Versatile, fast response, long Life Energy Storage

Robin Lane
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World Bank Energy Storage Partnership
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Technology overview

“Like hydro, but we don’t need mountains or water”

“New engineering, new integration, but not new science”

Surface equipment - Heavy lift equipment / working as a generator in reverse / weight management

Underground equipment: Cables, weight and shaft
Design of technology underpinned by scientific principle

E=MGH... Energy = mass x gravity x height

2 design principles

Heavy weights
- Tonnes? ✗
- Tens of tonnes? ✗
- Need weights in hundreds of tonnes to generate interesting amount of electricity ✓

Big drops
- Cranes? ✗
- Buildings? ✗
- Going underground allows us to use the geology of the earth to hold up the weight* ✓

* Existing shaft depths may be 800m or 1km. New, purpose built shafts, at c.250m, will be less deep but will be larger diameter of 8m or more
Timeline of achievements & next steps

**2018-2021**

- **> £3.5m**
  - Total R&D funding

- **> £4m**
  - Raised in equity funding

- **7**
  - Patents filed (4 granted, 3 pending)

- **2**
  - Independent studies by Imperial College London verifying levelised cost of storage over 25 yrs below Li-ion, CAES, Flow batteries

- **1**
  - Grid connected, 250kW Concept Demonstrator validates technology capabilities (s response, multi weight system)

**2021-'24**

**Full scale, 'first of a kind' commercial deployment**

- Evaluation of potential sites underway in Czechia & Poland
- 4MW / 1MWh, single weight system designed to optimise revenues from balancing services
- Series A, Tranche 2, scheduled for 2022, seeking £6-£10m
250kW Concept demonstrator

Gravitricity battery generates first power at Edinburgh site

By KevinDone
BBC Scotland's environment correspondent

21 April

This 'giant battery' has generated electricity for the first time.

A project to create electricity from gravity has generated its first power at a demonstrator site in Edinburgh.
Gravitricity vs. alternative ES technologies

- Lifetime
- Round trip efficiency
- Non degradation in performance
- Standing losses / parasitic loads
- End of life costs
- Location flexibility
- Speed of response (<1s)

Lithium Ion
Pumped Hydro
Gravitricity
## Gravitricity vs. alternative ES technologies

### Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Feature / benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economics</strong></td>
<td>• High efficiency, every year (no degradation)</td>
</tr>
<tr>
<td></td>
<td>• Long life</td>
</tr>
<tr>
<td></td>
<td>• No standing losses or parasitic loads</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>• Rapid response (&lt;1s) for lucrative fast response markets</td>
</tr>
<tr>
<td></td>
<td>• Versatile energy / power ratio (15 mins – 8 hrs)</td>
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<tr>
<td><strong>Implementation</strong></td>
<td>• Low embedded carbon footprint (no ore mining)</td>
</tr>
<tr>
<td></td>
<td>• No explosive chemistry</td>
</tr>
<tr>
<td></td>
<td>• Small footprint</td>
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### LCOS Formula

\[
\text{LCOS} = \frac{\text{Capex (initial) + Capex (replacement) + O&M + Charging cost}}{\text{units generated}}
\]

*Note: End of life costs are not included.*

### Graph

- **Sodium sulphur**
  - Charging: $532
  - Replacement: $367
  - O&M: $310
  - Investment: $274
  - Total: $171

- **Lithium ion**
  - Charging: $532
  - Replacement: $367
  - O&M: $310
  - Investment: $274
  - Total: $171

- **Compressed air (tanks)**
  - Charging: $532
  - Replacement: $367
  - O&M: $310
  - Investment: $274
  - Total: $171

- **Flow battery**
  - Charging: $532
  - Replacement: $367
  - O&M: $310
  - Investment: $274
  - Total: $171

- **Gravitricity energy-design**
  - Charging: $532
  - Replacement: $367
  - O&M: $310
  - Investment: $274
  - Total: $171


**Long-life, reliable, energy storage for Critical National grid support infrastructure**

*LCOS = (Capex (initial) + Capex (replacement) + O&M + Charging cost) / units generated; n.b. no end of life costs are included*
Behind the year on year growth, we see three key trends changing the shape of the energy storage market in years to come:

**Key trends in global large scale energy storage market**

- **Longer duration**
  - Increased renewable penetration will drive need for longer duration energy storage – average duration of 1.8 hours in 2013 has already grown to 3.3 hours
  - Ancillary services ... daily peak shaving ... solar & storage for 24/7 power

- **Longevity of service**
  - Growing vision of storage as an infrastructure asset, with associated requirements for asset lifetime
  - Short term opportunism vs. long term strategic

- **Higher cycling**
  - Storage increasingly used to balance fast changing, localised variations in supply & demand
  - Fast changing = need high cycling
Our Single weight system has been focus to date; other variants entering product roadmap

<table>
<thead>
<tr>
<th>Variant</th>
<th>Description</th>
<th>TR Level</th>
<th>Existing / new mine</th>
<th>Work to date</th>
<th>Work underway</th>
</tr>
</thead>
</table>
| 1. Single Weight                   | Gravity based electricity storage deploying single weight                   | 5/6      | Both                | • Imperial College (2018) validates cost competitiveness  
• Concept demonstrator            | Actively assessing sites for ‘first of a kind’ full scale commercial deployment |
| 2. Multi weight                    | Gravity based electricity storage deploying multiple weights               | 4/5      | New                 | • Imperial College (2019) validates cost competitiveness                                              | Funded FEED development now under way                                        |
| 3. Single weight w/ hydrogen       | Mine shaft deploys single weight system and stores hydrogen                | 3        | New                 | Preliminary analysis undertaken  
|                                    |                                                                             |          |                     | Working with Arup to develop FEED (BEIS Funded project)                                               |                                                                                  |

Other possible variants include interseasonal heat storage, and adaptations for open cast mines, boreholes and raised bore mining
Targeting four markets with distinct use cases, customers and areas of value

<table>
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<tr>
<th>Description</th>
<th>End Customer</th>
<th>Value to End customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Grid services&lt;br&gt;Power or energy for grid balancing &amp; frequency regulation</td>
<td>• DNOs / TSOs</td>
<td>• Ensuring quality &amp; security of supply&lt;br&gt;• Longevity of operation</td>
</tr>
<tr>
<td>2. Co-location&lt;br&gt;Coupling storage and large scale renewable generation at same site</td>
<td>Solar farm owners &amp; operators, asset optimisers</td>
<td>• Time shift solar supply to high price peak periods&lt;br&gt;• Reduced connection costs&lt;br&gt;• Revenue stacking (voltage control)</td>
</tr>
<tr>
<td>3. Commercial &amp; industrial&lt;br&gt;Supporting industrials to decarbonise operations</td>
<td>• Mining&lt;br&gt;• Oil &amp; Gas&lt;br&gt;• Data centres</td>
<td>• Reducing grid demand (Triad or similar)&lt;br&gt;• Resilience / reliability of supply&lt;br&gt;• Ancillary service income</td>
</tr>
<tr>
<td>4. Energy Access&lt;br&gt;Designed into mini grids delivering energy access to rural and off grid communities</td>
<td>• Utilities&lt;br&gt;• Mini grid developers</td>
<td>• Mini grid integration&lt;br&gt;• Improves energy access to off grid communities, esp. during non daylight</td>
</tr>
</tbody>
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* Connection costs based on capacity not throughput, which means developers have to choose between having to curtail at times or paying costs for a capacity they rarely use. Particularly acute with solar, with c. 12% load factor (av. output / peak output)
Selected use cases & local demand drivers support selection of key geographies:

- **IUK funded EC7 feasibility study now complete**
- **Discussions ongoing with mine owners & other stakeholders**
- **Feasibility study underway** in India
- **Site evaluations underway. Probable site for first full scale deployment** in the UK
- **LD FEED Study underway** in South Africa
- **Feasibility study underway** in Chile

Primary target markets:
- Australia
- South Africa

Secondary target markets:
- India
Is Energy Storage a format war?

Format wars – one problem, two solutions

1. At Gravitricity, we don’t think so!
2. Identifying characteristic of energy storage is the variance in requirements:
   - Duration
   - Energy & Power
   - Location
   - Conditions
   - High / low cycling
   - Importance of efficiency
   - Durability and longevity
   - Capex vs opex … and more

Different requirements = different technology solutions
Thank you

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