

Pumped hydro energy storage to eliminate fuel poverty

The idea is to make pumped hydro energy storage the number one energy policy for ensuring that we fully use our zero fuel cost wind energy to eliminate dependence on fossil fuel whilst ensuring dependable energy security at very low cost, thereby eliminating fuel poverty and ensuring affordable energy for businesses and other users.

Pretty water reservoirs can easily be deployed in many areas of Scotland where there is possibility of establishing upper and lower reservoirs (artificial and/or natural) where water from the lower reservoir is pumped to the higher reservoir during time of plenty cheap or excess wind energy. When the wind is not blowing then a valve is opened to run water from the upper reservoir down to the lower reservoir under natural gravity which drives a turbine-generator. Some quick study of contour maps shows that Scottish terrain offers thousands of opportunities from an engineering perspective. @WindFmAnalytics has done calculations and gathered data proving viability.

Apart from jobs in engineering #PumpedHydroEnergyStorage projects offer green jobs in all aspects of planning, construction and operation. Furthermore the enhanced use of zero fuel cost abundant local wind energy means that existing jobs and businesses will be protected from demand destruction caused by high gas prices.

Markets have failed Scottish households and businesses. There are shovel-ready pumped hydro projects which can trigger a beneficial boom in this sector but the investors are reticent to invest large capital up front without some long term price guarantees. The long term advantage of pumped hydro, with perhaps 120 years life time (better than a lithium battery with 5 year lifetime on daily cycle), becomes an investment difficulty if the long term revenues are uncertain. We need to recognise the strategic common sense of pumped hydro without excluding other possible energy storage technologies. The way to do this could be to provide an incentive for the initial decade of operation whereby an energy storage investor is provided a subsidy based on the energy storage usage of the unit. To ensure value for money of consumers the subsidy should be won

through a competitive auction process and should be of sufficient scale (eg successive rounds of 500 GWh capacity) to make a difference and enable large scale energy storage bidders such as #PHES, without excluding other technologies.

Wind Farm Analytics has provided numeric examples and suggestions on how this can work in practice without significantly impacting the consumer. Indeed there are many studies indicating that the flexibility and ancillary services offered by controllable #PHES will lower the cost of energy substantially. Yes, its another subsidy to get the market moving but we are talking about cost of pennies per MWh in order to eliminate costs of perhaps hundreds of pounds per MWh.

Wind Farm Analytics proposes the cost of the initial subsidy can easily be absorbed by an Energy Storage Use of System (ESUoS) charge similar to but much smaller than existing Transmission and Distribution Network Use of System Charges (TNUoS, DNUoS). In this way the cost of the subsidy can be spread across all users (or alternatively all generators) without any noticeable impact on bills, but nevertheless guaranteeing energy storage winning bids to get a known subsidy for the first decade of their operation in proportion to the services they provide. No government money is needed up front since the price guarantee (paid only on delivery) should be sufficient to win investment for winning bids.

<https://www.wind-farm-analytics.com/wp/energy-storage-use-of-system-esuos-charging/>

@WindFmAnalytics has been proved correct as we argued for pumped hydro energy storage since more than ten years. Maybe it would be a good idea to employ strategic thinkers who have been proven correct instead of employing the same old people who got it wrong? Here is an article we wrote for Holyrood Scottish government magazine in 2014, if only we were listened to then by now Scottish consumers could have been entirely protected from high prices by pure wind pumped hydro with no risk of fracking pollution or nuclear meltdowns or mythical carbon capture which is economically and environmentally unviable:

<https://www.wind-farm-analytics.com/wp/wp-content/uploads/2014/12/32-33.pdf>

Why the contribution is important

Some people want to decarbonise our energy system with intention of protecting the environment.

Others may not be convinced of this need but if you don't believe carbon dioxide causes dangerous climate change please consider wind energy is delivered for free to Scotland by nature and it makes basic common sense to utilise it fully when it can be delivered cheaply without damaging grid stability. Wind energy also produces no acid rain nor air pollution which might be considered advantages.

Making use of renewable energy is true sustainability and nothing to do with corporate greenwash or devious globalist conspiracies which sometimes do exist. The hijacking of renewable energy by deceitful hidden hands should be resisted but this does not mean renewable energy and sustainability should be resisted. It is the hijacking, greenwash and deceit that must be resisted. Renewable energy may be considered as "freedom energy" and offer resilience and energy security by being a distributed system, whether off grid or on a grid.

#PumpedHydroEnergyStorage is the key because it has the large scale required to store days and even weeks of national energy demand without any need for expensive fossil fuel which will one day run out. By making use of our local renewable resource we avoid the export of wealth to foreign fossil fuel suppliers, and avoid need for stealing fossil fuel of others via immoral and unnecessary foreign wars. North Sea gas and oil production has been in severe decline for twenty years and even if you can get a bit more out it won't last forever. We need to plan for the long term instead of just preparing another crisis a few years later.

Fossil fuel vested interests try to argue that wind energy is expensive even though recent gas prices have been around ten times higher per MWh than wind energy. They claim renewables benefit from subsidies even though wind farms are now operating without subsidies and anyway the nuclear and fossil fuel industries have benefited immensely from subsidies. They claim that wind energy requires fossil fuel back up but this is not correct because we can back up variable wind generation using #PumpedHydroEnergyStorage

We need to incentivise #PumpedHydroEnergyStorage because this is the only tried and tested technology to truly manage grid scale wind energy. This technology is highly efficient and in any case, whilst always desirable, efficiency is less of a problem when you have a resource delivered by nature for free and which will never run out, as opposed to a fossil fuel resource delivered at increasing cost from depleting reserves which will one day run out.

#PHES also enables electrification of transport and heating via wind energy. #PHES also enables cheaper-than-diesel green hydrogen generation using Scottish wind power because the low cost delivery of wind energy without pause even on non-windy days means that electrolyzers can split our abundant rain water using our abundant wind energy with high utilisation close to 100% of the time which is key for low cost zero emission transport including cars, buses, ships and aeroplanes. Battery electric vehicles may also be beneficial but green hydrogen has an important advantage that it can be stored, also seasonally. In fact Scotland can utilise, export and monetise its bad weather as cheaper-than-diesel-clean-fuel. Green hydrogen from electrolyzers powered using wind pumped hydro can eventually replace gas heating and cooking when we transition the gas grid section by section to pure green hydrogen. This is much better than injecting green hydrogen into the existing gas grid because in that case it becomes uneconomic to extract the pure green hydrogen in order to run hydrogen fuel cell vehicles which require high purity hydrogen. Even if you are a supporter of nuclear energy, which Wind Farm Analytics argues is too expensive compared to pure wind plus matching pumped hydro, then pumped hydro offers advantage since it can store and deliver the nuclear power during demand peaks beyond nuclear capacity.

Simple common sense. Pumped Hydro Energy Storage. @WindFmAnalytics
by [WindFarmAnalyticsLtd](https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd) (<https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd>) on September 03, 2022 at 01:39PM

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Comments

Posted by [AlasdairPhilips \(https://www.ideas.gov.scot/author/AlasdairPhilips\)](https://www.ideas.gov.scot/author/AlasdairPhilips) September 05, 2022 at 10:31

In my view more pumped storage is essential. Scotland is ideally suited for this technology with relatively remote deep valleys near the main Beaulieu - Stirling 400 kV main transmission line. It is a Green and efficient way of storing energy for later use. They are now typically 80%+ efficient - i.e. a 20% loss, mostly as heat losses. Whereas the new Hinkley C nuclear plant will use vastley more carbon-based resources to build and when running will dump. on an on-going basis more heat power into the environment than the electrical power it exports. See: <https://www.save-the-severn.com>

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Posted by [Tony \(https://www.ideas.gov.scot/author/Tony\)](https://www.ideas.gov.scot/author/Tony) September 05, 2022 at 13:00

I agree that pumped storage is an important potential and sites should be identified. But I do get worried when people suggest a solution as the only solution. Pumped hydro needs to be compared to other technologies such as green hydrogen, liquid air and so forth and how everything links together. The idea talks about green hydrogen but if you are producing green hydrogen why bother with pumped hydro as well? Just store it as hydrogen which is something like 6000 times more energy dense.

For example liquid air has a project cost of about \$100/MWh vs \$150/MWh for pumped hydrogen (and also has a side effect of extracting CO2 from the air which can be used in industry). You can also locate liquid air

solutions at existing power generations sites which reduces the overall need to rewire the grid.

In the idea there is a discussion about green hydrogen. If we are moving to a hydrogen based economy why not just build hydrogen storage

The environmental impact of pumped hydro needs to be carefully considered - pumped hydro can have negative impacts on the local environment both flora and fauna. As these are likely to be built in remote locations then there is also a need for infrastructure which again can impact the local environment and add cost to the overall project.

In saying all that - starting to identify suitable sites and obtaining necessary planning permission for pumped hydro now would make sense - otherwise we will continually be waiting.

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Posted by [WindFarmAnalyticsLtd \(https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd\)](https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd) September 05, 2022 at 13:18

Thanks for your comments. On John's point about green hydrogen I have done plenty of work including physical and financial parameter optimisation simulations which proves that the key to economic deployment of green hydrogen is that the electrolyser needs to keep running with high utilisation such as 90% of the time. This means that if you want to use variable wind or solar it really needs to be combined with some energy storage and in my opinion pumped hydro is the only affordable solution. Regards calling for only one solution I am calling for a mechanism to encourage any energy storage which can prove itself competitive. In my opinion pumped hydro is the most competitive and will beat all competition (on grounds of the key determining auction metric of support cost per energy storage kWh delivered to ensure low cost for consumer) but I agree that all options must be allowed to compete.

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Posted by [WindFarmAnalyticsLtd \(https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd\)](https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd) September 05, 2022 at 13:18

Excuse me Tony! I was just on the phone to someone called John! Pardon me and thanks to Tony!!!

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Posted by [WindFarmAnalyticsLtd \(https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd\)](https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd) September 05, 2022 at 13:26

Another important point on green hydrogen is that there is insufficient manufacturing capability at current time. I support green hydrogen for its advantage of long term storage of zero-emission-cheaper-than-diesel-transport-fuel but we should encourage more electrolyser manufacturing. ITM Power of Sheffield opened their Gigafactory and we need more of them, perhaps some in Scotland too! Also on that subject we should

encourage pumped hydro manufacturing in Scotland too. I don't understand why companies like Weir Group are not going big on pumped hydro components.

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Posted by [Tony \(https://www.ideas.gov.scot/author/Tony\)](https://www.ideas.gov.scot/author/Tony) September 05, 2022 at 17:33

Playing devils advocate again.

Liquid air has become much more cost effective than it was. The last figures I saw demonstrated that it was on a par with the cost of pumped hydro. With the ability to have small scale local liquid air systems you can place them in remote communities as well at the site of existing power stations taking advantage of existing infrastructure. So it could be cheaper considering transmission charges etc.

Even if we accept the need for pumped hydro - why use reservoirs? Why not use closed-loop systems in old coal mines and the like?

Answers most of the problems and means we don't damage fragile ecosystems.

I do feel strongly for the highlands. They're going to be full of windfarms and now pumped hydro. If care isn't taken you're end up with a second highland clearances.

As an aside how long would it take to ramp up manufacturing capability of green hydrogen? Building a pumped hydro-storage solution would take something like 3-5 years. Could you not use the same time frame to ramp up manufacturing capability?

Locate the electrolyser near appropriate locations and you can use the waste heat in community heating systems as well. You can pump the hydrogen directly into existing gas systems which will reduce gas consumption by 5-15%.

You can use the savings here to offset the cost of the electrolysers not running at 90% efficiency.

An interesting discussion to be had by the powers that be.

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Posted by [WindFarmAnalyticsLtd](https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd) (<https://www.ideas.gov.scot/author/WindFarmAnalyticsLtd>) September 06, 2022 at 17:17

I agree we must protect the highlands and other picturesque locations and natural environments too. That's a matter for the planners contemplating also strategic needs. However, there are literally thousands of locations possible and a head height of 300 metres does not necessarily require the biggest mountains. I would say wind farms are generally more visible than reservoirs. Wind farms can also be out of sight at sea. But there are perhaps some locations onshore which do not necessarily need to be protected from development!

I once calculated that a single valley and its nearby terrain could accommodate one week of whole-GB electricity demand of around 30 GW, ie around 5000 GWh. That was two big reservoirs considered. Personally I would argue we should have at least 10 major PHES around the UK (including hilly regions of Northern Ireland, England and Wales) to avoid "single" points of failure although it should be noted multi-GW facilities would require very many turbines and penstock pipes. But let's get started! Let's have an initial auction for 500 GWh of energy storage and see what projects will bid in the cheapest support cost for their investment, according to a competitive metric of £ per MWh delivered.

I'm not sure about mines. One would need to consider chemical contamination. In theory it could be possible to have both reservoirs underground at upper and lower levels but generally it might be preferable to have the upper reservoir above ground. In this case it might be preferable if the water were clean as dirty water might not be acceptable. The pump turbines deep underground would need a shaft for installation and service. I think it's possible and @WindFmAnalytics would be glad to investigate further if someone has a budget for that study!

Please note that Japan has demonstrated sea water pumped hydro at Okinawa. Molluscs may be a problem but there may also be solutions. If we use sea water then this eliminates cost of one reservoir. Also when using natural lochs it can be possible to avoid reservoir construction costs.

I think it's best to build strategic policy around tried and tested non-experimental technology implementations and it's likely that even with support mechanisms investors may rule out sea water or coal mine reservoirs

unless they have studied all relevant aspects and satisfied all questions. Therefore I would expect conventional pumped hydro to win. It could also be possible to allow only qualifying technologies including pumped hydro for most of the auction capacity with maybe a small percentage such as 5% reserved for novel energy storage such as coal mine based.

There are also interesting trading opportunities combining wind farm with pumped hydro because at the moment wind farm owners can't control when they sell their generation to market whereas a fossil fuel plant owner can choose good moments at higher price when energy is needed most. Why are clean generators accepting this disadvantage? In a free market as opposed to a rigged market clean energy generators should combine their assets with pumped hydro energy storage and deliver their energy to market when it serves their shareholders best, when the energy is indeed most needed assuming a true market price signal.

Come on Scotland, lets lead the world with wind pumped hydro!

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Posted by [AlasdairPhilips \(https://www.ideas.gov.scot/author/AlasdairPhilips\)](https://www.ideas.gov.scot/author/AlasdairPhilips) September 07, 2022 at 14:55

I agree with almost all of the Wind Farm Analytics comments. For final use of electricity as a fuel, pumped storage wins by a large margin - easy to build and maintain and very efficient. Tony is right to raise "green hydrogen" - but, in my view, only for use as a fuel for heating or motive vehicle power - that will be very useful and efficient. But it is far less so when converted back to electricity. Pumped storage can also often be combined with addition water feeds (i.e. de novo hydrower) especially as we seem to be getting more rain in Scotland now - and it is safe to store a vast amount of energy.

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Posted by [NatalieM \(https://www.ideas.gov.scot/author/NatalieM\)](https://www.ideas.gov.scot/author/NatalieM) September 08, 2022 at 13:13

I've given this a five-star rating, despite having a few reservations similar to those voiced by Tony - I would prefer more diversification in this sector. I'm enthusiastic about real sustainable power solutions, and pumped hydro seems like it could be one of them. But it shouldn't be seen as the only or the main solution and there should be some regulation to ensure that the profit motive doesn't turn it into the green box-ticking cash cow that windfarms have become.

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Posted by [aarogers \(https://www.ideas.gov.scot/author/aarogers\)](https://www.ideas.gov.scot/author/aarogers) September 08, 2022 at 19:53

As with nuclear, too slow & too expensive in the short/medium term. We don't have that luxury any more.

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Posted by [AlasdairPhilips \(https://www.ideas.gov.scot/author/AlasdairPhilips\)](https://www.ideas.gov.scot/author/AlasdairPhilips) September 10, 2022 at 08:49

I am responding to aarogers September 08, 2022 at 19:53

Yes, it certainly is not short-term, but the Beaully-Stirling 400 kV powerline was routed with the idea on pumped storage in mind and it could certainly be implemented in the medium term. It is the safest and most ecological way of storing vast amounts of power for when there is no or little wind and solar power being generated. The Just Transition is to work towards Net Zero by 2045. In my opinion, with Government support for site permissions and funding backing, one could be up and running by 2035.

See:

<https://www.coireglas.com/case-for-phs>

<https://www.cowi.com/about/news-and-press/scotlands-largest-ever-hydro-project>

<https://www.scotlandstowns.org>
/the_glenmuckloch_hydro_pumped_storage_project_near_kirkconnel_granted_planning_permission
<https://www.sdi.co.uk/business-in-scotland/invest-in-scotland/project-investment-opportunities/ili-energy-red-john-pumped-storage-hydro>
<https://www.sserenewables.com/hydro/foyers/>

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Posted by [Tony \(https://www.ideas.gov.scot/author/Tony\)](https://www.ideas.gov.scot/author/Tony) September 10, 2022 at 11:07

AlasdairPhilips is right in that you could complete one by 2035 if you start now.

If you look at the Glenmuckloch scheme above. Planning permission was granted in 2016. It still hasn't started and is expected to start by 2027.

That's ten years from getting planning permission approved let alone the time it took to get planning permission.

(I think this reflects aarogers view of the situation as well. Apologies if I have misunderstood).

So it's doable - but requires a focused effort from government.

And we'll need more than one. Projects like this require extensive specialised knowledge and equipment - there is a risk that the skills needed are not available worldwide and the supply chain may not be sufficient.

NatalieM raises a really good point. Projects like this are very expensive to do. The Scottish Government can't run a deficit so funding for this would have to be from private investment.

This is not going to be cheap especially with interest rates going up. If you look at the issues surrounding

funding for Sizewell C there is a real risk that projects like this will end up costing a fortune and some private companies getting very rich off the back of this as they have with CfD.

Schemes like this are paid for over decades - I'd rather not put the excessive profits of companies onto our children and grandchildren.

One of the reasons I'm a fan of compressed air and liquid air solutions is that although they're not as proven as a technology they do work and small scale solutions can be knocked out rather quickly. (Compressed air is in essence a tank, compressor and turbine - that's it.)

Having factories and other large energy users having to maintain a weeks worth of energy on site would be technically feasible today and would allow them to go off-grid when renewables are stretched, it's a useful load balancing tool.

AlasdairPhilips point about green hydrogen being less useful if just used for electricity generation is true if you throw the heat away - if you link it into community heating schemes the numbers get better. Not good, but better. It's a good marginal resource as gas is at the moment (we just need to make sure prices aren't based on it as a marginal producer).

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Posted by [AlasdairPhilips \(https://www.ideas.gov.scot/author/AlasdairPhilips\)](https://www.ideas.gov.scot/author/AlasdairPhilips) September 10, 2022 at 18:13

Thanks. Tony.

I agree that it will be quite expensive - but not as expensive as new Nuclear. We do need a large supply that can fill in when wind and solar are generating little.

Nuclear needs to run near full power all of the time. It can't respond quickly to a dip in supply, whereas pumped hydro can respond in under about 3 minute from standstill and about 30 seconds if 10 minutes earlier it was started into spinning standby.

Hickley C (£30bn cost now?) will produce more waste head than electricity. It is not a long-term sustainable option. And none of the similar design power stations are running properly now -either on half-power or stopped at present due vibration problems in their cooling systems.

I agree that pumped storage wilol require strong government backing - but I think if they act as a loan guarantor, private finance will be available.

Two of my cousins are in the nuclear power industry - one a senior safety officer at Torness - so I have some personal info as well as published info.

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Posted by [Tony \(https://www.ideas.gov.scot/author/Tony\)](https://www.ideas.gov.scot/author/Tony) September 11, 2022 at 17:25

Hi Alasdair,

Current generation nuclear is (in my opinion) not a valid option based on cost alone and the issues you mention, I'm also wary of comments around SMR and all the new slow breeder (thorium) reactors that people seem to think will be a silver bullet to nuclear energy. I doubt it. Snake oil salesmen would balk at the claims being made for these.

I get very twitchy about financing of large projects - it would be very easy to get into another PFI situation but I hope the government pushes forward with pumped hydro as a matter of urgency (along with other storage solutions).

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