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Alternative pathway for Mechanical Storage

Rui Shan

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Basic Mechanism

Commercial Demonstration Unit (CDU) in Switzerland, completed construction in July 2020, now under final testing and software commissioning.

- Moving concrete bricks up and down

3D demonstration

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Public available parameters

- 20-80MWh, with 35MWh as default (CDU)
- 35 tons composite bricks
- 4-8MW for 8-16hr
- 30+ year life with zero degradation
- 85% (80-90%) round trip efficiency (RTE)
- Also developing a more modular and flexible product with faster response time and wider range of capacity (1MWh-GWh)
- 200-250 $/kWh[1] (Capex or LCOE or LCOS?)

1. https://www.greentechmedia.com/articles/read/energy-vault-stacks-concrete-blocks-to-store-energy

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Other info we might need

- Details of capex and opex; (PCS, BOP etc.)
- Their growth with the single project size
- Construction time and estimated permitting time
- Quantity of the bricks (at least) for CO2 accounting
- Jobs per project by phases
- Wind proof, stability and resilience to disaster
- Response time (start-up, ramp, mode switching)
- Capability of blackstart, voltage support and other services
- Expected value position and revenue composition

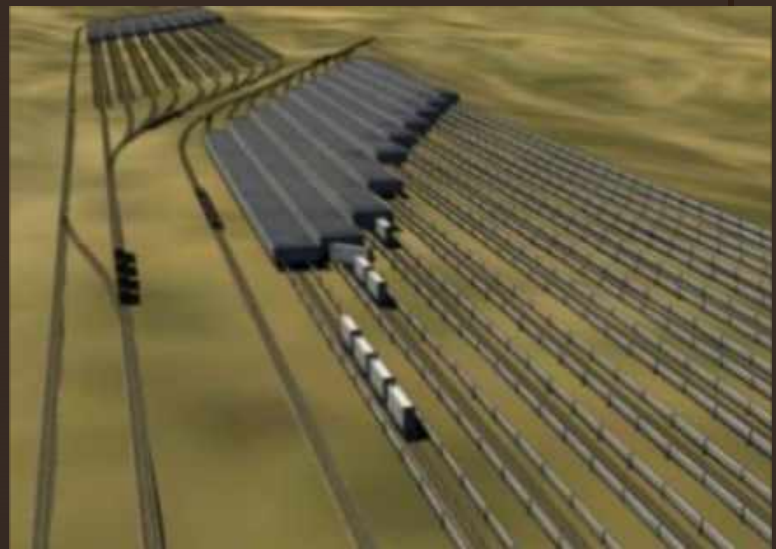
From lab demonstrations to pilot projects

Other Gravity Storage Technologies

Advanced Rail Energy Storage

https://www.aresnorthamerica.com

- A heavily loaded locomotive that drives up and down a hill to storage and generate energy;
- Founded in 2010; Complete demonstration project in 2013 Tehachapi, CA; Began a commercial project in 2016 at Pahrump, NV, 2.5 yrs to get land and other permits , planned operation in 2020, participating CAISO.



Advanced Rail Energy Storage

General Specification

- Scalability: 100-3000MW
- Storage duration: 2-24hr
- Response time:
  - Charging from 0-100%:5 sec
  - Discharging from 0-100%:25 sec
  - Full charge to full discharge:7-34 sec
- RTE: 80%
- VAR capability: 25 – 125% of rated power
- System life: 40+yr
- Able to provide frequency response
- ~1350$/kW, ~168$/kWh

Advanced Rail Energy Storage

Specification of the NV project

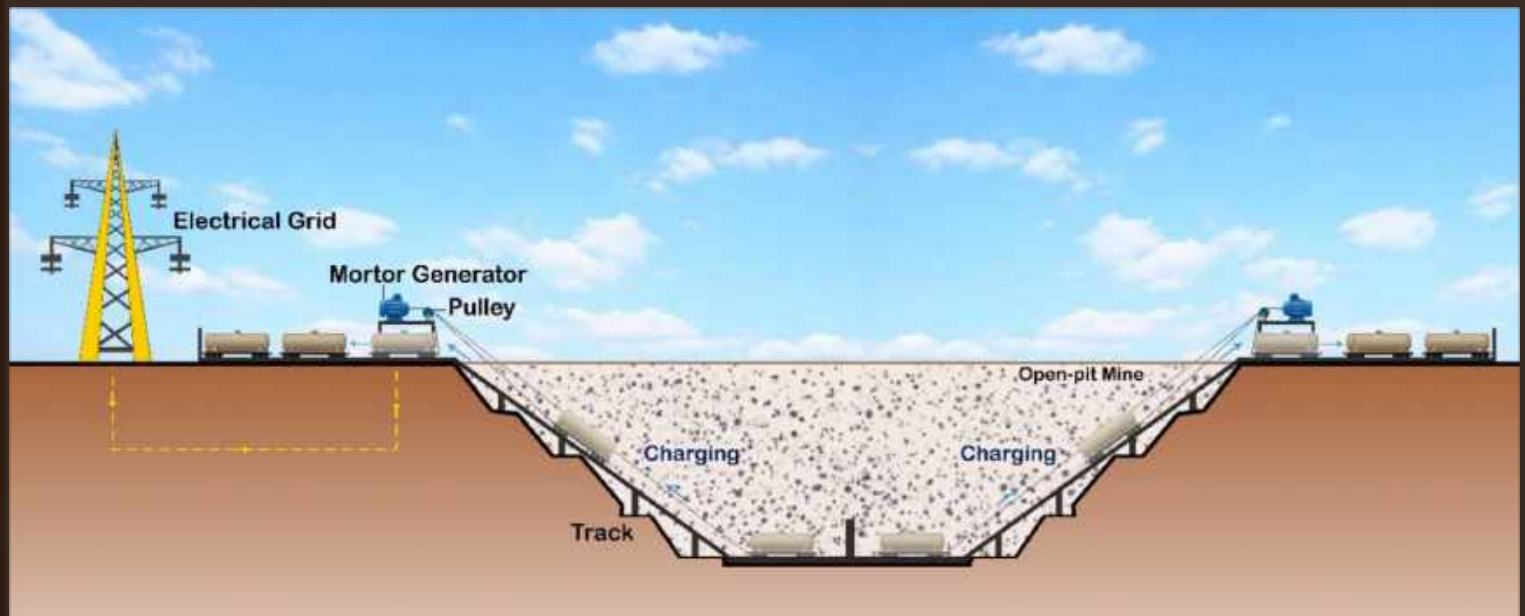
- Electric:
  - Energy: 12.5 MWh,
  - Charging 56.7 MW,
  - Discharging: 44.1MW
  - Power factor of load: 0.95
  - RTE: 80%
- Plant and Train
  - Length of track: 5.5mi
  - Elevation Differential: 2000 ft
  - Max Grade: 8%
  - Area: 43 acre
  - Total train weight: 9280 tons
  - 0 to full charge: 10s
  - 0 to full discharge:15s
  - Average speed: 18mph
- Social Economic
  - Project cost: 55 mm$
  - Construction: 100-125 full time equivalent (FTE) for eight months
  - Operation:16 FTE for 30-40 yrs

EarthPumpStore

Backed by Prof. Saffa Riffat from University of Nottingham. Got patent in 2019.

Estimated cost ~50$/kWh

Estimated RTE as 90%

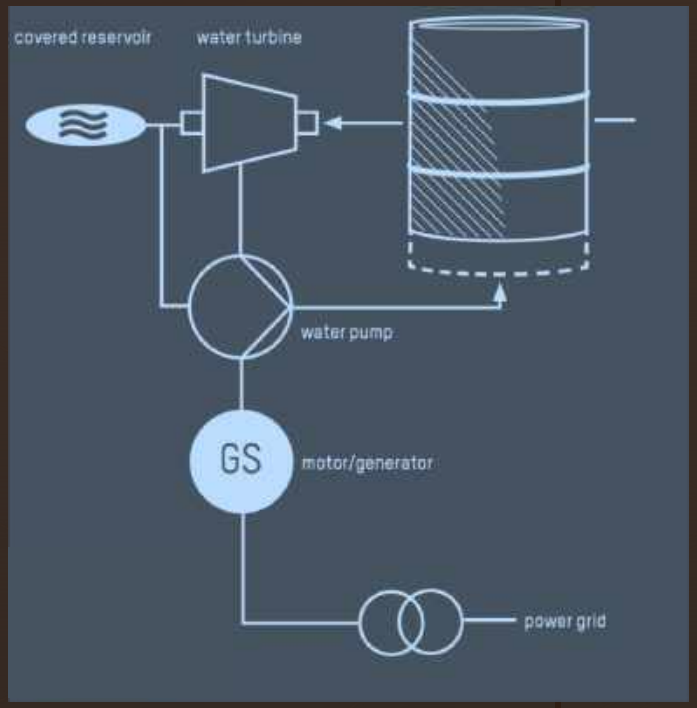


Heindl Energy

https://heindl-energy.com

Underground pumped storage with a large rock

Just filed for insolvency in 2020, IP and some engineering work sold to an interim investor. Still looking for investor for a pilot project.



Heindl Energy

General Specification

- Scalability: 1-10 GWh
- Duration: 6-14 hrs
- Life span: 60yrs
- Rock piston should have a diameter of at least 100 meters/ 300 ft to be economic competitive
- 8GWh~ 250m diameter
- Capex: 120-380 $/kWh
- Opex: 1% of Capes per year
- RTE: ≤80%
- Services: Blackstart, Voltage support, frequency regulation etc.
- Already identified 54 sites from 117 available sites internationally

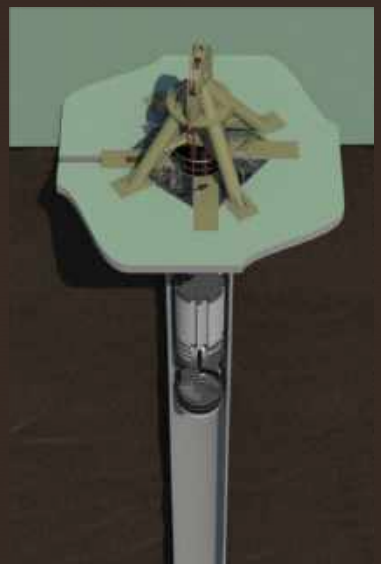
Energy SRS

https://energysrs.com

Lifting mass in a deep vertical shaft or borehole.

Funded by UK Research and Innovation and five UK companies from Jan 2017 to Mar 2020.

It is currently exploring commercial opportunities in Sub-Saharan Africa and South Asia



Gravitricity

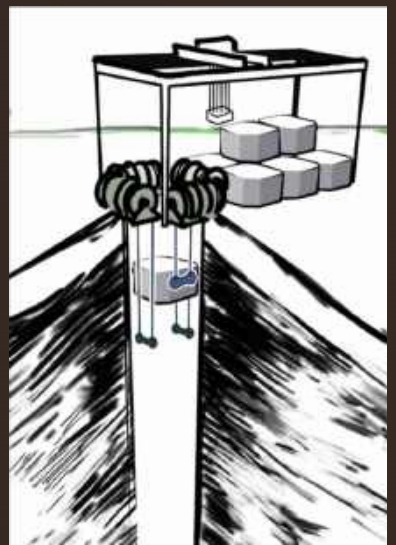
https://www.gravitricity.com/

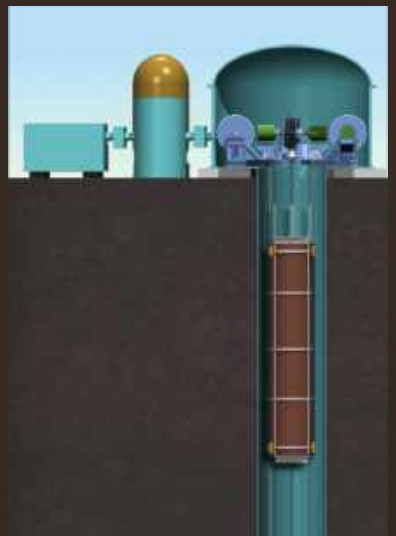
Similar to Energy SRS.

Start Building 250kw proof of concept in Edinburgh, Aug 2020. Around 1.1 million Euro.

Plan first full-scale 4MW project commence in 2021.

1-20MW, 15min-8hr,80-90% RTE, zero to full power~1s





Sink Float Solutions

http://sinkfloatsolutions.com/

Put similar system in ocean

Capex 250-500 € /kW, 15-60 €/kWh

Underwater Powerline: 1 k€/MW/km (>50MW)

Lifespan: 15yr for some components, 20yr for floats