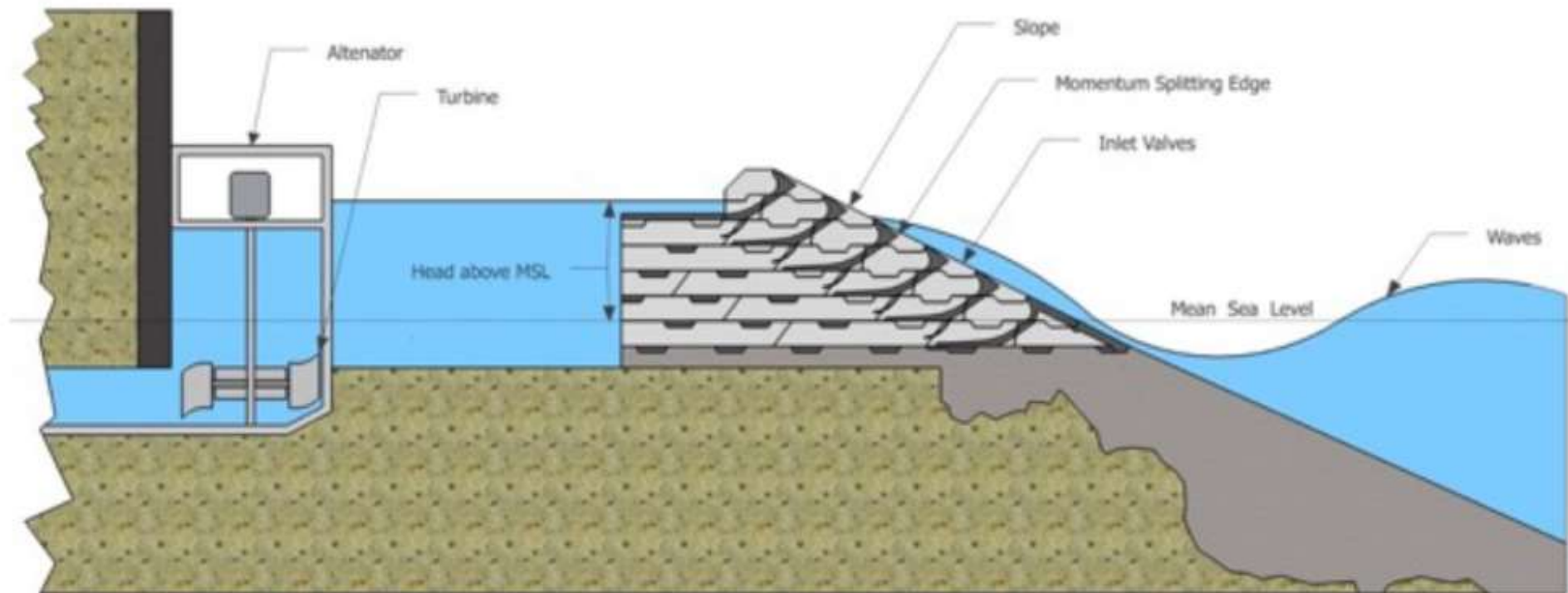


Ing



Mean
Sea Level

Figure 4: MSL's optimised overtopping wave energy converter





After successful commissioning of a 100 kW salt water hydroelectric energy recovery plant, Mean Sea Level is currently constructing its first fully operational 1 MW Wave Energy Converter. These projects will serve as proof of technology and demonstration plants in South Africa.

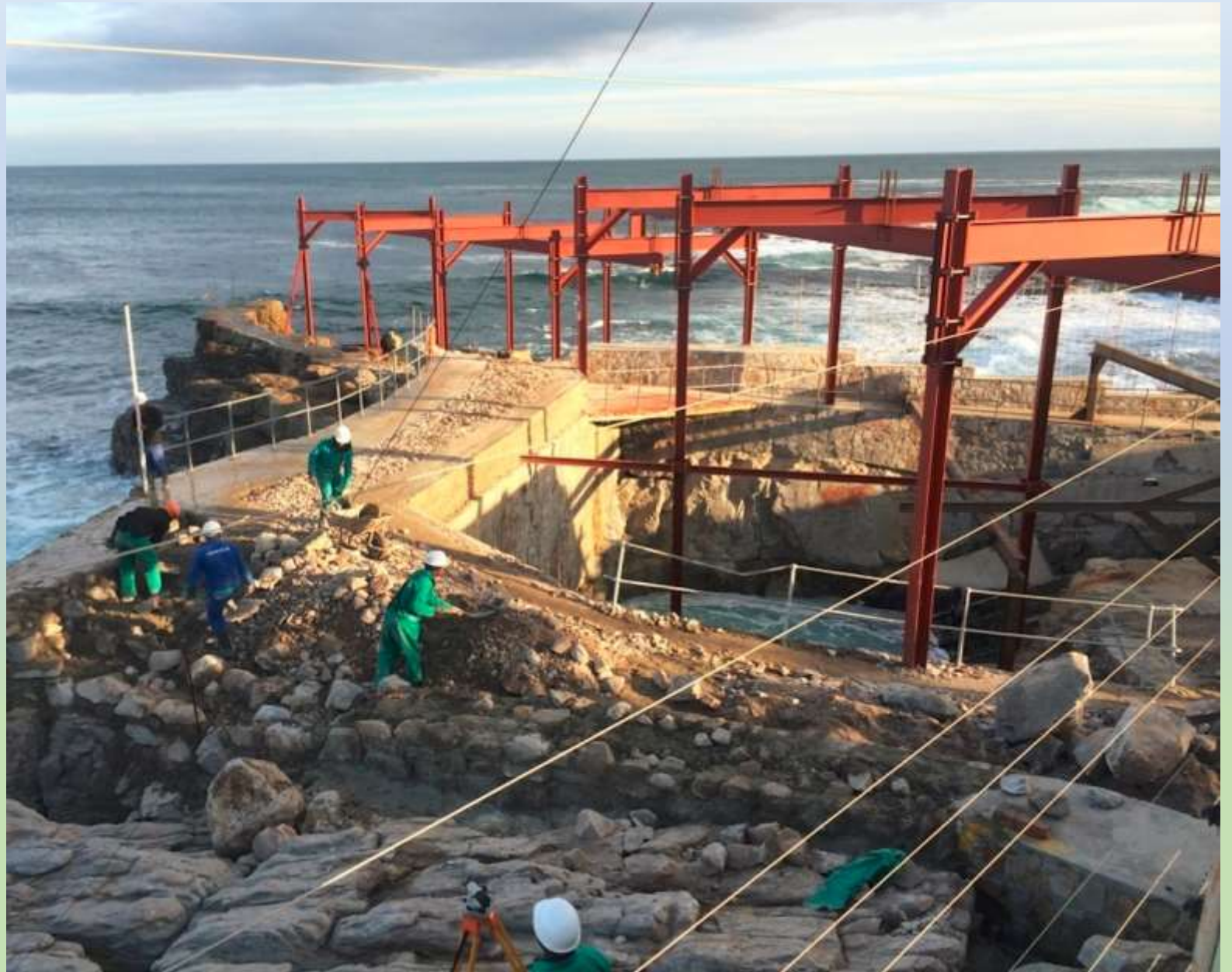
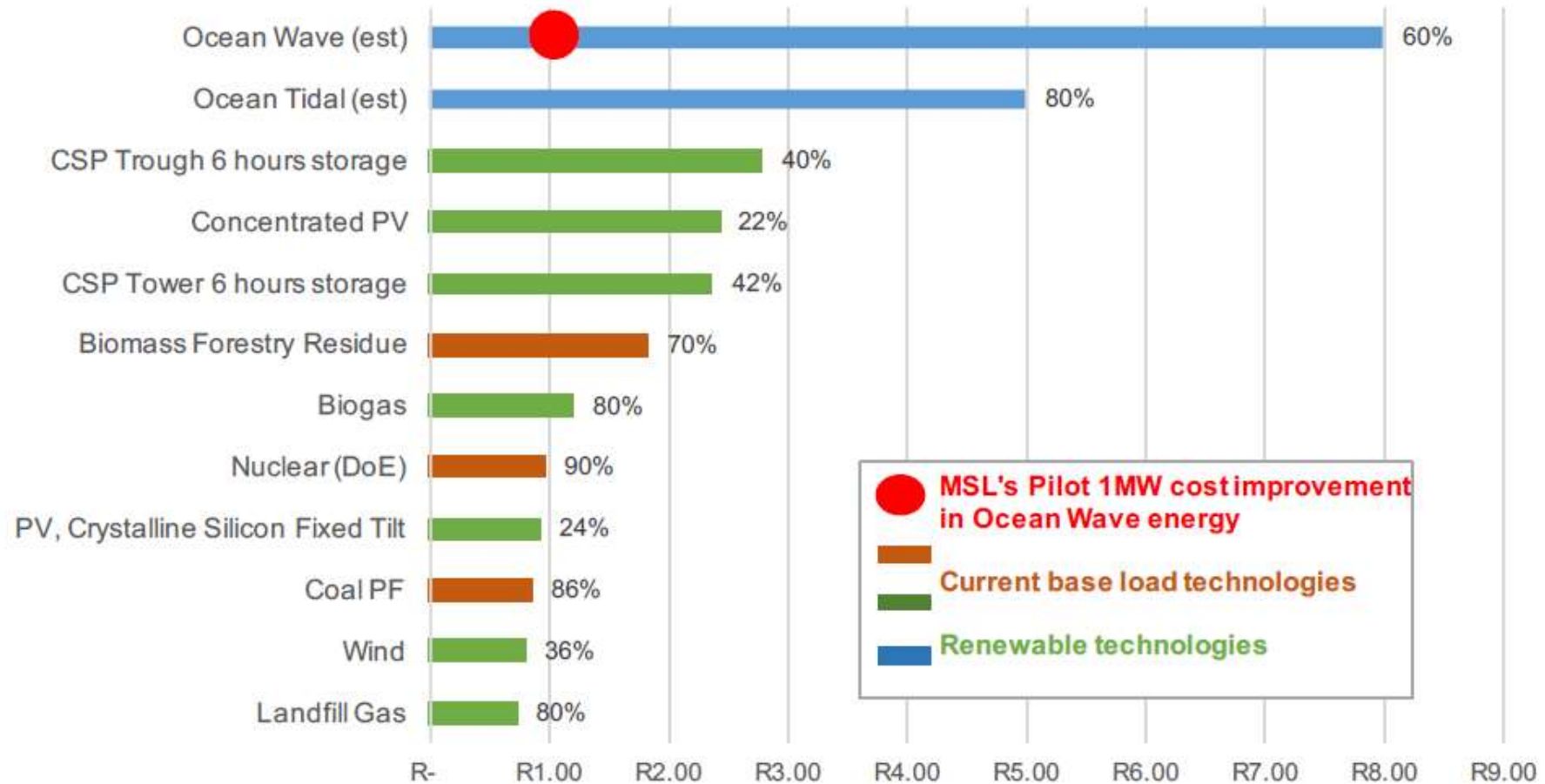
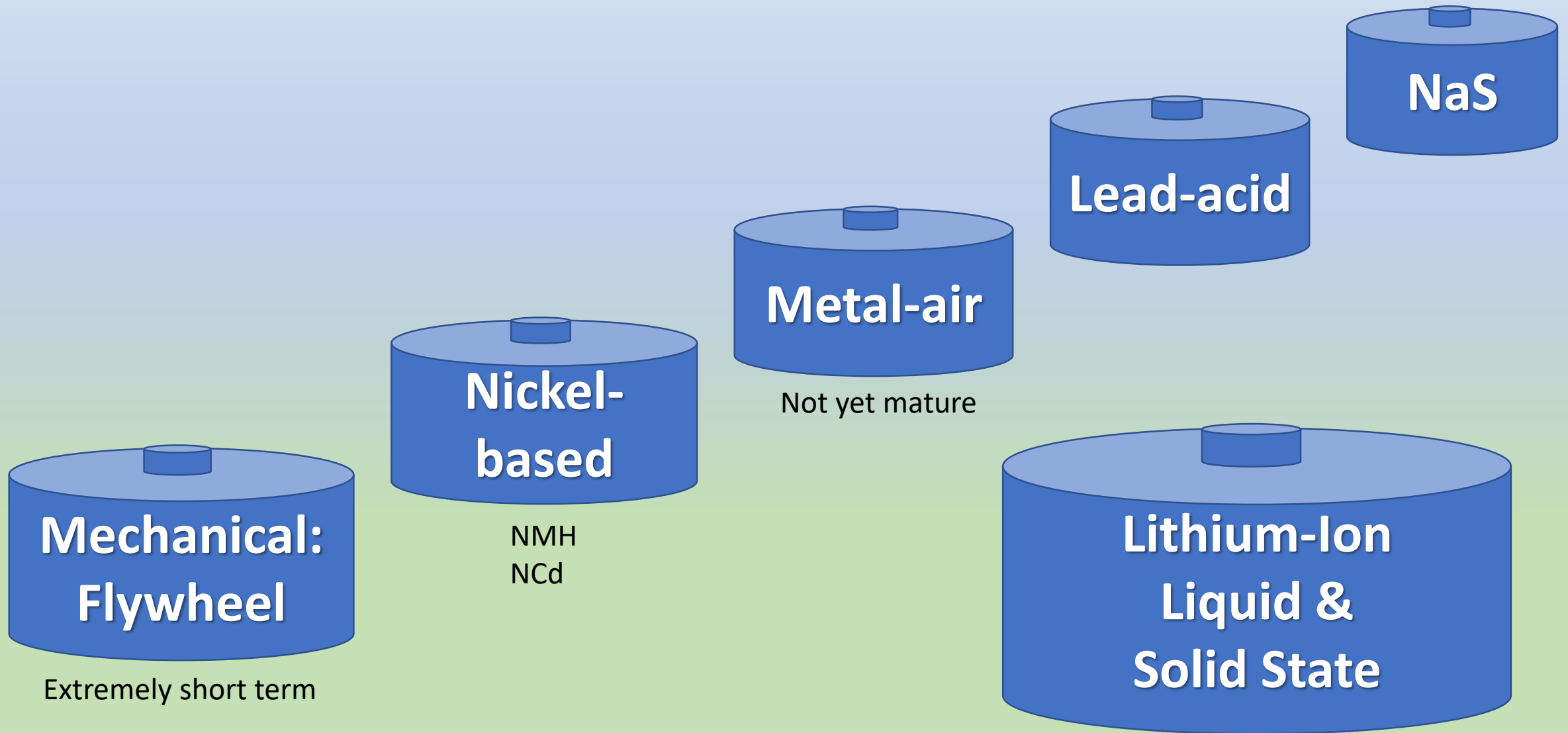


Figure 1: South African Levelised Cost of Electricity (R/kWh, % load factor)



Source: South African Department of Energy, Integrated Resource Plan, March 2017

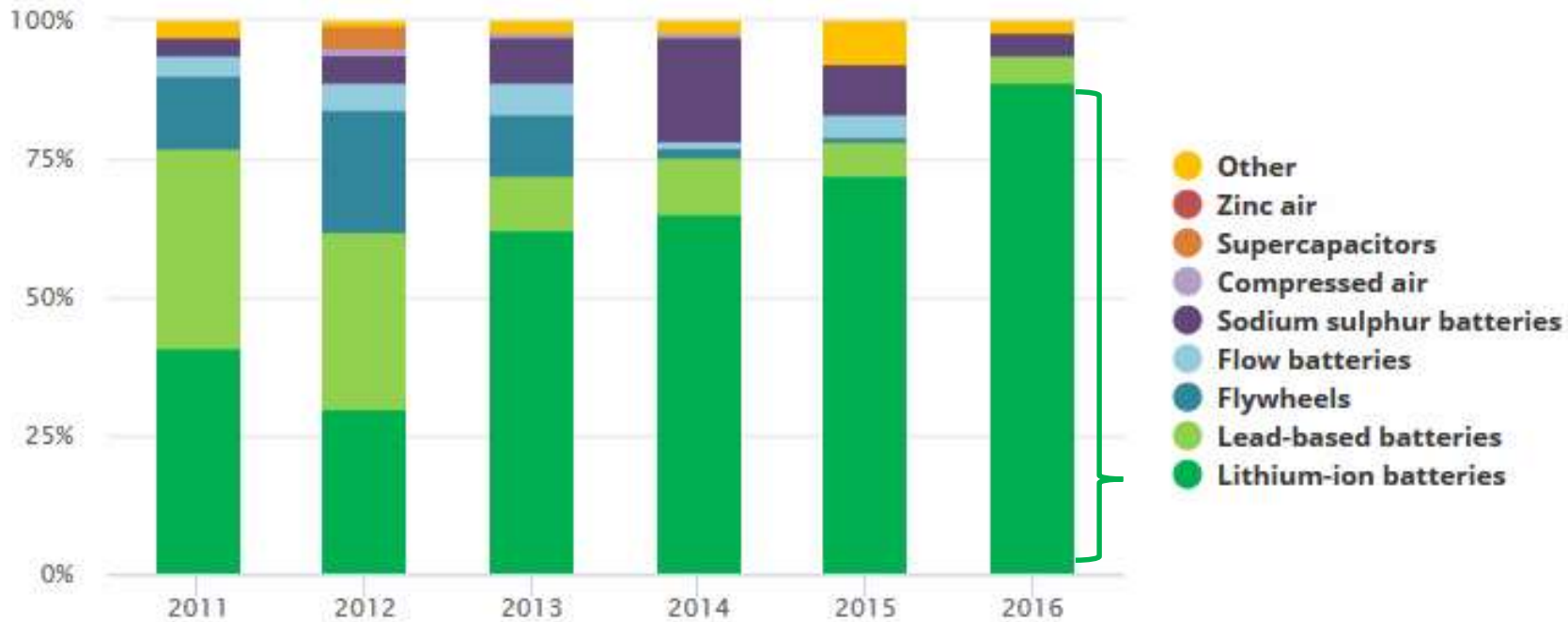
Lithium & Other Batteries



Energy storage - Tracking Clean Energy Progress

Technology mix in storage installations, excluding pumped hydro

Lithium-ion continues to dominate among all storage technologies excluding pumped hydro.



IEA. All rights reserved.

South Africa made an important commitment to distributed energy storage at the end of 2018, with up to 1.44 GWh of battery storage planned in two phases starting in mid-2019 (?).

Lithium-ion

Positives

- High energy density
- Higher cell voltage
- Economies of scale
- Tesla Hype 😊
- Versatile
- Intensive research to resolve issues

Negatives

- Danger of overheating and fire
- Limited lifetime
- Performance degradation
- Use scarce materials
- Contains toxic elements, e.g. Cobalt
- Pollution hazard

Environmental Issues

In drought-stricken Chile, the Lithium extraction process uses 1,9 million litres of water per tonne of Lithium produced.

In May 2016, hundreds of protestors threw dead fish onto the streets of Tagong, a town on the eastern edge of the Tibetan plateau. They had plucked them from the waters of the Liqi river, where a toxic chemical leak from the Ganzizhou Rongda Lithium mine had wreaked havoc with the local ecosystem. There are pictures of masses of dead fish on the surface of the stream. Some eyewitnesses reported seeing cow and yak carcasses floating downstream, dead from drinking contaminated water.

Artisanal miners as young as seven were seen by researchers who visited nine sites including deep mines dug by hand using basic tools. Miners, the youngest of whom were earning as little as \$1 a day, reported suffering chronic lung disease from exposure to cobalt dust.

Electric Vehicle Batteries:

Tesla Model S uses 7104 Lithium Cells = 85kWh

**One Tesla Model S = 1 000 x as much Cobalt
than a smart phone = 10kg**

Utility Scale Batteries:

**83 576 470 Lithium cells & 117 647 kg of Cobalt
per GWh of storage**

**1st Tesla Utility Scale Plant in Australia :
100MW / 129MWh**

Lithium-ion & Cobalt

https://www.youtube.com/results?search_query=Sky+TV+Cobalt+DRC



**Cobalt – the
“Blood Diamond”
of Lithium
Batteries**



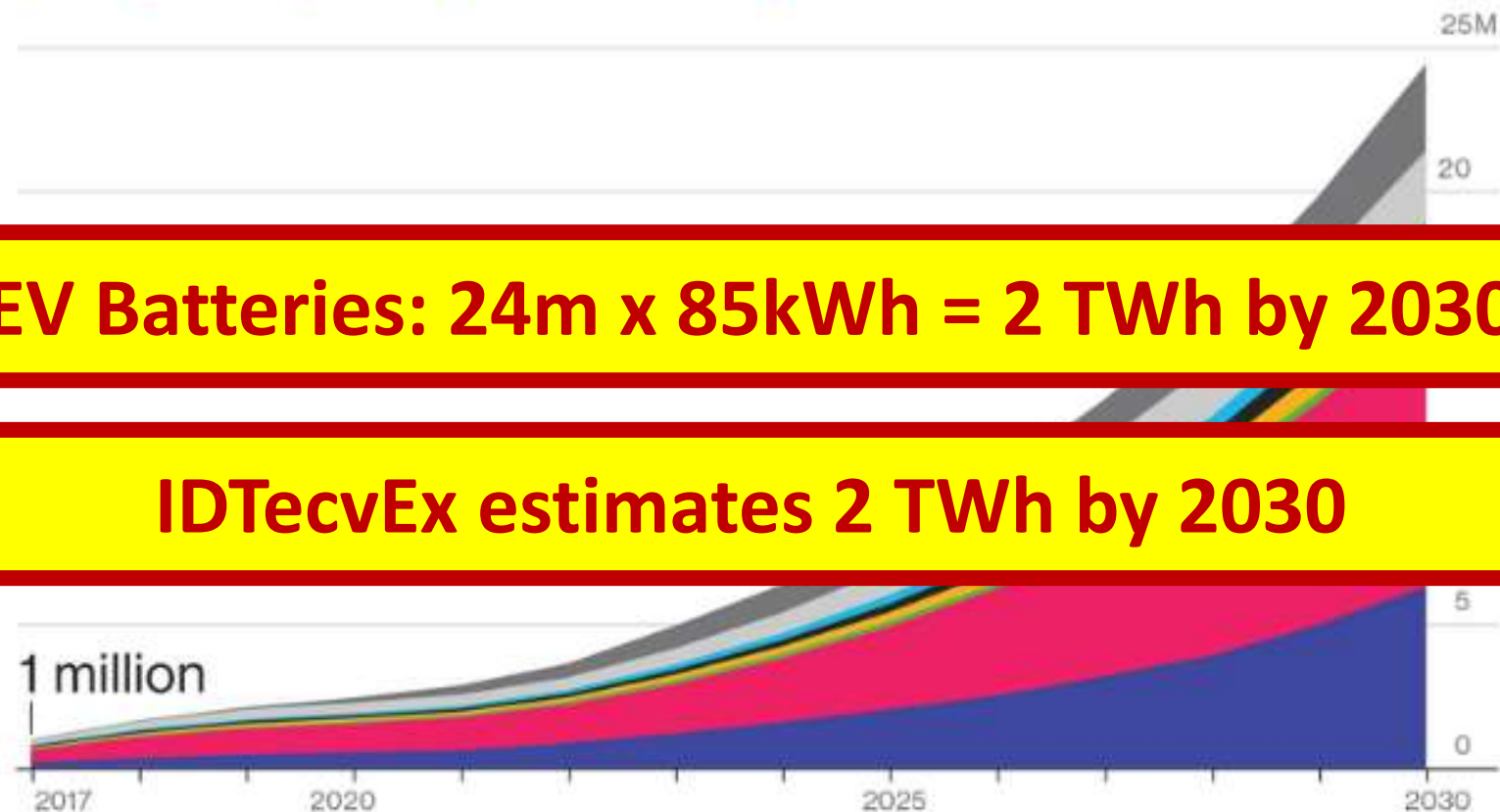
Elon Musk wants cobalt out of his batteries — here’s why that’s a challenge. Everyone wants to cut out cobalt, but doing so creates performance and safety problems. – theverge.com



Lithium-ion & Cobalt – EV impact

Annual global electric vehicle sales are forecast to hit 24.4 million by 2030

■ U.S. ■ China ■ Japan ■ Germany ■ U.K. ■ France ■ Rest of Europe ■ Rest of World



EV Batteries: 24m x 85kWh = 2 TWh by 2030

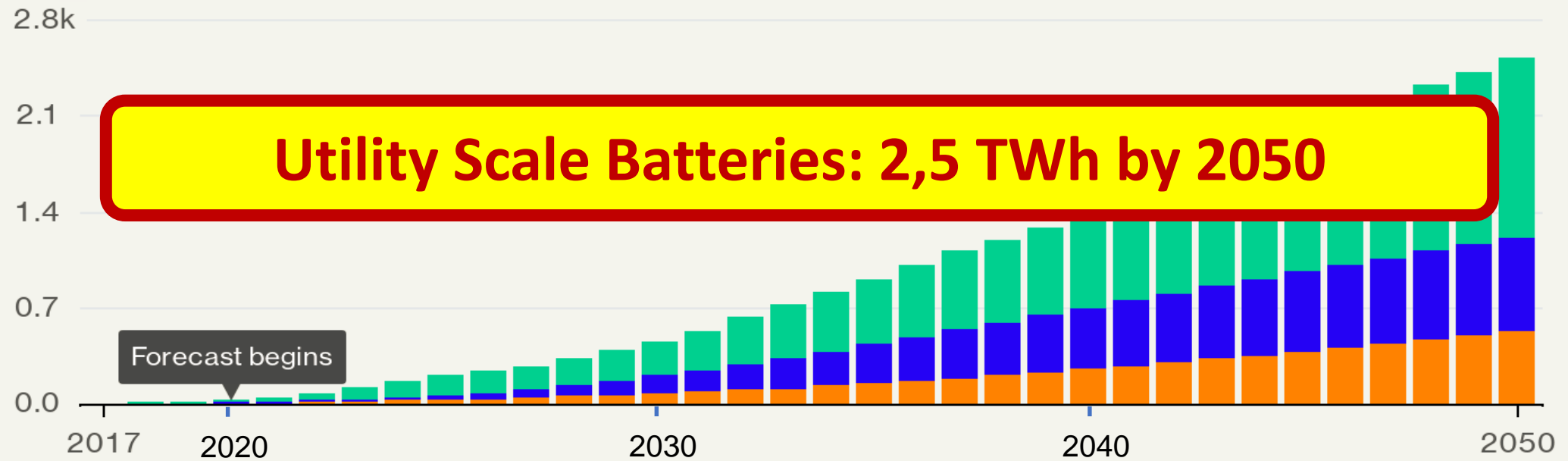
IDTevEx estimates 2 TWh by 2030

Lithium-ion & Cobalt

Storage Room

Cumulative global installed battery capacity, in gigawatt-hours

Residential small-scale Commercial small-scale Utility-scale



Source: BloombergNEF

Bloomberg


Lithium Batteries

 GlobalData. **Prepare For a Strong Growth in Solid-state EV Batteries**

This emerging field of energy-storage devices seeks to replace the potentially volatile liquid electrolyte in today's lithium-ion (Li-ion) batteries with more stable solid materials. If perfected, these batteries promise greater storage, faster charging times, enhanced fire safety and reduced production costs.

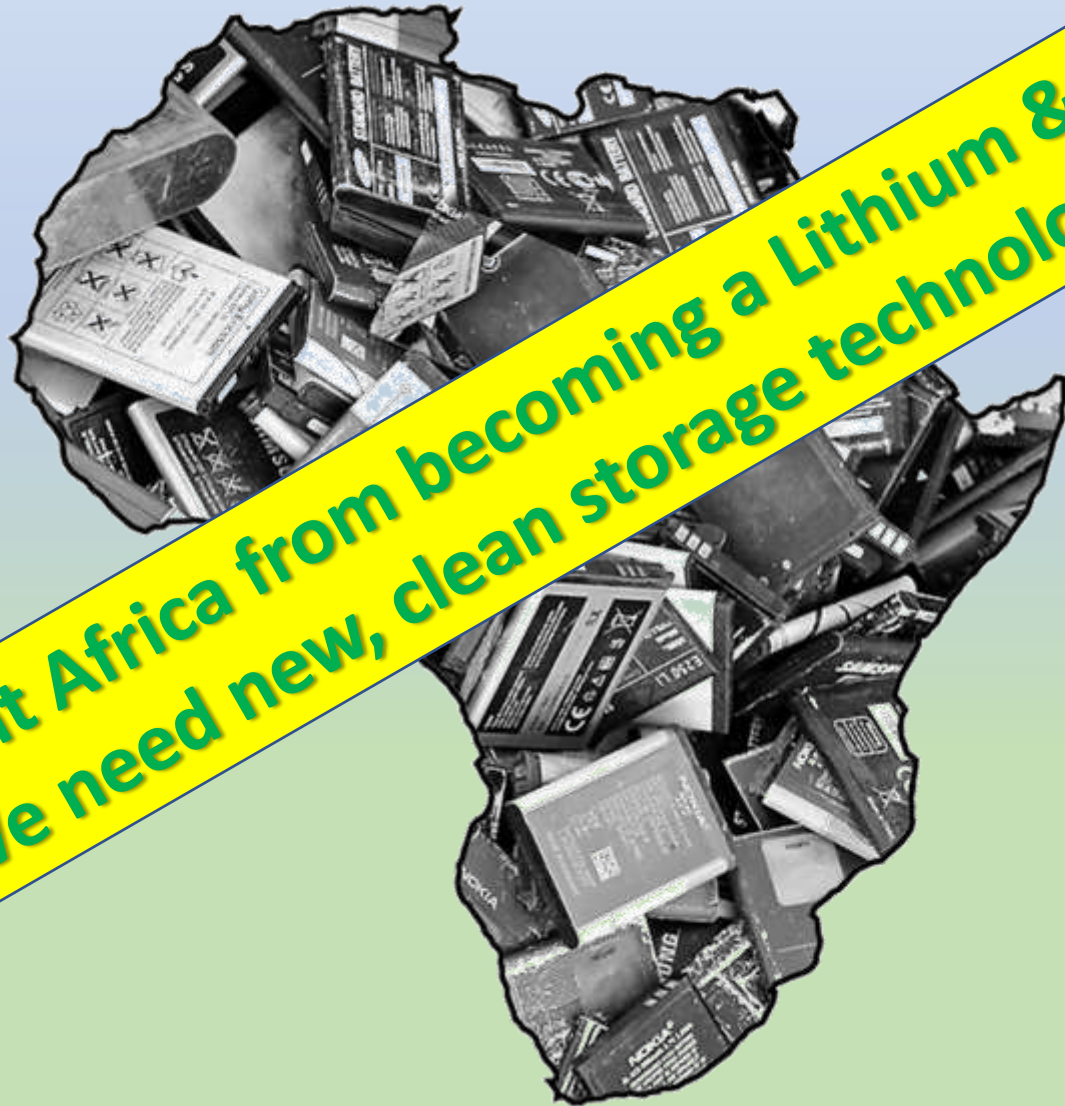


**Yesterday's
News**



**Lithium-Ion
Liquid &
Solid State**

Lithium-ion & Cobalt



**We must prevent Africa from becoming a Lithium & Cobalt Dump.
We need new, clean storage technology!**

Super-capacitors

- Energy density of 70-80 Wh/kg
- Very high power density
- Projected calendar life of 45 years
- Cycle life of 1,000,000 cycles
- High charge / discharge capability
- Wide operating temperature range (-30 to 85°C)
- No performance degradation
- DC to DC round-trip efficiency : 99%
- Safe: Non-toxic & no risk of thermal runaway
- Fast charging : Std. 1,7C = 35 minutes



Super-capacitors - Applications

- Cell towers – already in service in SA
- Residential storage – also established in SA market
- Industrial – excellent to handle peak loads & time-of-use tariffs
- Behind-the-meter applications
- Off-grid / micro-grid applications
- Electric vehicles, including E-bikes
- Re-generative braking (Trucks, trains & hoists)
- Can Upscale & Downscale (even to AA format)
- UPS (e.g. hospitals, data centres)
- EV charging stations



Super-capacitors - Applications



- 1000 buses already running on super-capacitors in China
- Very short range, but charging at each stop for minimum 10s

Super-capacitors - Applications

Bombardier light rail and others use supercapacitor energy harvesting

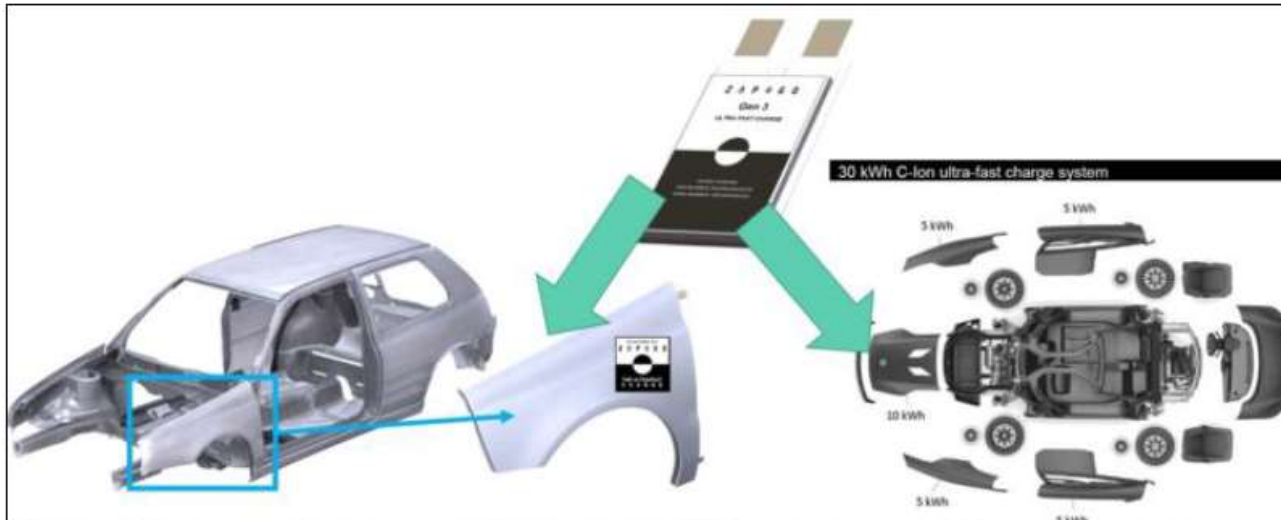
Bombardier light rail and others use supercapacitor energy harvesting recovering up to 35% of electricity on braking of trains and trams. This used to be done with lithium-ion batteries



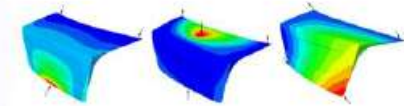
Tolerates faster charging. Fit and forget. Space/cost not a problem.

Super-capacitors - Developments

Longer term: structural supercapacitors ZapGo, Lamborghini Terzo Millennio and others



Technology Demonstrator – Boot lid Design



Imperial College London



and it stores energy!!

25



Super-capacitors – The future?



- Energy density → 250 Wh/kg in 5 years
- Charged in seconds

Superdielectrics Ltd has developed a supercapacitor material that can store "remarkable amounts of electricity, far beyond what we've seen before," according to its CEO Jim Heathcote.

It's cheap to produce, uses no rare elements, and because it's mostly water, it can't catch on fire like traditional batteries. The discovery happened almost by accident, says Highgate, who is now director of research at the company.

- wired.co.uk

Super-capacitors – The future?



Supercapacitor Advantages

Rapid recharging

Very long life

Safe

No rare elements

High cycle efficiency

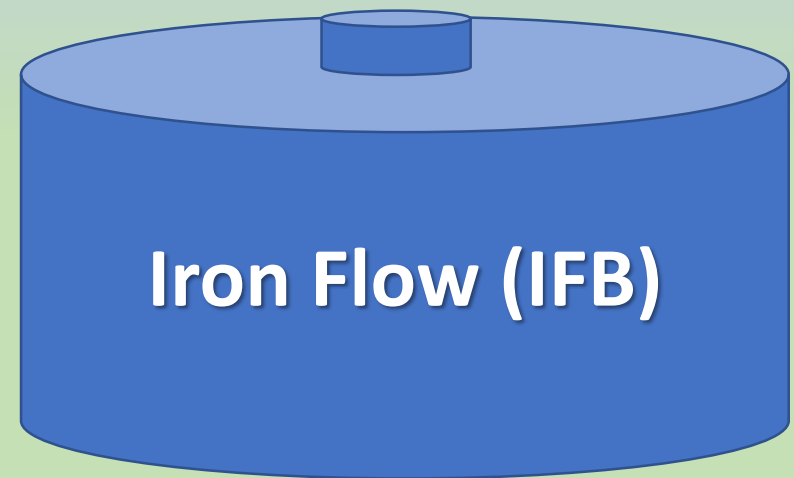
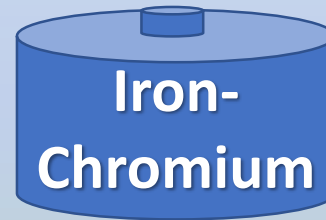
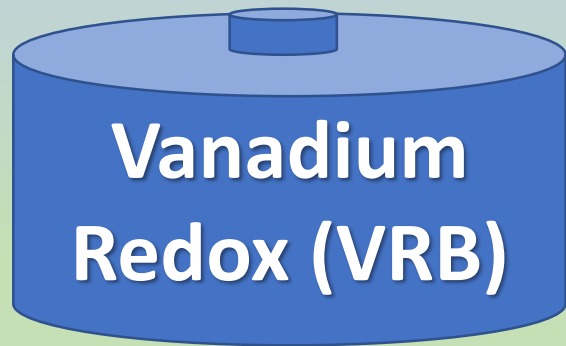
Wide operating temperature range

Specifically for Sd Ltd's supercapacitors:

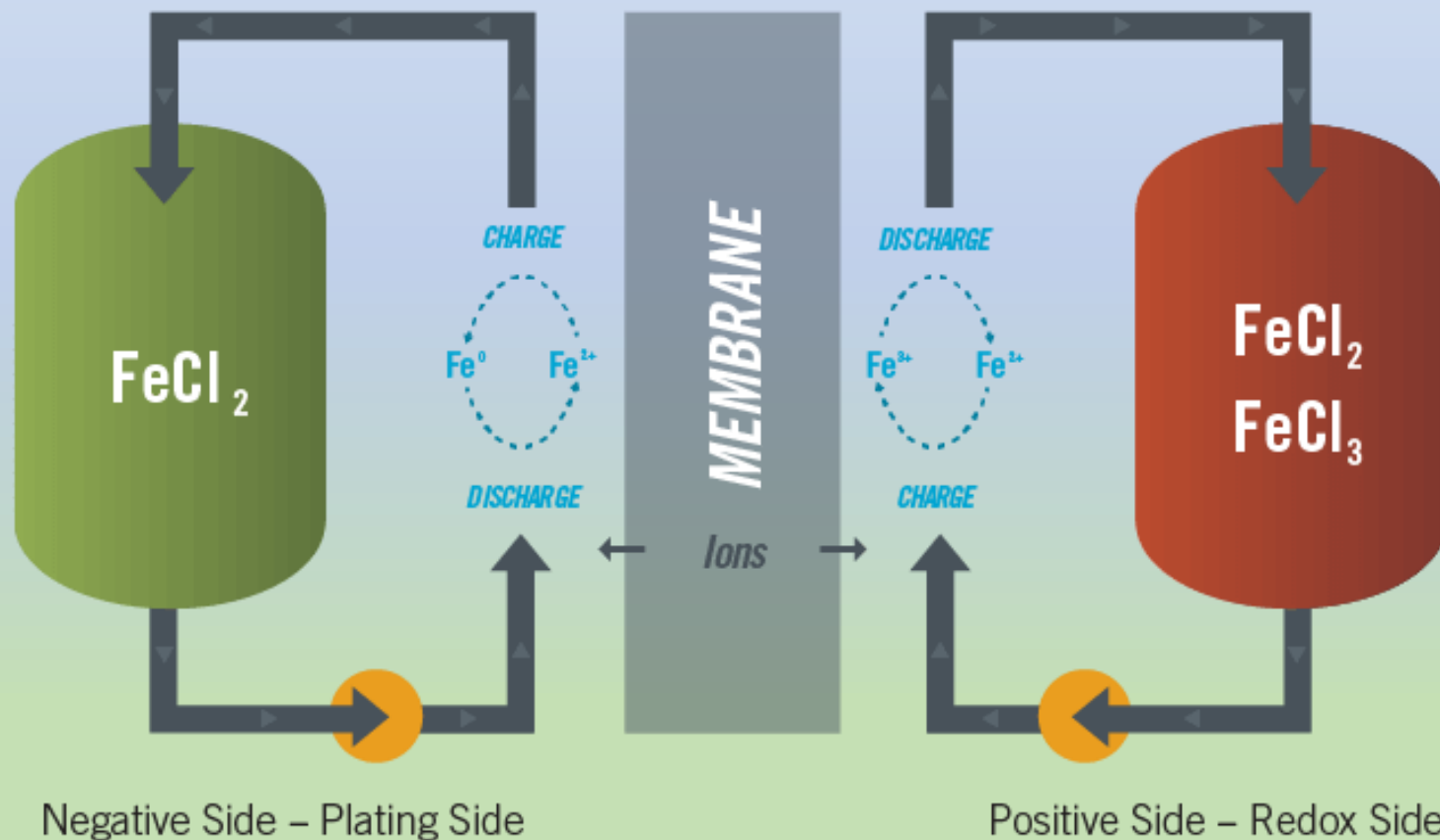
No rare materials or conflict metals

No end of life recycling problems

Flow Batteries

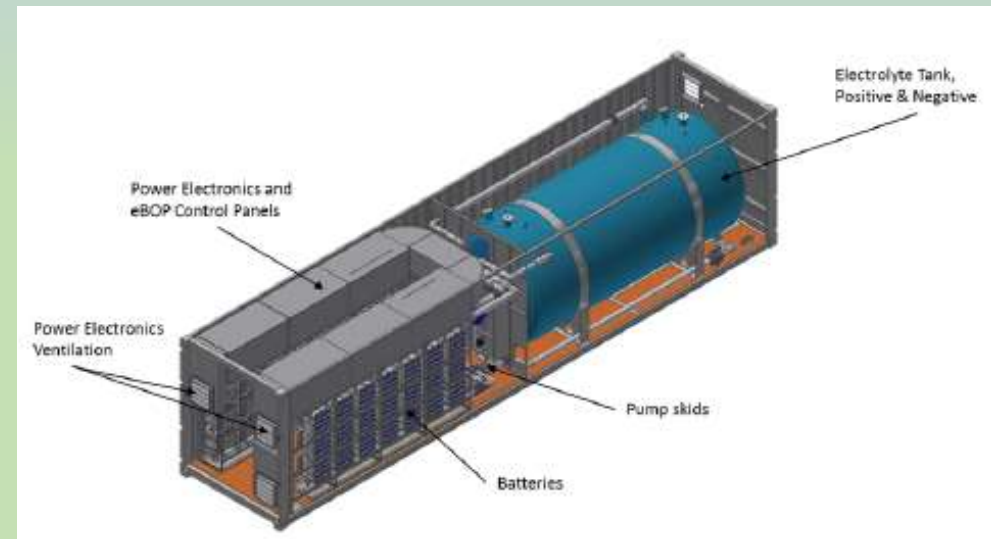
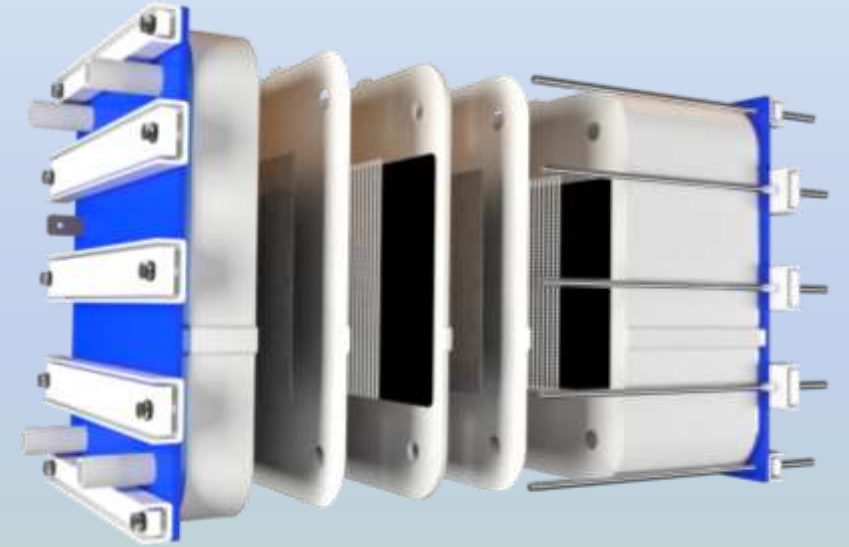


Iron Flow Battery



Iron Flow Battery - Features

- **Lowest Levelised Cost of Storage →
US\$0.05/kWh over 25 years 1 cycle /day**
- **Long Life (25+ years)**
- **Excellent for long-duration storage & multiple charge cycles per day**
- **No performance degradation**
- **Minimal O&M**
- **Low-cost, non-toxic, non-corrosive chemistry**
- **No cooling required up to 50°C ambient temp.**
- **SAFE**



Iron Flow Battery – Energy Warehouse

- **Military Microgrids (reduce vulnerable fuel deliveries, no heat or sound footprint) – US Army, Afghanistan**
- **Agriculture & Industry**
- **Microgrids for remote communities**
- **Where energy density is not critical and low O&M is critical.**
- **Complete module is shipped with built-in control system, then filled with potable water and connected to solar or other source.**
- **50kW/400kWh or 100kW/400kWh, stackable**

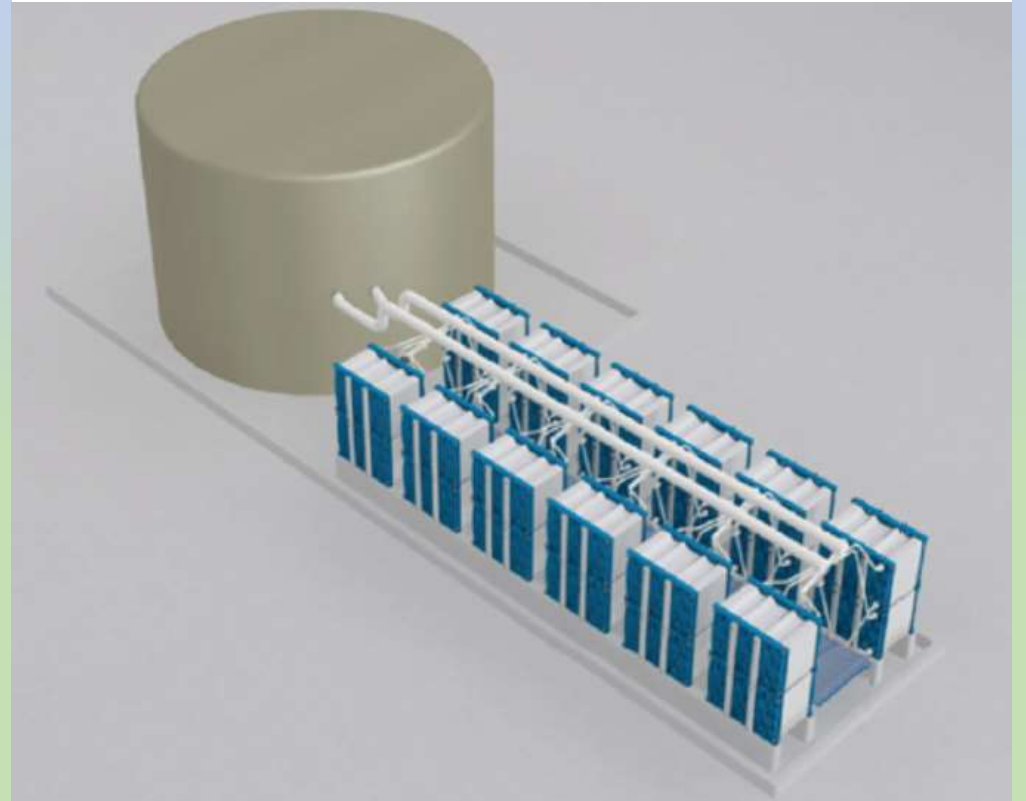


Forward operating base in Base Logar, Afghanistan

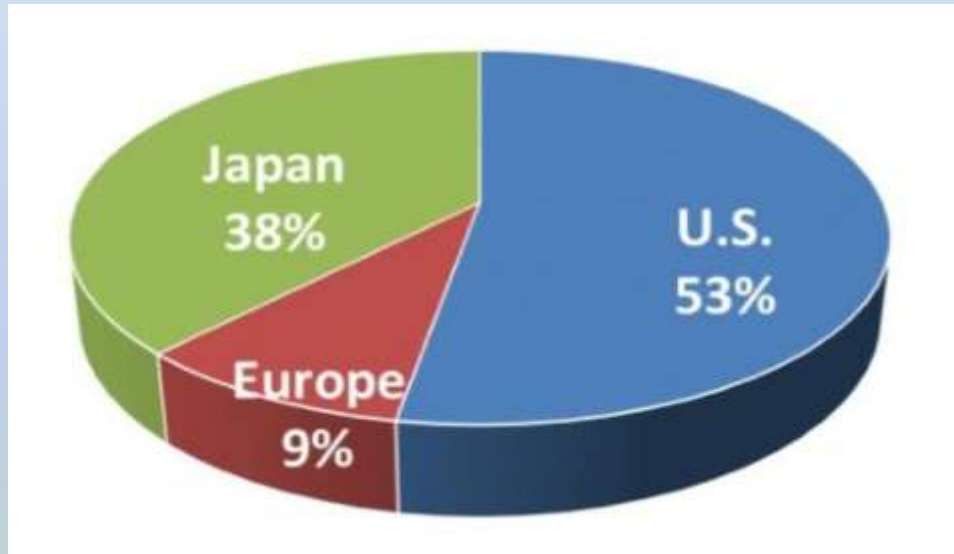
Iron Flow Battery – Energy Centre

- Battery in a building
- For larger & Utility scale applications
- Power (MW) and Energy (MWh) capacity may be optimised separately
- Recently selected as preferred energy storage technology by an African Energy Company – 1st phase: 10MWp/40MWh
- Scalable to 100s of MW/MWh

ENERGY CENTER™: ENERGY STORAGE SOLUTIONS DESIGNED AND SIZED TO YOUR PROJECT'S ENERGY REQUIREMENTS



Hydrogen + Fuel Cell



- Works for seasonal energy storage on remote islands with extreme weather conditions
- EV applications explored through Toyota Mirai, Honda Clarity & Hyundai Nexa
- 6500 H₂ cars sold since 2013



- Requires H₂ infrastructure
- “Renewable” Hydrogen from PV or Wind

Hydrogen + Fuel Cell



Anglo American and Impala Platinum is promoting Hydrogen-fuelled Fuel Cell vehicles – also implementing underground mining trucks using Hydrogen + fuel cells in Platinum mines – many benefits and obviously savings in ventilation costs.



Hydrogen + Fuel Cell : Impala Platinum



Impala Platinum

- Using Hydrogen Fuel Cell Forklift
- Installed an 8 MW Doosan fuel cell plant, moving one step closer to taking its refinery, near Johannesburg, off-grid. The long-term goal is to generate between 22 MW and 30 MW of power.



JOHANNESBURG (miningweekly.com) – Former South African President, Kgalema Motlanthe, admiring a platinum-catalysed Anglo American fuel cell, which was on display in Durban.

Hydrogen + Fuel Cell – UK developments



- **A number of hydrogen buses have been running in London since 2010.**
- **The UK's transport secretary announced he was looking to add hydrogen trains to the network in the near future**
- **Potential to reduce shipping emissions (15% of greenhouse gas emissions in the EU during 2015)**
- **Hyundai Nexo HFCV sold with range of 414 miles/666 km on a tank**
- **Infrastructure still limited**
- **ITM Power, a specialist in manufacturing hydrogen energy systems, has launched a hydrogen refuelling station where a wind turbine provides power for an electrolyser, then stores the hydrogen ready to refuel a passing fuel cell vehicle in a few minutes.**

Hydrogen + Fuel Cell

BALLARD®



Fuel Cell Electric buses have travelled more than 14 million km in China – www.ballard.com.



Light rail FCEV in China

Hydrogen + Fuel Cell vs. Li-ion

Class 8 Trucks: Fuel Cell or Battery?

Nikola truck



Fuel
cell

Tesla truck

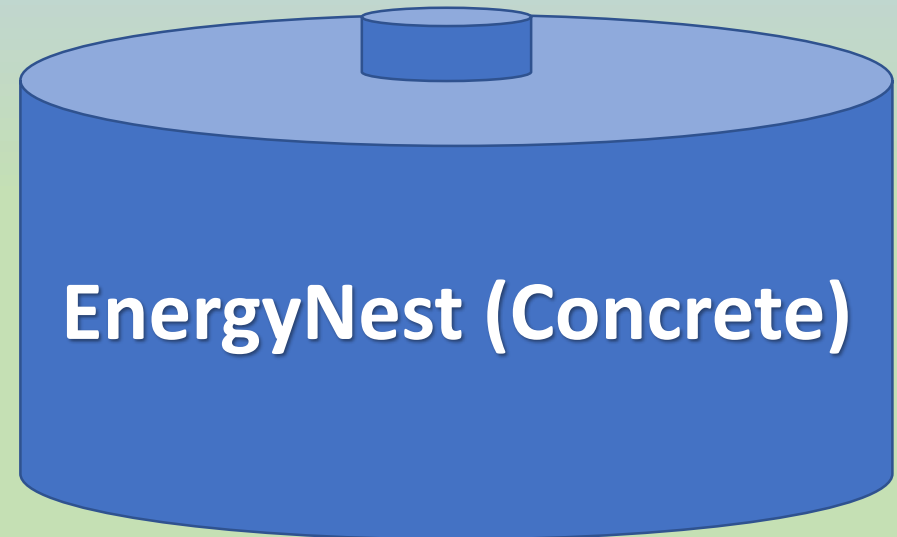
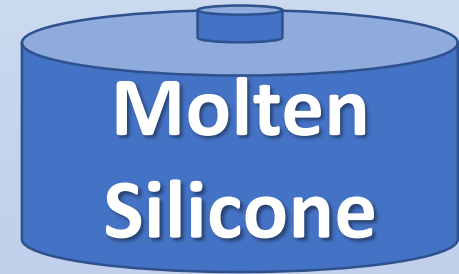
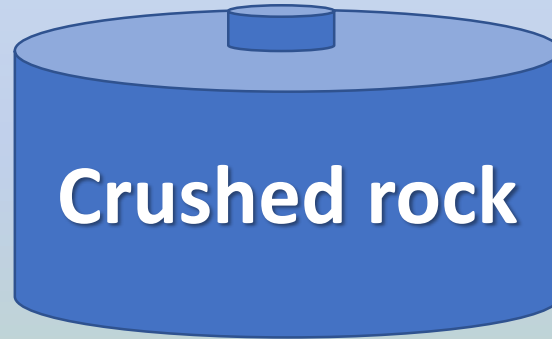


Li-ion

Also Toyota

Also BYD, SAIC, Xos and many others

Thermal Energy Storage



Thermal Energy Storage - Molten Salt

Molten salt is stored at 566°C until electricity is needed – day or night, whether or not the sun is shining

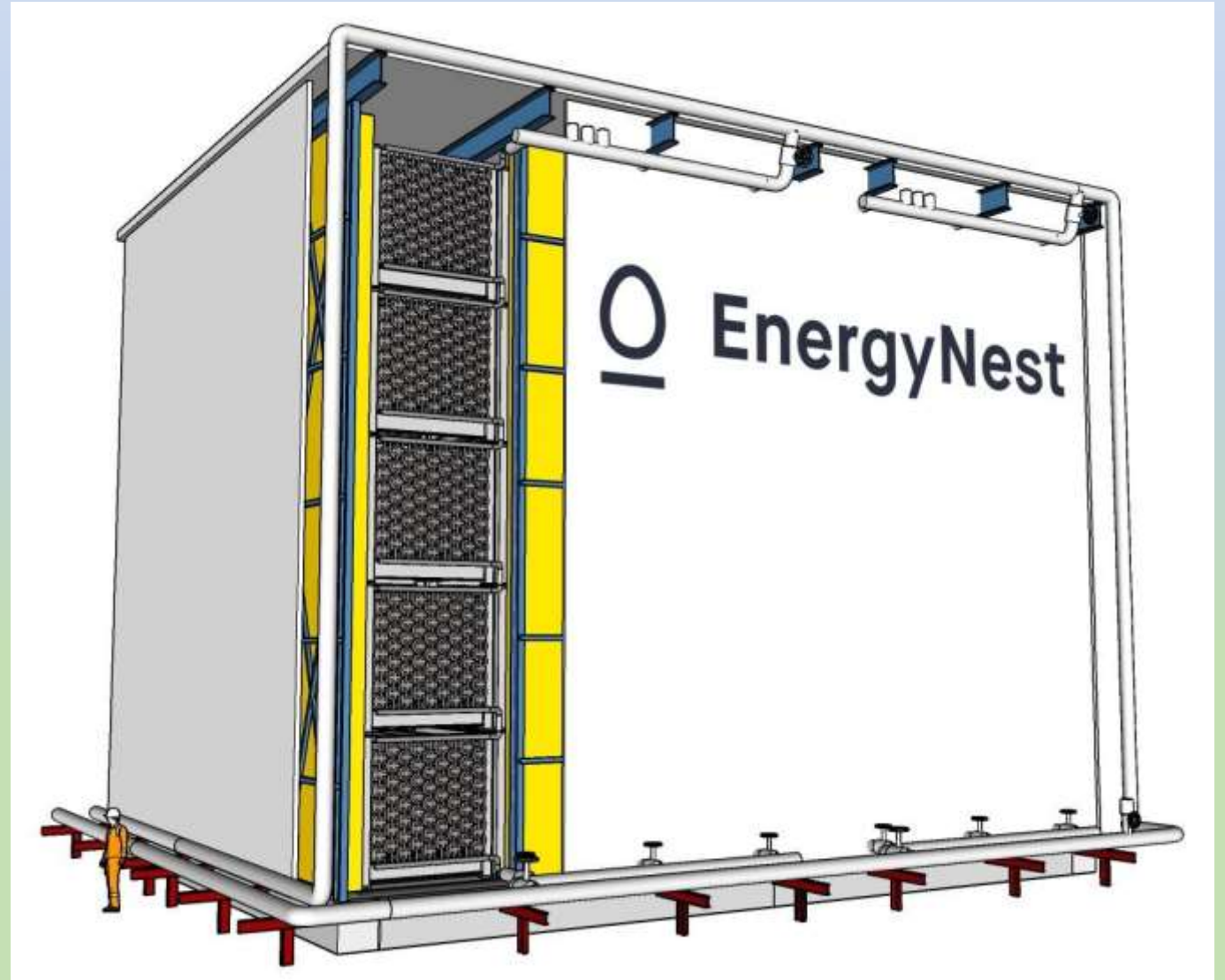
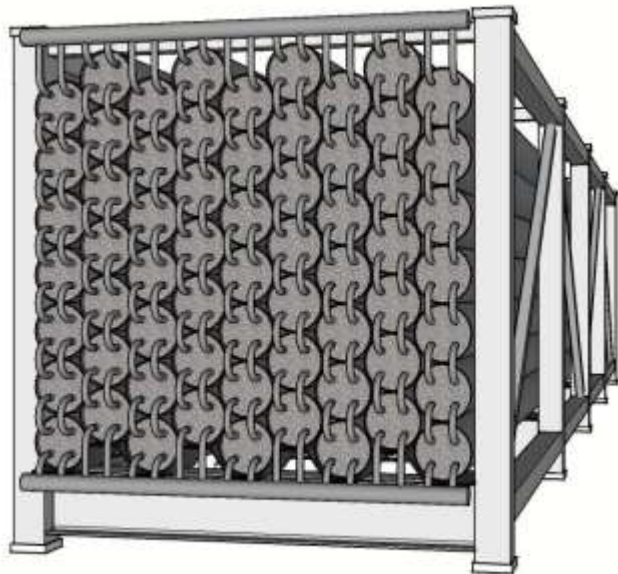
Complex to commission and operate. Molten salt freezes at 240°C .

Risky business!

Large investment in CSP technology.



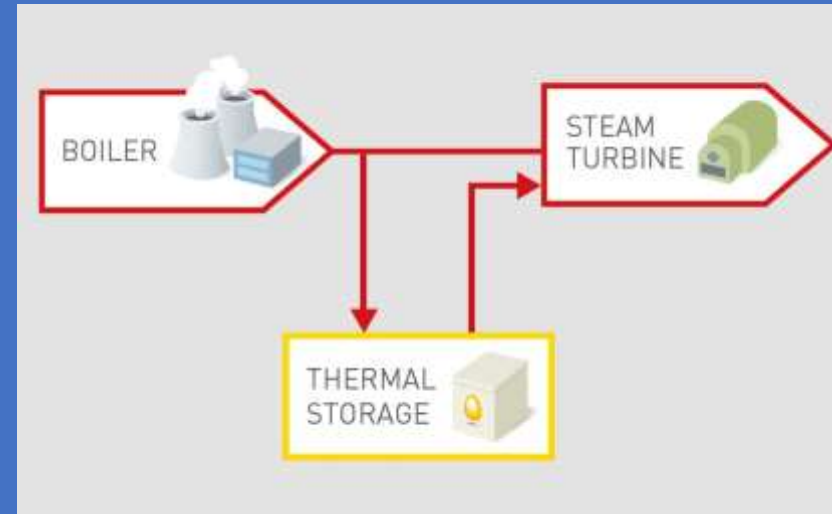
Thermal Energy Storage - EnergyNest



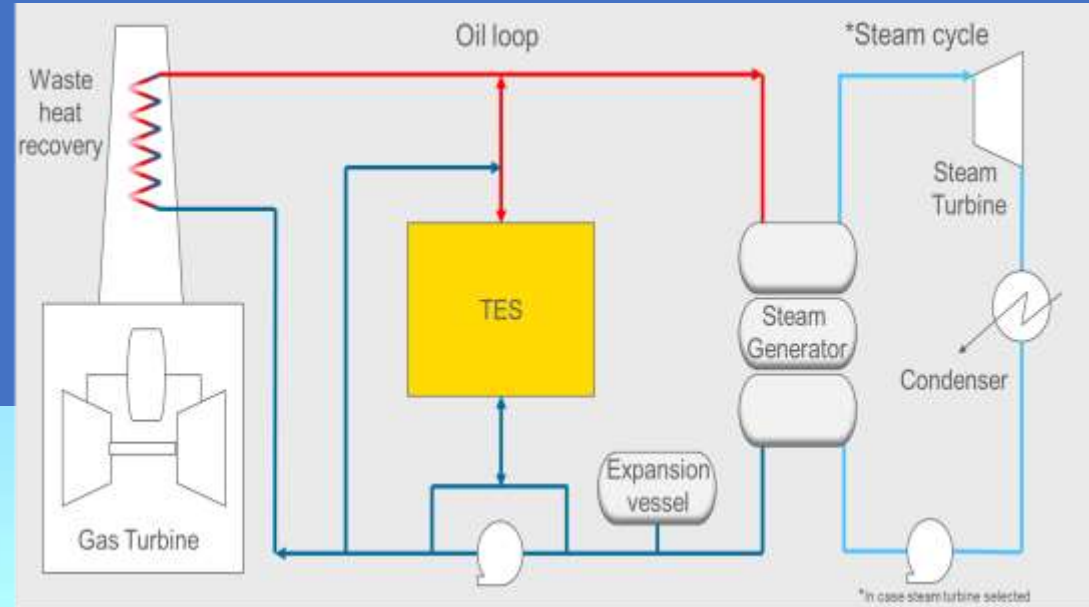
- **Steam Power Plants**
(integrated with steam cycle)
 - Balancing the load
 - Frequency Regulation

Case study:

EnergyNest is developing a 55 MWh_{th} Thermal Battery project with a steam-cycle power plant built in the 1980's. The retrofitting is designed to divert steam away during low-power price events, and reintroduce the steam during high-price events, enabling for a larger steam flow through the turbine, increasing its output by 4.5 MW_{eI} for up to four hours.



Open Cycle Power Plants

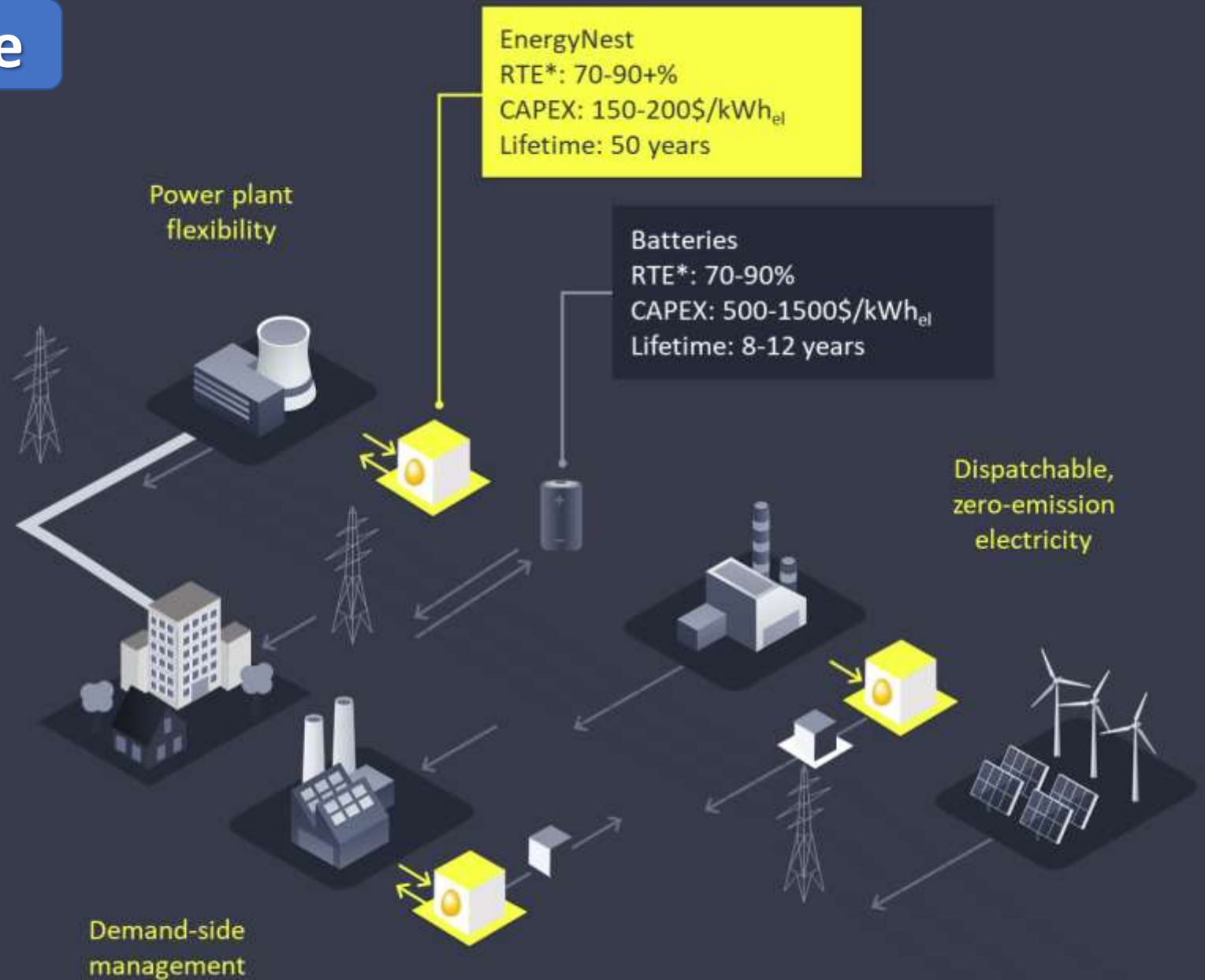


Recovering heat energy lost to the atmosphere for re-use as heat or electricity

Thermal Energy Storage

- Low LCOS
- Long life expectancy
- Excellent Roundtrip efficiency
- Low technology construction
- Can scale to 100's of MegaWatts
- Well-tested and certified

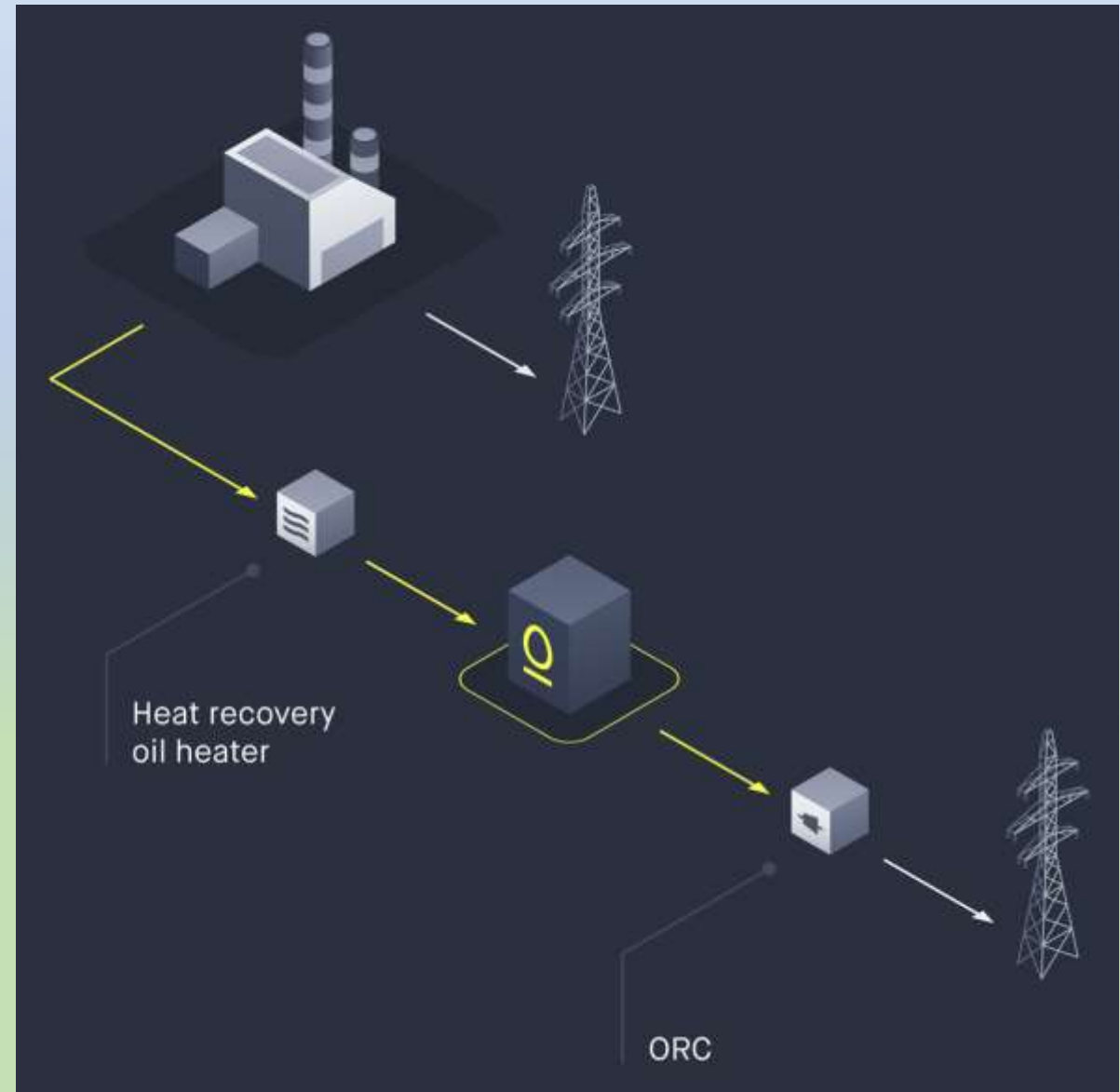
 EnergyNest



Thermal Energy Storage - EnergyNest

- Storing energy at lowest cost
- Making energy flexible, dispatchable for suppliers & manageable for demand side
- Increasing energy efficiency of power plants & energy-intensive industries

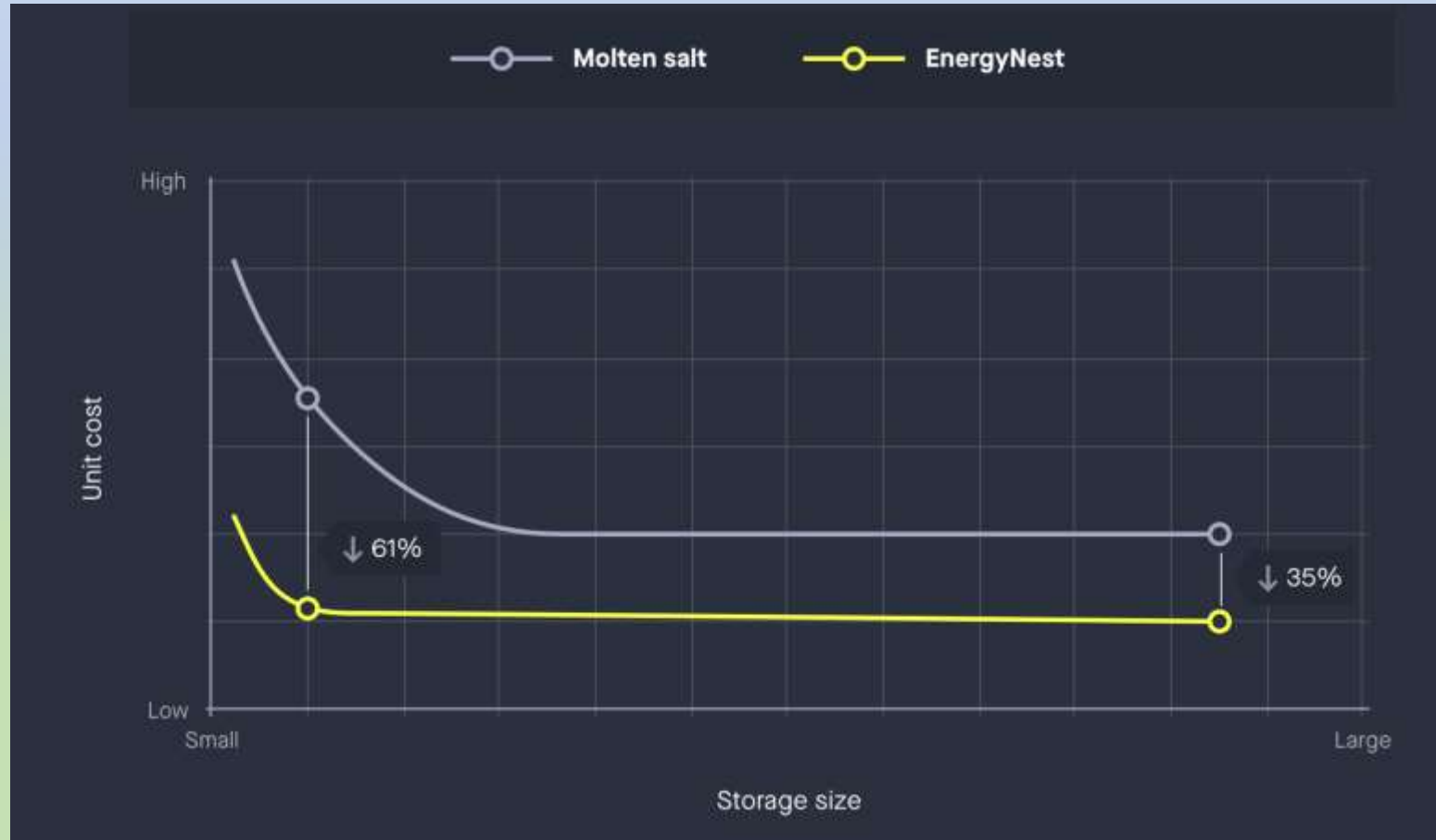
 EnergyNest



Thermal Energy Storage - EnergyNest

EnergyNest offers a thermal battery that is perfectly tailored for parabolic trough plants and direct steam tower plants. Its performance has been validated by DNV GL and comes at a much lower CAPEX and OPEX compared with molten salt systems.

This will make CSP cost-competitive with other renewable sources.



“A next-generation smart grid without energy storage is like a computer without a hard drive: severely limited.”

- Katie Fehrenbacher, GigaOm

Energy Storage
The Future Starts Now!

Africa Energy Storage Solutions is focused on providing appropriate, clean energy storage solutions into Africa. These include proven Thermal Energy Storage (TES) and Flow Battery technologies, while also exploring other storage technologies such as supercapacitors and hydrogen. We are available to work with potential clients to explore how our storage systems may be integrated into an optimal and cost-effective solution to suit their needs.

- Micro/Mini-grid
- Off-grid, including hybrid applications
- Medium to large (MWh) storage
- Balancing of grids
- Harvesting and re-use of wasted heat energy

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