# GBES – Ground-Breaking Energy Storage

## Introduction (GBES-01)

Put simply, GBES will provide affordable electrical energy storage on a scale that removes all operational restraints to the most ambitious targets for low carbon electricity. It will also bring all the usual benefits of high power, high energy storage.
**But only if it works, of course – are there any fatal flaws?**

## WHY IS STORAGE SO IMPORTANT?

Electrical energy storage is towards the top of most lists of “technologies-that-will-change-the-world”. It certainly makes life easier for the electricity supply industry, helping to match supply and demand, cope with intermittent renewables, improve asset utilisation, maintain stability/security and much more. This translates into a major business opportunity. The global installed capacity of grid-scale storage has a replacement value of ~$300 billion. Many observers expect this to pass the trillion dollar benchmark before 2050.

There are numerous grid-scale storage technologies, but pumped hydroelectric storage (PHES) accounts for more than 95% of the present installed capacity. This is despite the fact that few networks can accommodate PHES, which requires terrain suitable for moving water between large reservoirs with a difference in elevation of several hundred metres. Even when suitable sites are available, many PHES proposals are defeated – it is extremely difficult to get approval for large hydro projects (often in sensitive areas) and their transmission links. No prizes for guessing the proportion of the last $100 billion of PHES proposals in the USA that are actually under construction!

GBES aims to meet or beat PHES commercial and performance benchmarks. More importantly, it has much lower environmental/social impact and does not need mountains. It can be located near load centres or other strategic points in the transmission network. It can be constructed in flat or hilly terrain, in deserts or even under water. It can be used in stand-alone storage projects or integrated with large-scale renewables, public water supply, flood control or coastal protection schemes.

## THE OPERATING PRINCIPLE

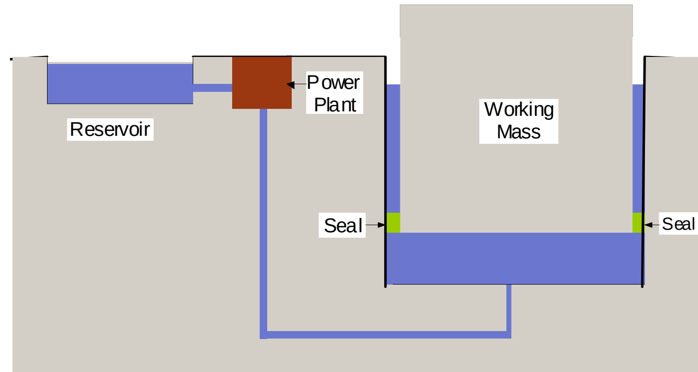
The principle is simple. For context, 20 gigawatt-hours (20GWh) is a useful amount of energy for a network – it might keep a city of one million going for a day in Europe or for half a day in the USA. A typical 2GW PHES project could store 20GWh by pumping 20 million tonnes of water 400m uphill over a period of 10 hours. The project value would be several billion dollars. In the absence of a suitable mountain, we could get the same result by pumping 400Mt of water up a 20m hill. That would be absurd because of the huge cost of reservoirs the size of small countries. We would not need reservoirs if we were to raise a 400Mt concrete disc by 20m – but the disc would be far too expensive (even if we could work out how to lift it).

**However, since we live on a rocky planet, we might be able to make a comparable disc quite cheaply by excavating a tiny amount of material from around a disc shape.** In this case, “tiny” still equates to millions of tonnes, but that is not too daunting – the world’s extractive industries dig up about five million tonnes every hour.

And, of course, excavation means that GBES really is a Ground-Breaking Energy Storage concept!

GBES incorporates the components of a gravitational storage system in a single construction:

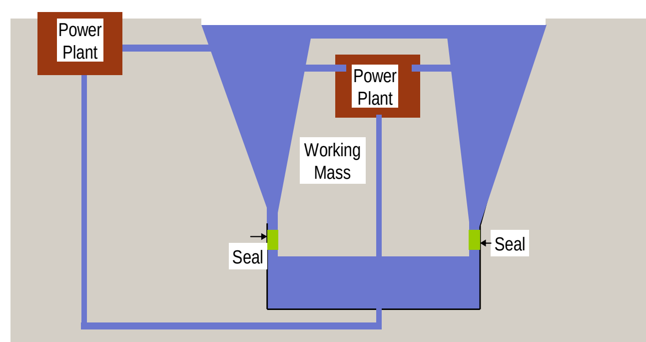
- The working mass (the disc or piston)
- The containment system (the cylinder in which the piston moves)
- The support mechanism and working medium (using water as the hydraulic fluid)
- The energy conversion system (hydro-electric pump-turbines / motor-generators / ancillaries).




The concept is straightforward and construction looks simple. In practice, the method and sequence would differ greatly from this highly simplified outline but, in essence:

- Excavate and reinforce a deep trench to form the periphery of the piston and the cylinder wall.
- Excavate horizontally to form and reinforce the base of the piston.
- Install a seal between the trench and the working area beneath the base.
- Store energy by pumping water into the working area to raise the piston in the cylinder.
- Recover the energy by releasing the water through hydroelectric generators.

The concept is versatile, with many possible configurations of reservoir, working mass and power plant. For example:




– The walls need not be vertical, above the travel zone, easing issues relating to construction tolerances, reinforcement and local geology.

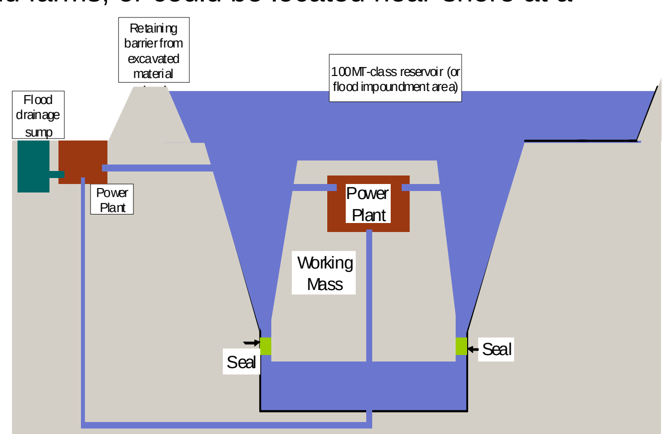
– A large piston might accommodate some (perhaps all) of the power plant, providing short, cheap pressure tunnels and more piston control options.

– The piston could be excavated within the reservoir, reducing the footprint and cost.

– It could be submerged to be unobtrusive and aesthetically pleasing (the reservoir level remains constant, avoiding the unsightly cyclic drainage issues of PHES).

– It could be used to upgrade an existing PHES plant, or to add energy storage capability to a conventional hydroelectric station, without requiring additional reservoir capacity.

– We could dispense with a dedicated reservoir altogether and use a lake or the sea instead (the piston would fit within turbine separation distances in offshore wind farms, or could be located near-shore at a coastal or lakeside load centre).




– Alternatively, we could accommodate a large public water supply reservoir above the storage system, using the excavated material to create a retaining barrier around a substantial area (e.g. thousands of hectares inside a 10-20 metre barrier).

– A similar arrangement could store surplus seasonal water or be used for flood relief, temporarily using part of the power plant to pump external water into the impoundment area. Energy supply and water management rank amongst the century's greatest challenges. A technology that tackles two high-value issues could be useful in sharing costs and gaining support (unlike energy storage, flood control and water provision have tangible and popular local benefits).

# HOW BIG IS IT?

For given targets (e.g. 2GW and 20GWh), key parameters are the height and diameter of the piston and the vertical travel distance. Piston height determines the operating pressure. High pressures result in physically smaller hydroelectric equipment, reservoirs and tunnel diameters. PHES pressure is limited by terrain. There are few examples above 7MPa (70bar or ~700m head) and very few above 10MPa / 100bar / 1000m head).

Briefly, we are dealing with large constructions with dimensions of 100s of metres, moving extremely slowly (please ask for note GBES-02 for a fuller technical description). To give an idea of scale:

- A piston height of 500m would provide a working pressure of about 7.5MPa or 75bar at the power plant.
- If we also choose a diameter of 500m, a 2GW system could store 20GWh by pumping around 10Mt of water to raise the piston 40m over ten hours (at just over 1mm/sec).
- A 700m diameter piston could do the same, rising 20m over ten hours.

Other interesting features (ask for GBES-02) include:

- Additional energy can be stored at low cost with small changes in configuration and greater lift height. If needed, a GBES design could deliver power at rated output for 30, 100 or 300 hours. There is little need for long duration at this time, but that will change (for example, to cover multiple days of low wind conditions).
- GBES can incorporate asymmetric cycling – "fast-charging" at a multiple of the turbine rating
- Utilisation equivalent to >3,000 annual hours power delivery at rated output is entirely feasible (most storage systems have to pay for themselves with ~1,000 hours of annual power delivery).

GBES structures should be realistic, despite their size. Manufacturing a piston and retaining cylinder of this size would be out of the question. In comparison, we have to remove only a small amount of material to make an equivalent geological working mass. Also, removal (quarrying / mining) has far lower $/tonne costs than manufacture (concrete / structural materials). Finally, you have to pay people for concrete, but people may be prepared to pay you for quarried rock.

# WHAT COULD POSSIBLY GO WRONG?

It's easy to make compelling cases for new energy technologies: so easy that the development path is littered with expensive failures. GBES has attractive features, but we also need to look at pitfalls:

### Are there practical and affordable solutions to the engineering challenges?

It will take extensive (and expensive) proof-of-concept work to provide a definitive answer and there are bound to be concerns with anything on this scale. However, there appear to be plausible solutions to all the problems considered so far (e.g. construction methods, sealing systems, stability). **We may be wrong, of course, and we would welcome your advice – is the idea stupid rather than smart, and what are the issues that are most likely to kill the concept?**

### Assuming GBES is developed successfully, would there be a worthwhile market?

1. PHES dominates the ~$300 billion grid-scale storage portfolio **(True)**
2. PHES is excluded from much of the world and approval difficulties limit progress in the rest **(True)**
3. GBES will be a shoo-in if it can remove these constraints and beat PHES on cost/performance **(False)**.

In fact, the market will be very different by the time that commercial GBES might make an entry:

- Large-scale storage will lose its stranglehold on the market. There is strong interest in smaller-scale distributed assets (both generation and storage), which can be located throughout the network.
- Many attractive storage technologies are under development. Some will set competitive benchmarks for large-scale storage. Others will focus mainly on lower powers, accelerating growth in distributed resources.
- Alternatives to storage, providing similar benefits, will take part of the available business.

Large-scale systems will continue to hold an important position in the market, but GBES-type technologies will face stiff competition, even in areas where PHES cannot be used.

### How difficult would it be to develop a commercial GBES system?

Storage has been an outstanding area for cleantech investment, but relatively little has been directed at new high power technologies. These are more difficult because of the extra risks associated with long timescales, high development costs and lack of small niche applications that can be used to gain experience and early revenue. GBES is inherently a high power technology. It scales up brilliantly, but this means that it scales down badly.

## Would GBES be outgunned by similar geological energy storage systems?

At least three other programs share the same principle, with different starting points within the past ten years or so.
**GBES started in 2007 as an idea for GW-class seabed storage** for use within large offshore wind turbine arrays – an interesting and topical application, although not a sensible market entry point.
**Gravity Power** is probably the longest established and furthest advanced, initially based on relatively small diameter pistons fabricated from high density concrete, moving a considerable vertical distance in very deep shafts. The present focus is on larger units (up to about 100m diameter), introducing the option of either geological or fabricated pistons.
The **Heindl Energy GmbH** program has been based on geological pistons from the outset, including extremely large designs as well as systems on the same general scale as GBES.
**Grid Energy Storage** is a more recent Texas-based entrant – we are not aware of a website URL at this stage.
Other gravity and hydro systems (mainly smaller scale) include JolTech, ARES, Subhydro and MIT.

The existence of other programs, especially those based on the same operating principle, is encouraging. It adds credibility to what might otherwise be seen as an eccentric idea. Diversity of design features and configurations improves the chances of finding practical engineering solutions. Competition also helps gain market acceptance in a sector that would be very averse to a supply chain dependent on a single technology provider. In any event, if there is a market for this, it will be on a scale that can support multiple suppliers. This does not guarantee a place for the original developers – historically, very few originators survive amongst successful suppliers of new energy technologies.

EscoVale has no ambitions to be a supplier or to hold intellectual property in this area. We believe that GBES offers unique advantages (see also GBES-02) and would welcome an opportunity to cooperate with others interested in developing GBES-type systems, subsystems and components, or in exploring the concept further.

# WHAT HAPPENS NEXT AND HOW CAN YOU HELP?

**We would be very interested in your first impressions.** Development of a technology on this scale would be costly, difficult and risky, but we have not found any reason to abandon the idea so far. **Are we wrong and, if so, what obstacles are likely to be insurmountable?**

If it is worth taking this further, a proof-of-market study is the logical next step:

1. It is vital to see if there is a genuine opportunity, given the changing market structure and future competition.
2. The proof-of-market study is manageable and does not depend on external funding. We can probably recover the costs, but it can be undertaken with internal resources if necessary.
3. EscoVale plans to transfer its interests to an entity with appropriate expertise and resources, if the concept still seems viable after this step. That might involve a single organization or may be of interest to a wider group comprising energy suppliers, technology companies, government agencies, research centres, investors and other parties.

It is too soon to say whether there would be any point in proceeding further, but we would welcome contact from **organizations with technical expertise or commercial interests relevant to work in this area.**

| Step | Questions to be answered before committing to the next step | Cost |
|---|---|---|
| **Inception** | Concept formulation. Design outline and initial consideration of construction, subsystems and economics. What are the main problems? Are there fatal flaws? | Internal (~10k hours) |
| **Proof-of-Market** (in progress) | How large is the accessible market? Could commercial geological piston storage capture a worthwhile share in competition with well-established contenders and attractive new entrants? What are the critical performance and cost benchmarks? | \$150k-\$250k |
| **Proof-of-Concept (A)** | Can industry experts suggest and improve on plausible and affordable solutions to technical and commercial problems that would be faced during development? | ~\$1M |
| **Proof-of-Concept (B)** | Can these solutions be demonstrated convincingly in test rigs, by computer simulation or by other means? | >\$10M |
| **Proof-of-Concept (C)** | Do trials with a modest pilot system prove the concept, meet performance targets and provide a sound economic case for a commercial product? | >\$100M |
| **Demonstrator** | Does a larger-scale pre-commercial unit operate reliably and to specification? What refinements can be incorporated in commercial systems? | >\$1bn |

Please let us know what you think at frank.escombe@escovale.com or phone +44 1737 230820.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