Dear Sir/Madam,

I would like to respond to question 38 and 40 of the consultation document

Question 38. Are there further aspects of storage or other storage technologies we should consider when looking forward to 2020?

Question 40. Is our mapping of technology to Balancing Services reasonable?

Isentropic has designed a system that uses the Isentropic heat pump to store electricity in thermal form ("Pumped Heat"). The storage comprises two large containers of gravel, one hot (500C) and one cold (-150C). Electrical power is input to the machine which compresses/expands air to 500C on the hot side and -150C on the cold side. The air is passed through the two piles of gravel where it gives up its heat/cold to the gravel. In order to regenerate the electricity, the cycle is simply reversed. The temperature difference is used to run the Isentropic machine as a heat engine.

As you will see from the attached presentation we have very similar characteristics to pumped hydro, but with the ability to install in any location and any size.

Key features are

72% charge/discharge efficiency
1MW-1GW size installations possible
1-10 hours storage
Cost per kWh $125

This technology is being developed in the UK and has already attracted significant interest from utilities, wind turbine and pv manufacturers. I would ask that you include 'pumped heat' in your report tables 12 & 14 as one of the possible options for storage, along with a description of the technology.

best regards

James

--
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Isentropic Ltd.

Utility Scale Pumped Heat Electricity Storage

James Macnaghten, Isentropic

July 2009

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Who Are We?

- **Isentropic, Ltd.**
  - Pre-revenue
  - Cambridge, UK based private company
  - Developer of gas-cycle heat pump/heat engine

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What Does The Market Need?

- There is a need for utility scale storage solution that is:
  - ✓ Low cost
  - ✓ High efficiency
  - ✓ Not geographically constrained
  - ✓ Safe and environmentally inert
  - ✓ Modular and scalable
  - ✓ Rapid response to load variation
  - ✓ Very large number of cycles
- Isentropic's Pumped Heat Electricity Storage meets all these objectives.

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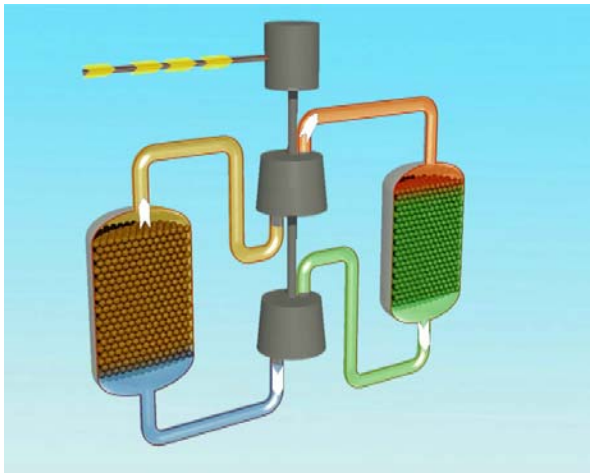
How Does it Work?

- Electrical energy is used to pump heat between 2 vessels
- The energy is stored as sensible heat (+500 deg C) and cold (-160 deg C) in solids (gravel) contained in the insulated vessels
- Electricity is recovered by reversing the process



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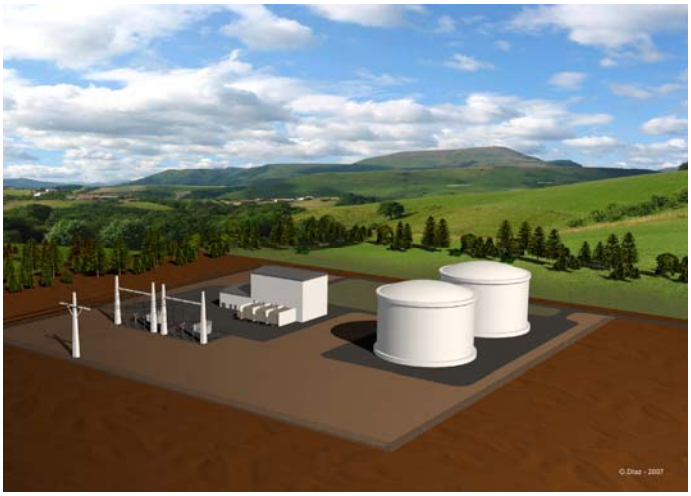
High Efficiency – High Density Storage

- 72% Charge/Discharge ("round-trip") Efficiency
- Energy recovery efficiency depends on the temperature difference and on the efficiency of the machinery
- The larger the mass the easier the insulation, the lower the heat losses
- 25 kWh/ton Energy Density – similar to Lead-Acid and Flow batteries



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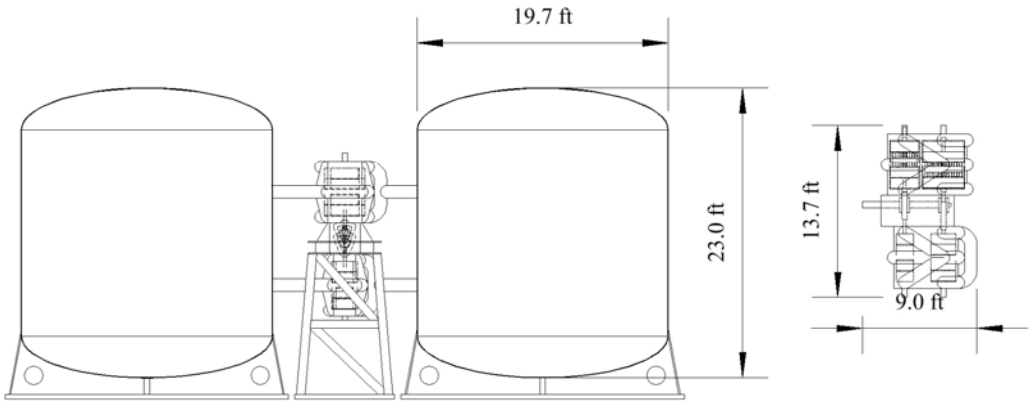
Heat pump and engine : Reciprocating equipment

2MW machine
9 MWh storage capacity



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What is the Isentropic Heat Pump?

- A reciprocating heat pump using the Ericsson cycle (developed in 1833, last used in early refrigeration ships)
- Major innovations using modern technologies and materials:
  - Machine layout
  - Piston structure
  - Valve design
  - Seal design
- The utility-scale heat pump only uses gas as its working fluid
- Exceptional efficiency over a wide temperature range at low cost
- Scalable power handling capacity, from 1MW to any size

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Low Cost

Type of Storage	Plant $/kW	Storage $/kWh*	$ for 6 Hrs	Capital $/kWh	$/kWh***
Isentropic Pumped Heat Storage	**450**	**50**	**750**	**125**	**0.017**
Pumped Hydro 1GW	600	37.5	825	138	0.019
Compressed Air Underground 300MW	580	1.75 + 146**	1467	244	0.033
Compressed Air Above ground 15MW	750	250 + 146**	3126	521	0.071
Na-Sulphur Batteries	500	350	2600	433	0.059
Flow Batteries	425	280	2105	350	0.048
Lead Acid Batteries	420	330	2400	400	0.055

* Assuming electricity stored is nil cost
**Compressed Air burns gas at ~100% efficiency due to the use of the pressurised gas. One kWh of gas currently costs $0.02. To get an equivalent storage cost, we capitalise the gas required for one discharge per day for 20 years = $146
*** Capital Cost per kWh divided by total hours used (assume 20 years life and 1 charge/discharge per day – 7300 hours)

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Not Geographically Constrained

- 2 x 140,000 m^3 LNG tanks in Bilbao constructed by Saipem
- Filled with gravel, these two stores would have a 11 GWh electrical storage capacity using pumped heat

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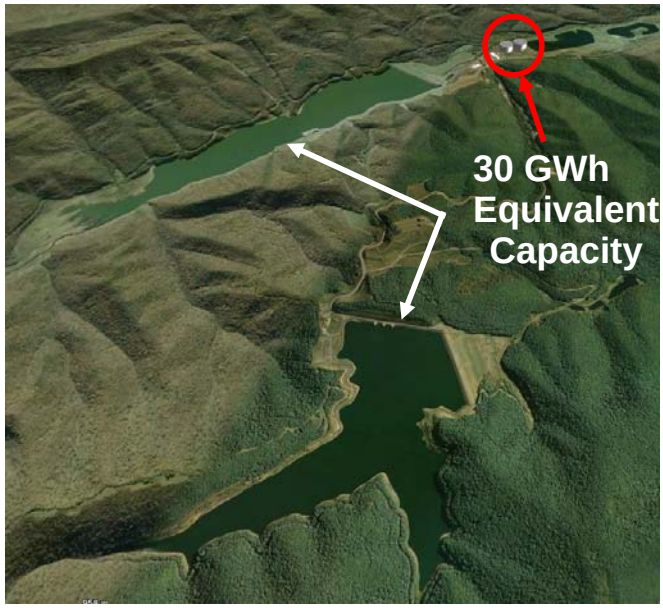
Compared to Pumped Hydro

- Bath County Pumped Storage, Virginia, USA. Two reservoirs covering 820 surface acres (3.32 sq. km)
- 30 GWh storage capacity (largest in world)
- Pumped Heat Storage Plant of same capacity would occupy 1/300th of the area



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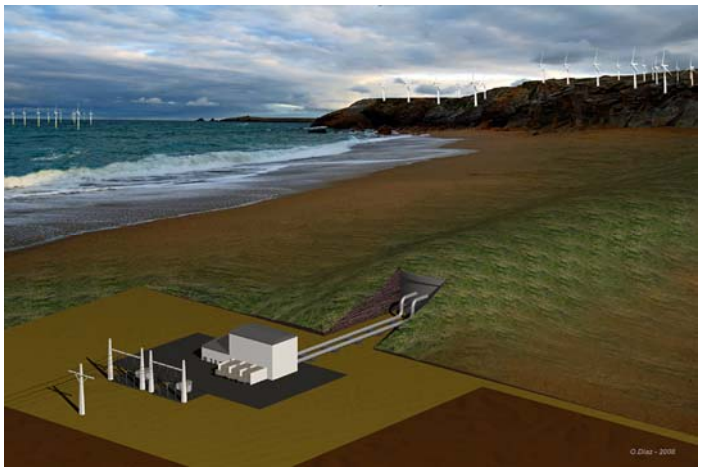
Rapid Load Response

- Zero power (spinning) to full power <1s
- Change from full input to full output mode <1s
- Suitable for a wide range of applications
  - ✓ Reserve Services
  - ✓ Renewables (Intermittent Matching)
  - ✓ Renewables back-up
  - ✓ Generation, Load Levelling
  - ✓ Ramping, load following
  - ✓ UPS



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Safe and Environmentally Inert

- No harmful chemicals – all inert materials
- No fire risk – safe to locate near major cities
- Construction materials can all be locally sourced

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Summary

- Lowest cost - $450/kW, $50/kWh = $125/kW for 6 hours
- Good efficiency – 72%
- No mountains, no caverns – place anywhere
- Safe and inert – locate near to load
- Scalable – From 100kW to very large size possible
- Sub 1 second response time
- Very large number of cycles

- Performance verified by two development prototypes
- Looking for demonstration project

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Pumped Heat Storage is Coming!

Thank you. Any questions?

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