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Goal: keeping the lights on during a global energy transition

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Renewables

Nuclear

Electrification

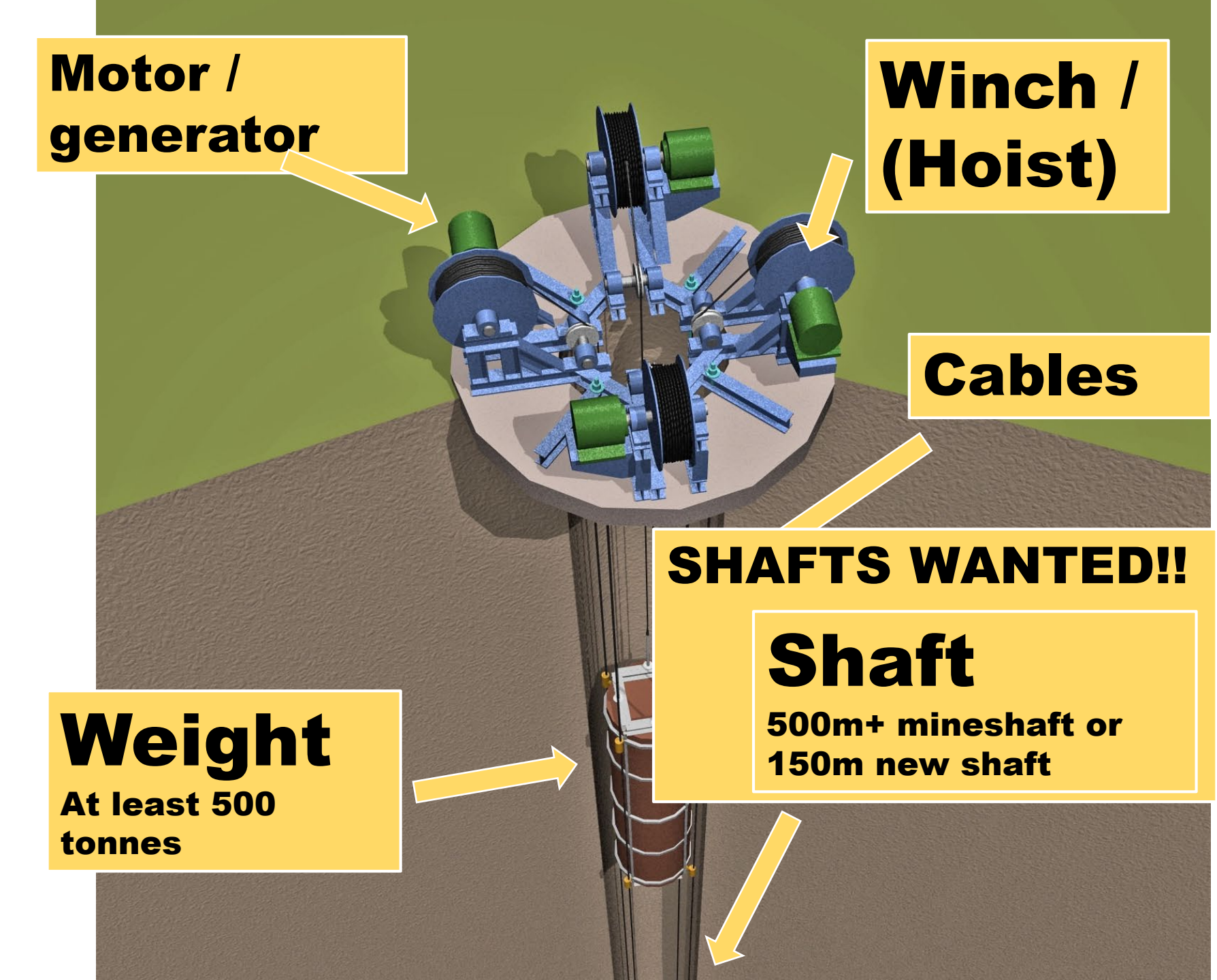
Full Energy system transition

Massively increased flexibility required

$3.2 billion 2017

$620 billion to 2040

Image Credit: Wikipedia Commons. Market Size: Bloomberg New Energy Finance 2018


Motor / generator
Winch / (Hoist)
Cables
SHAFTS WANTED!!
Shaft
500m+ mineshaft or 150m new shaft
Weight
At least 500 tonnes

USPs

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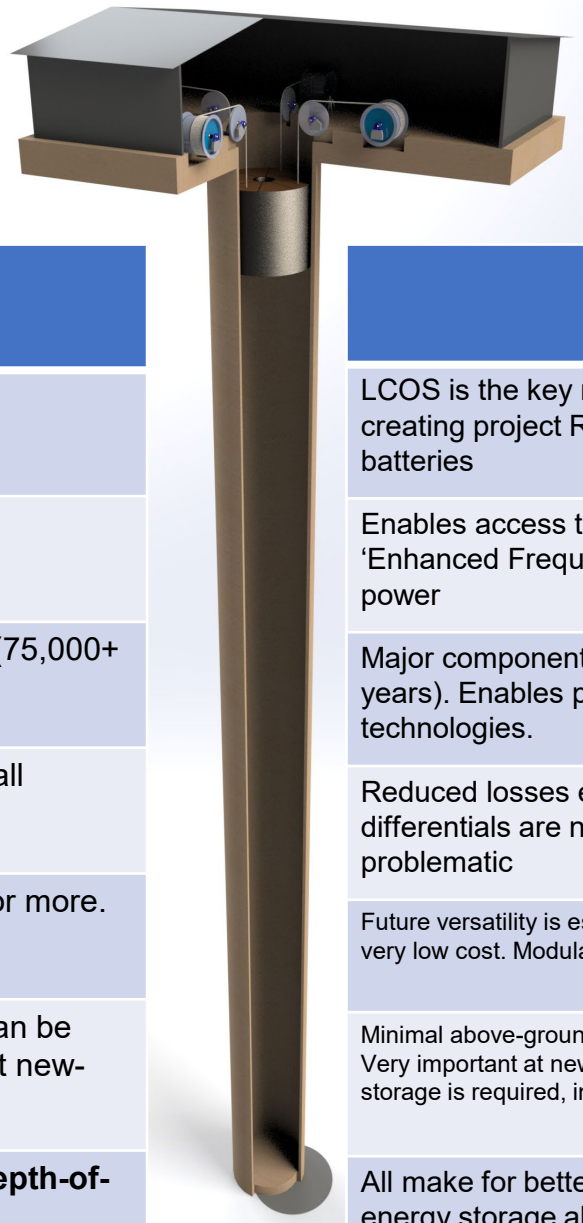

Technical Characteristics (USPs)	Why this matters
Low levelized (lifetime) cost of storage.	LCOS is the key metric for comparing storage options and creating project ROI. Gravitricity's main competitor is Li-Ion batteries
Rapid response: full rated power <1s	Enables access to highest value revenue streams (ie 'Enhanced Frequency Response'), and rapid-reaction backup power
Long cycle life with **no cyclical degradation.** (75,000+ cycles)	Major components have lifetime beyond 20yrs. (Most >50 years). Enables project duration of 25yr+, like other energy technologies.
High efficiency: >85%. As good or better than all alternatives	Reduced losses enables revenue generation even when differentials are not significant. Thermal generation not problematic
Versatile Power/Demand ratio: c-rate up to 8 or more.	Future versatility is essential. Increased Power can be added to system at very low cost. Modular energy increases can be added at later dates
Small footprint: <30mx30m for 8MW facility. Can be sunk below ground. **No locational constraint** at new-shaft sites	Minimal above-ground disruption. Less important at existing mineshaft sites. Very important at new-shaft sites, which can be deployed exactly where storage is required, including urban sites.
No parasitic loads, no standing losses, no depth-of-discharge limits.	All make for better long-term commercial projects than chemical energy storage alternatives.

USPs

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FAST response (<1s)

DURABLE (>75,000 cycles)

COST EFFECTIVE
(Icos <$150/kWy - Prototype)
(Icos <$200/kWh - future)

GRID	INDUSTRIAL USERS	GENERATORS
Frequency, balancing, upgrade avoidance Transmission & Distribution	UPS, Power quality, Peak reduction (TRIAD), upgrade avoidance Mines, Data Centres, etc	Power Quality, upgrade avoidance, hybrid services Wind, solar, gas

TEAM

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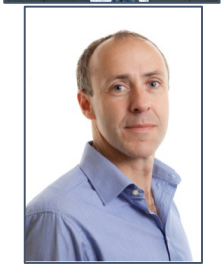

THE UNIVERSITY of EDINBURGH

UNIVERSITY of STRATHCLYDE
POWER NETWORKS DEMONSTRATION CENTRE

THE UNIVERSITY OF QUEENSLAND AUSTRALIA | Sustainable Minerals Institute

Imperial College London | Storage Lab

Huisman

VINCI ENERGIES

Electrical Machinery OEM
Motor generators, drivetrain, grid connection

Heavy Lift OEM
(Mining / offshore)
Winches, cables, heavy integration

Drilling / EPC Contractors
Geological expertise, project delivery

Public support
UK, Scotland,Europe

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Industrial consortium

Customers - utilities, grid, mines
Market pull

R&D

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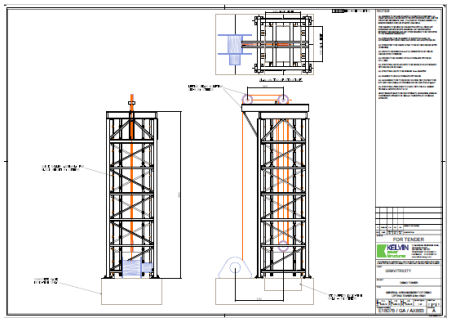

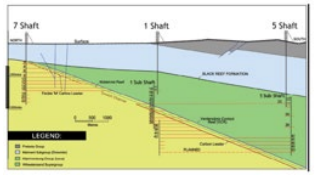

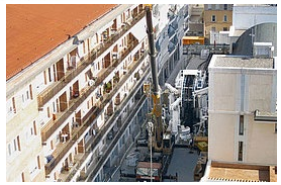

2013	2016-17	2019-20	2020-21	2021 -

Proof of Concept

- Underlying dynamic analysis
- Proof of market
- Patents x2

Detailed Modelling & Commercial Feasibility

- Full system simulation
- Business Plan developed
- Design for market
- Detailed de

Concept Demonstrator 250kW

- Modelling validation
- Pl
- (single module)
- Proof of commercial characteristics (response time etc)
- Control System development

Full-scale prototype 4-8MW

- Full system integration (multiple modules)
- Mineshaft HSE / consents
- Weight structure and installation demo
- Multi-module control system
- Proof of commercial operation (via aggregator)

Mineshaft Projects

- Own projects
- Equipment sales
- Licencing

New Shaft Projects

- R&D from 2020
- Projects from 2025

Disused shafts at operating mines
Shafts at closing mines
Shafts at disused mines

Existing Shafts

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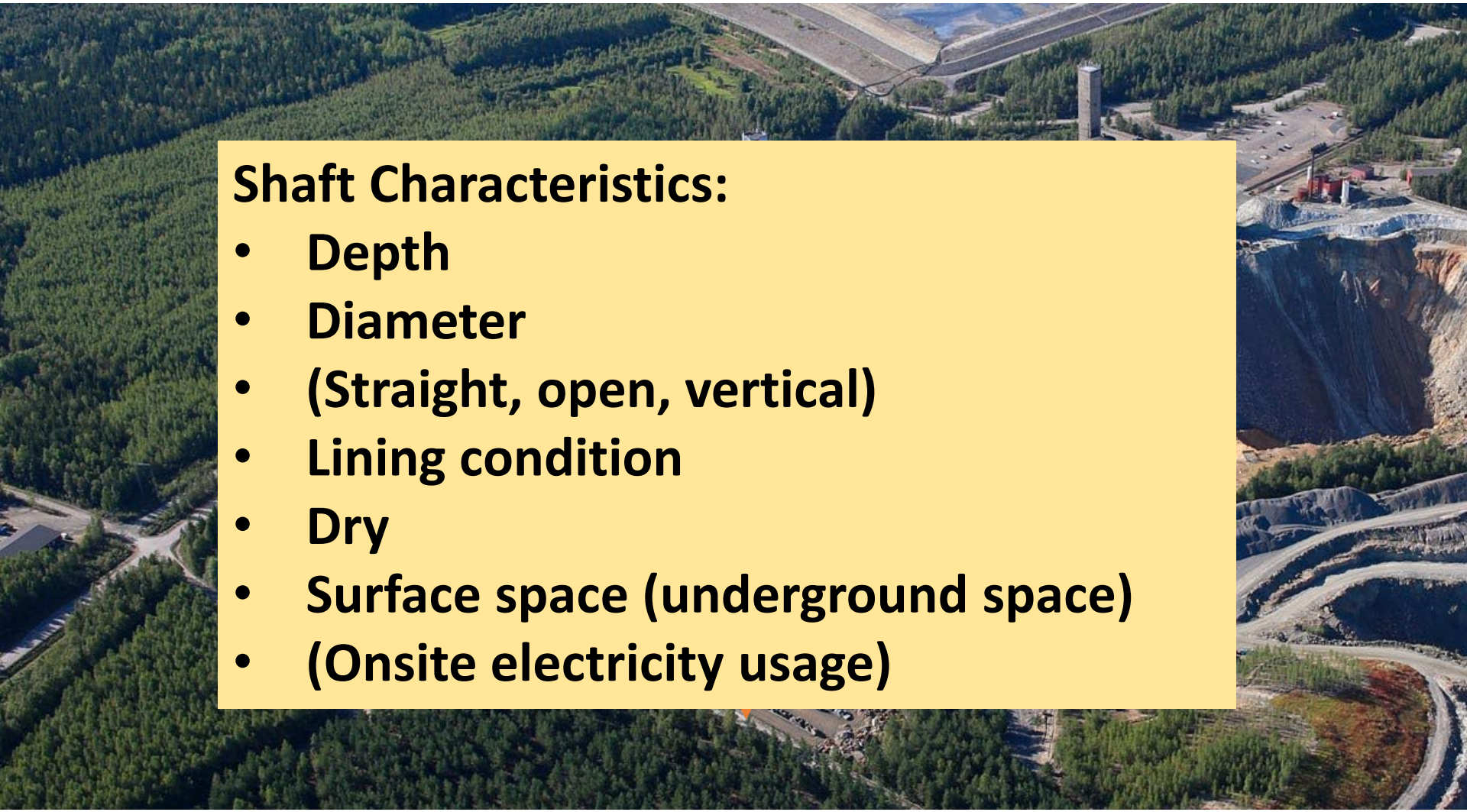

Shaft Characteristics:

- **Depth**
- **Diameter**
- **(Straight, open, vertical)**
- **Lining condition**
- **Dry**
- **Surface space (underground space)**
- **(Onsite electricity usage)**

https://callio.info/etusivu/about-callio/
1.4km deep

New Shafts (Open cast pits?)

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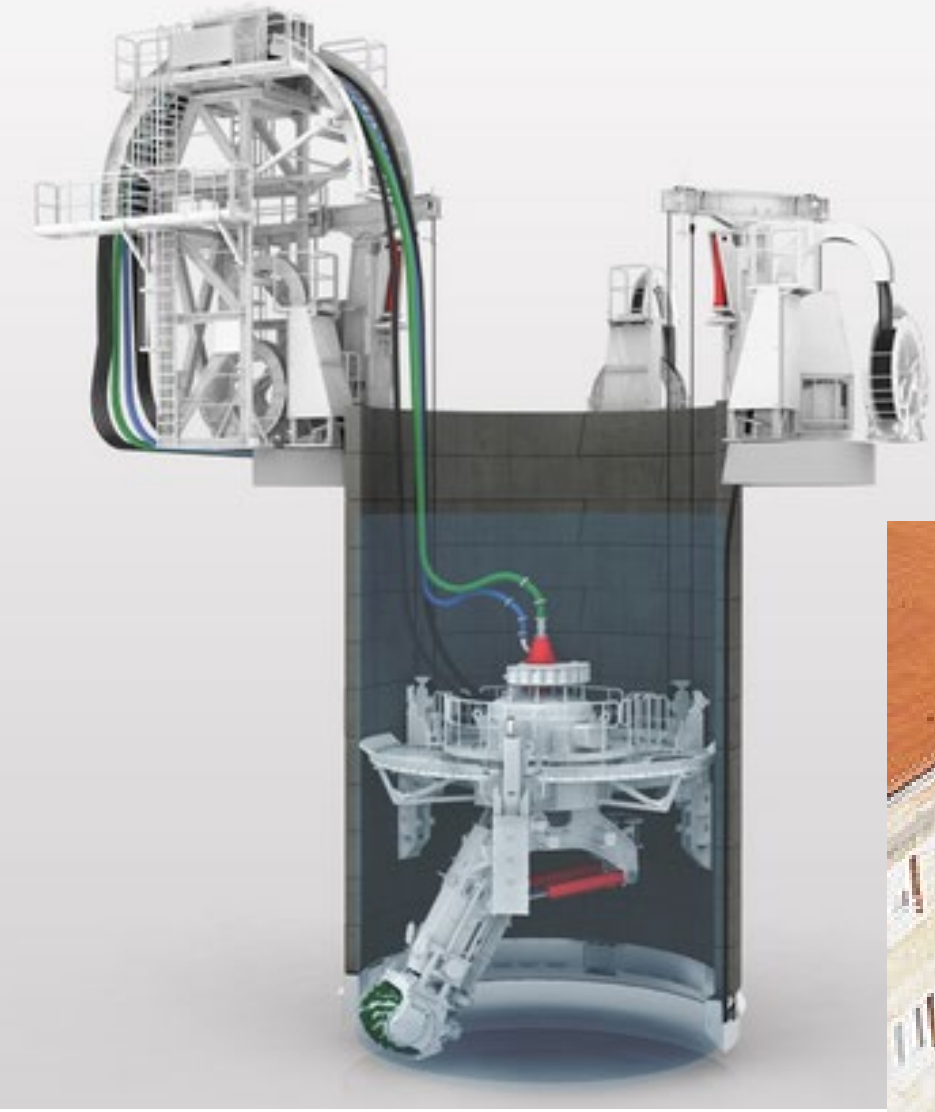

(Grid Spend: $277 billion in 2016.)

International Energy Agency ‘World Energy Investment 2017’

Image: Herrenknecht AG
VSM – 4.5m – 16m

A note on value

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POWER - 4MW/1MWh prototype

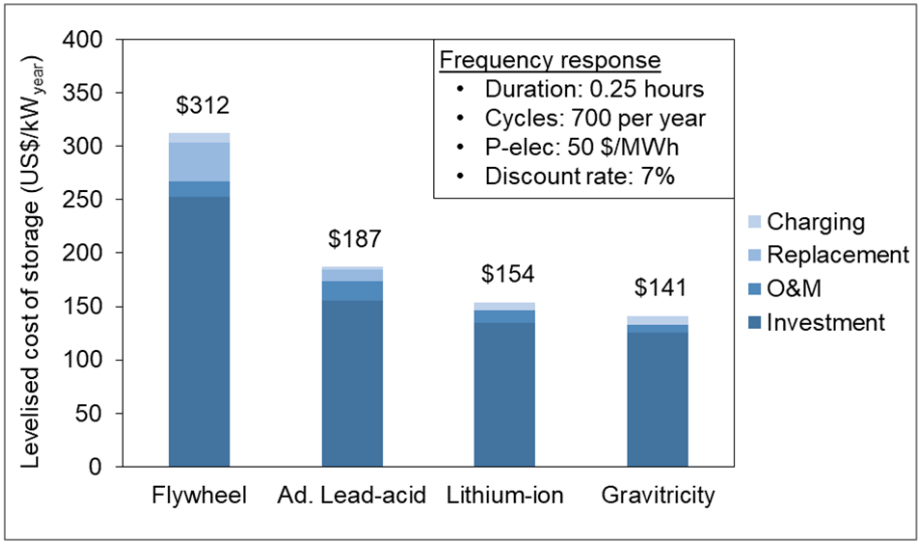
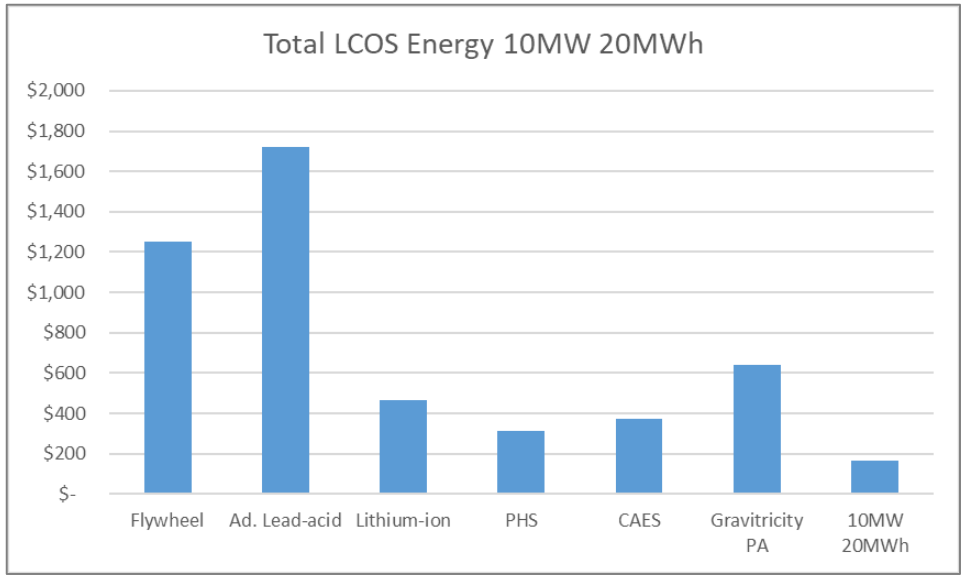


Figure 1 – Levelised cost of storage in power terms for the Gravitricity system and three comparison technologies in a frequency response application. Duration refers to the designed discharge duration of the storage systems. Cycles refers to equivalent full charge / discharge cycles per year in terms of energy throughput. P-elec – Electricity price relevant for Charging cost. O&M – Operation and Maintenance cost. Ad. Lead-acid – Advanced Lead-acid.

From Report *Levelised Cost of Storage for Gravitricity Storage Systems,* O Schmidt, Imperial College. March 2018. Project duration is 25 years.

ENERGY - 10MW/20MWh



Imperial College London Consultants

Storage Lab

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Versatile, long life, energy storage

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