Underground Energy Storage

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THE PROBLEM

Human development involves learning how to harness and store energy. We have only been able to live at seasonal latitudes, for example, because of agriculture: learning how to grow and store food for ourselves and our animals.

People and animals produce little of the power we use today, and plants no longer provide our main energy stores. Modern economies rely on an older energy store: fossil fuel, produced over millions of years from plants that grew before human beings ever evolved.

At current rates we will burn through this store in a few centuries, because fossil fuels, unlike the grain stores of ancient Egypt, are not replaced at anything like our rate of consumption. Burning them up entirely may even negatively disturb the balance of the atmosphere.

The Sun, the source of all the energy in both plants and fossil fuels, will always be there. The problem is that we have become dependent on an inexhaustible supply of energy, wherever and wherever we want it. Solar energy, whether direct or embodied in wind and water, is only available when and where it is generated.

So if we are to abandon fossil fuel as an energy store, we need new ways to store energy when and where it is available so that we can use it whenever and wherever we want.

THE GRID

The National Grid delivers electrical energy everywhere. This allows relatively few producers in relatively few places to reliably supply high-powered electricity to millions of homes offices and factories, wherever they are. The grid therefore solves (most of) the problem of having energy on tap wherever we need it.

But we still want energy available **whenever** we need it.

ENERGY STORAGE

Collective energy demand varies wildly over the course of a day, and a year. The UK's maximum electricity consumption is more than twice as high as its minimum, and it costs a lot to have generators that are idle most of the time. Shifting our electricity production to renewable energy makes this even worse.

Renewable energy generators like wind turbines and solar farms, have almost no “marginal cost” of production, so when they are producing power they do so at an overwhelmingly competitive price. This can (and does) render reliable fossil fuel generation uneconomic while failing to provide reliable continuous power. The answer, obviously, is to store renewable energy when it is available, in a manner that allows it to be instantly “dispatched” when needed.

Now we happen to have a storage battery in our own home that does just this but its purpose is to maximise our own use of our solar panel electricity, rather than make us independent of the grid. To be fully grid-independent today would require a fossil fuel generator as well.

For us and most other consumers, it makes more sense for there to be large capacity energy stores connected – as power stations are – directly to the grid. These could be sited near to large renewable generators like wind and solar farms, to store renewable energy that is surplus to demand at the time it is produced.

However, modulo the transmission losses incurred when electricity generation is separated from its consumption, a grid-level energy store can actually be sited wherever is most appropriate to the storage technology used. And that's important for the most efficient grid storage we have – pumped hydro.

PUMPED ELECTRICITY STORAGE

The Dinorwig pumped hydro station in North Wales was built to address the inflexibility of nuclear power generation rather than the intermittent nature of renewable power. Nuclear power stations do not meet wildly variable demand efficiently, and work best when operated continuously to service the minimum grid load.

So Dinorwig was built to keep nuclear power stations up and running at night – when demand is much lower. During the night off-peak electricity is used to pump water to an up-hill reservoir, from where it is released to generate electricity during times of peak demand using conventional hydro-electric turbines.

Nuclear power posed a problem for the power system planners who designed Dinorwig If we replace all power stations with nuclear ones, we either generate massive power surpluses at night, or have to shut some of them down, making the electricity they produce even more expensive. Night storage heaters and off-peak (Economy 7) tariffs were also designed to make fuller use of off-peak electricity as Dinorwig does.

But today, Dinorwig *also* addresses the problem of storing renewable energy generated at off-peak times, when it would otherwise be thrown away.

Unlike a conventional power station, Dinorwig starts up very quickly and produces its full power for a few peak hours. It was expensive to build, but that investment was more than justified as it is now a critical component in the National Grid's 24 hour juggling act of trying to match power supply to power demand.

GLYN RHONWY

Another pumped storage scheme, using two disused slate quarries, is now being built at Glyn Rhonwy[1] in North Wales. This is smaller than Dinorwig but will be cheaper to build because it uses old quarry workings and thus avoids some costly civil engineering.

Its 100MW turbine will be powered by 1 million cubic metres of water dropping 300 metres to produce about 600MWh of electricity, about 6% of Dinorwig's output. By storing off-peak electricity, Glyn Rhonwy can provide enough peak-time power for about 200,000 households.

Glyn Rhonwy is expected to cost £160M to develop, and its business model is to sell electricity at peak rates, having purchased it off-peak. This margin is expected to repay the investment in less than 20 years, but grid storage systems improve the viability of renewable and nuclear power by shifting power production from time of low demand to peak periods and reducing prices all round.

[1]https://www.theengineer.co.uk/issues/march-2015-digi-issue/pumped-storage-a-new-project-for-wales/

THE PROBLEM WITH PUMPED STORAGE.

A pumped storage scheme needs a high altitude reservoir and a low altitude one, and the greater the height difference, the better. It's expensive to build a high altitude lake, particularly in a scenic area. No-one wants to see huge pipes running down hillsides in a National Park, and tunnelling through solid rock for the piping is expensive.

Furthermore, to the extent that you can't practically place the lower reservoir directly underneath the upper one, the tunnels can be quite long. The bottom line is that there are few places in the U.K. where the natural landscape favours pumped storage schemes to be built, and even fewer where people will find them acceptable.

THE IDEAL PUMPED STORAGE LOCATION.

An ideal pumped storage scheme would be visually unobtrusive, with the lower reservoir directly beneath the upper one, separated by a straight drop of a few hundred metres. The good news is that Wales might have more such locations than almost anywhere else in the U.K.:- the South Wales coalfield.

It would be a pleasant irony if abandoned coal mines saw a new lease of life as energy stores – the fossil energy stores of the industrial revolution brought back as energy stores for the post-industrial society that Wales is destined to become.

All we need is a reservoir at the pit head, and enough of a cavity underground to hold its contents when passed through an underground hydro-electric turbine during peak periods. The water is then pumped back up to the pit head using off-peak electricity, and like Glyn Rhonwy, the difference in price funds the build costs.

NUMBERS

So let's use the figures from Glyn Rhonwy to assess whether we can store a comparable amount of electricity in an abandoned coal mine. Remember, Glyn Rhonwy produces 600MWh of power from 1 million cubic metres of water dropping 300 metres.

In East Carmarthenshire, at Cynheidre, is an anthracite coalmine sunk in the early 1950's (it closed in 1989). Its main shafts are 700 metres deep. The mine has 36 miles of abandoned tunnel, and since Cynheidre in its heyday brought up 10,000 tonnes of coal a week, there should still be an underground cavity is several million cubic metres. If appropriately sealed, that could hold a million cubic metres of water to be pumped back up at end of each shift.

There isn't a lake at the Cynheidre pithead so one would need to be dug. A 25 metre deep lake holding a million cubic metres would need about 100 acres. A deeper excavation would use less area and make it easier to enclose the space for safety and concealment. An open lake that empties daily would be a poor wildlife habitat or civic amenity, and an enclosed one could be properly landscaped.

That gives us 1 million cubic metres of water, two reservoirs one directly above the other, and a *700* metre drop. Because of the greater drop, this can in theory hold 1400MWh (1.4GWh) over twice the capacity of Glyn Rhonwy (600MWh). And, modulo the cost of underground sealing and the pithead lake, it could be as cheap to build if the heavy rock work done by the National Coal Board is intact. We could christen this new power station "Cynheidro".

CYNHEIDRO – A 21ST CENTURY POWER STATION

Using deep mine workings as sites for pumped storage is being explored elsewhere[2,3] and the expertise and technology will hopefully be developed and shared worldwide. Wales already has some of that technology, and lots of opportunities to exploit it.

As a high power energy source Cynheidro needs a high voltage grid connection, but if this can be buried at reasonable cost its scenic impact would be small. Construction provides some employment and the station would need permanent staff. Operation would have little environmental impact – the machinery is mostly deep underground, which limits noise, and there would be no atmospheric pollution.

One advantage of Cynheidro is that, if it works, it should be possible to replicate elsewhere in the coal field. And as large wind farms on the valley hilltops come on stream, hopefully augmented by the tidal lagoon in Swansea Bay[4], Wales should be able to store its renewable energy surplus to export later, at peak prices, to the rest of the UK and Europe.

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[2] https://www.deutschland.de/en/topic/environment/energy-technology/storing-electricity-in-mines

[3] http://reneweconomy.com.au/2016/new-energy-gold-mine-storage-solar-pumped-hydro-75572

[4] Interestingly, Cynheidro can store the entire daily projected output of the proposed Swansea Bay tidal lagoon. They would probably want to form a partnership to maximise return.