Sustainable Arnside

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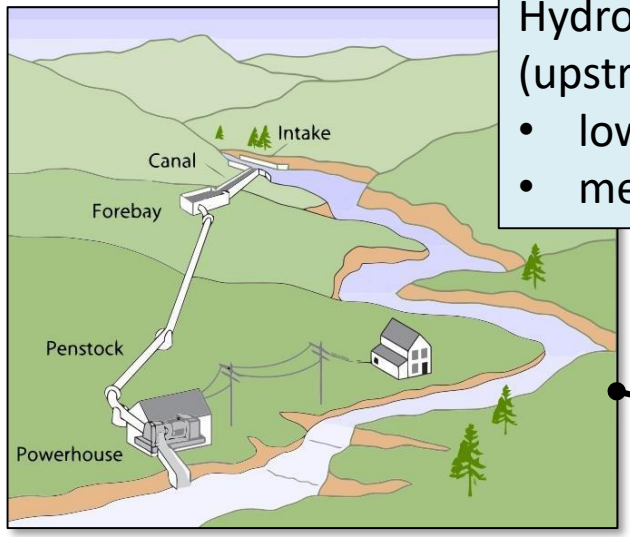
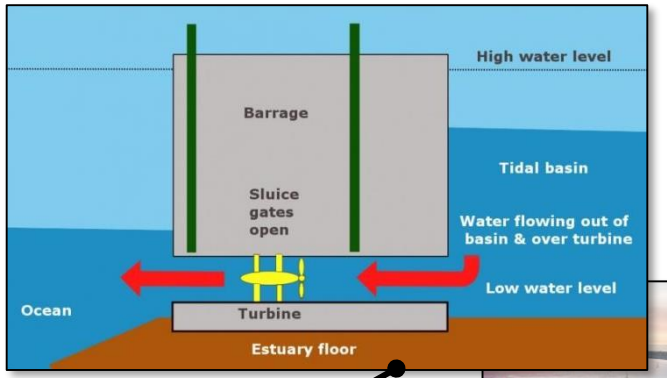
Energy generation options

Hydroelectric:
(upstream supply)
- low head
- medium head



https://www.researchgate.net/publication/330325483_Design_Optimization_of_A_Hybrid_Hydro-Wind_Micropower_System_For_Rural_Communities



https://www.powersystemsuk.co.uk/sectors/renewable-energy/tidal-energy/

Tidal range:
barrage / lagoon

https://wordlesstech.com/tidal-lagoon-energy-uk/

density: 1,000 kg/m³

gravitational acceleration: 9.81 m/s²

$$PE = mgh = \rho V g h$$

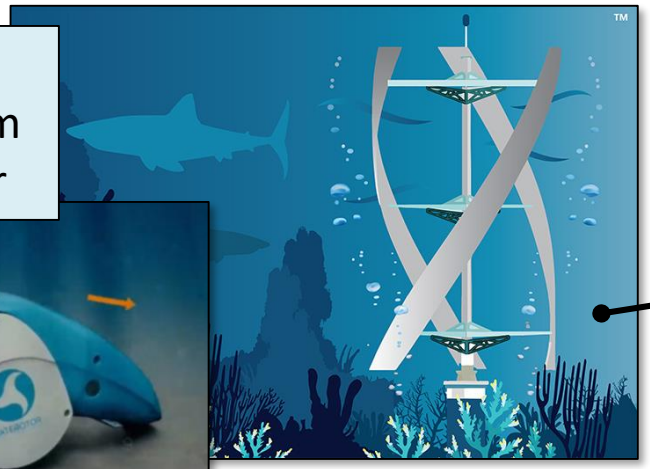
mass (kg)

volume (m³)

head (m)

https://www.engr.colostate.edu/se/2021/03/26/systems-engineering-professor-works-with-nrel-to-make-hydrokinetic-turbines-accessible/

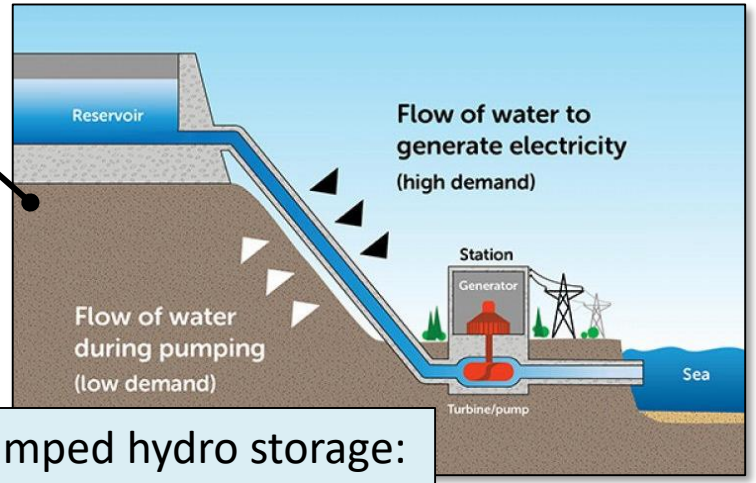
Hydrokinetic:
- tidal stream
- run of river



https://design1st.com/harvesting-hydrokinetic-energy-from-canadas-slow-moving-waters/

velocity (m/s)

$$KE = \frac{1}{2}mv^2$$



https://www.esru.strath.ac.uk/EandE/Web_sites/17-18/cumbrae/Seawater%20pumped%20hydro.html

Pumped hydro storage:
(nett value gain)

Hydroelectric

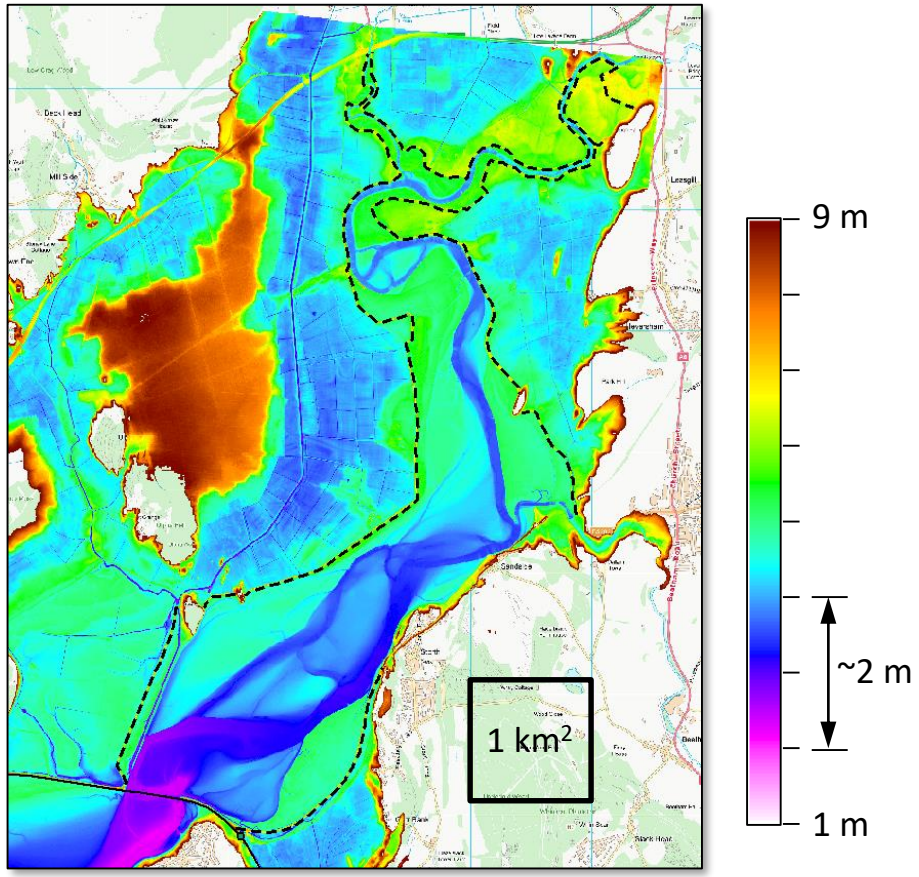
$$PE = mgh = \rho V g h$$

No streams of any note for medium head generation

height but no mass ☒

River Kent is the only sizable watercourse

- minimal elevation change over ~6 km
- head drops to zero at high tide



Lidar data. Open Government Licence

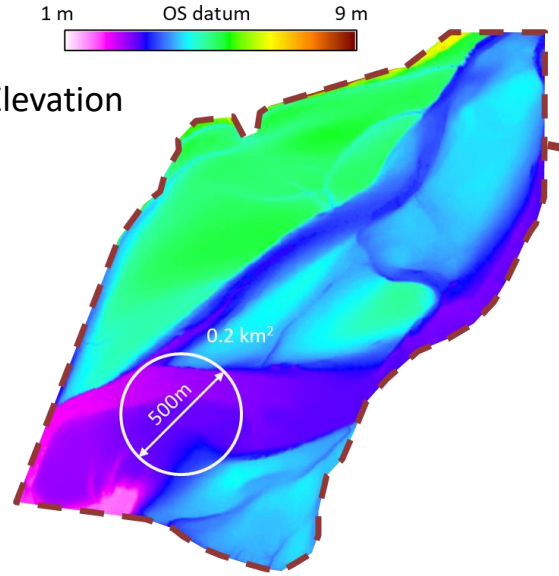
OS datum

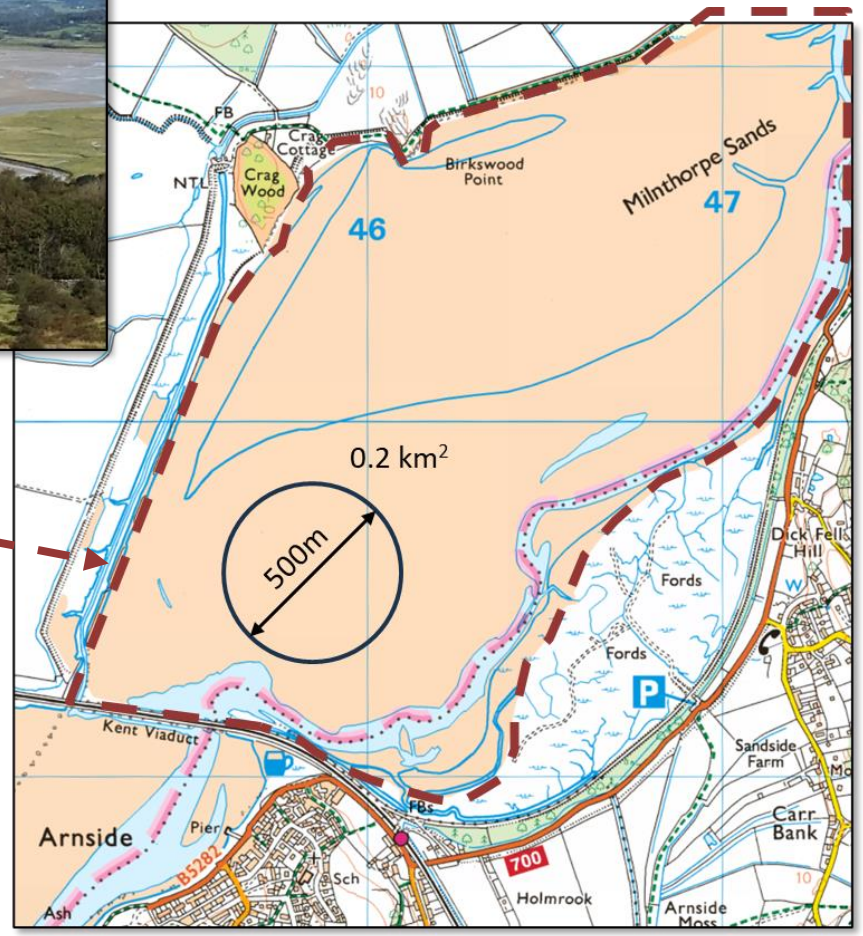
mass but no height ☒

Tidal range: lagoon

$$PE = mgh = \rho V g h$$

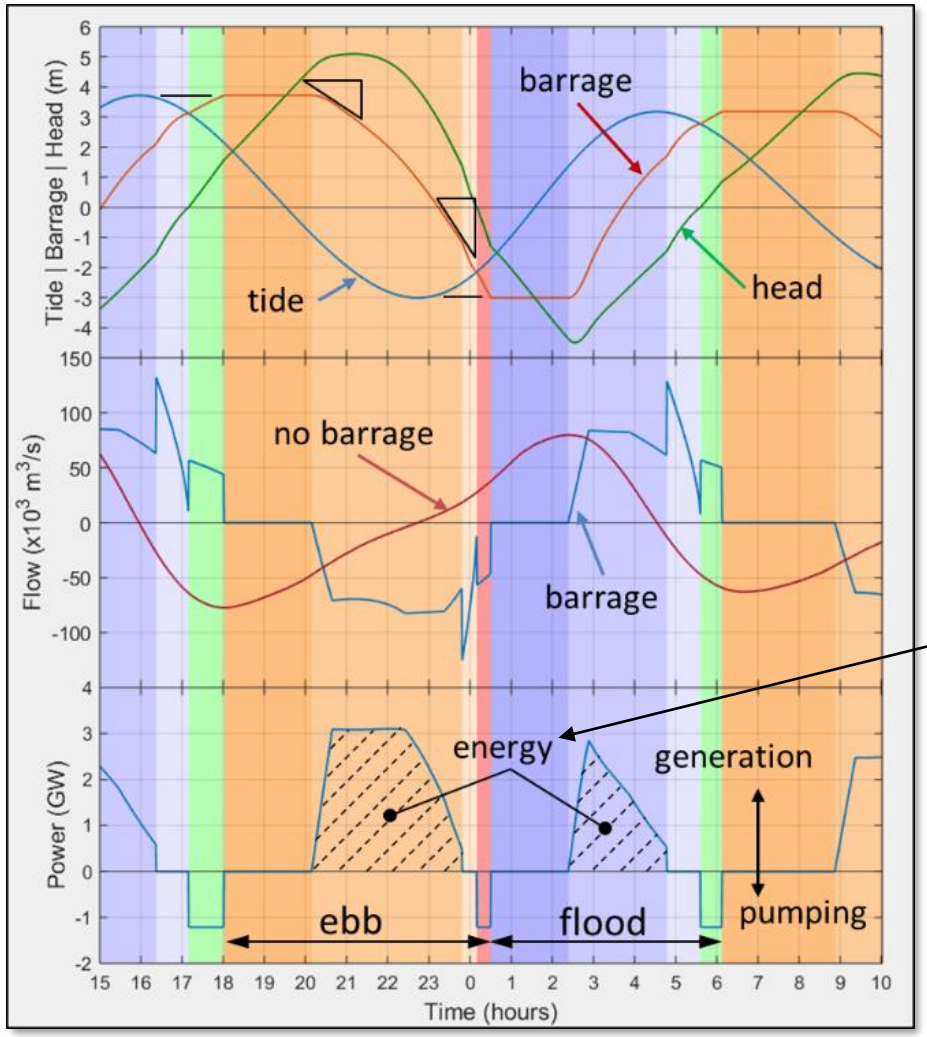
mass and some height ☑

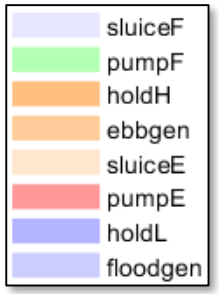




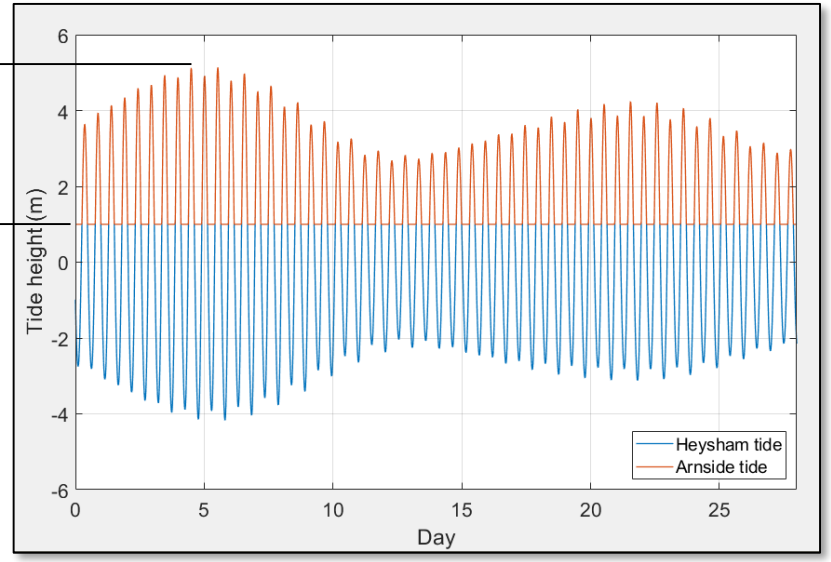
Lidar data. Open Government Licence

Tidal range: lagoon



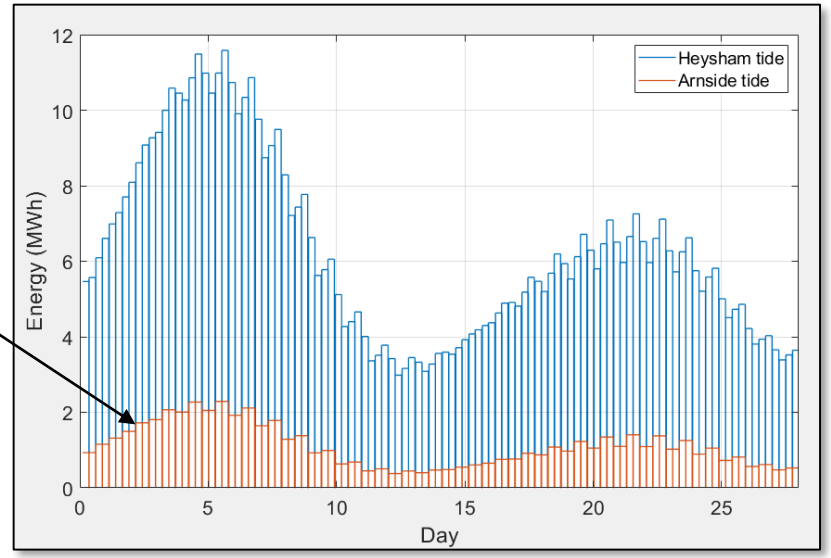


Tidal range limited by the base elevation



The timing of each generating phase follows the tide

Energy generated per half tide cycle (~4 per day)
=> ~4.2 MWh per day



high cost and low energy ☒

Hydrokinetic: vertical axis turbine

https://www.offshore-energy.biz/water2energy-makes-tidal-turbine-testing-optimizations-in-netherlands/

Vertical axis turbine:

- insensitive to the flow direction
- tolerant to varying water depth

mass and velocity ☑

$$Kinetic\ Energy = \frac{1}{2}mv^2$$

$$Power = C_P \frac{1}{2}\rho \emptyset d v^3$$

density: 1,000 kg/m³

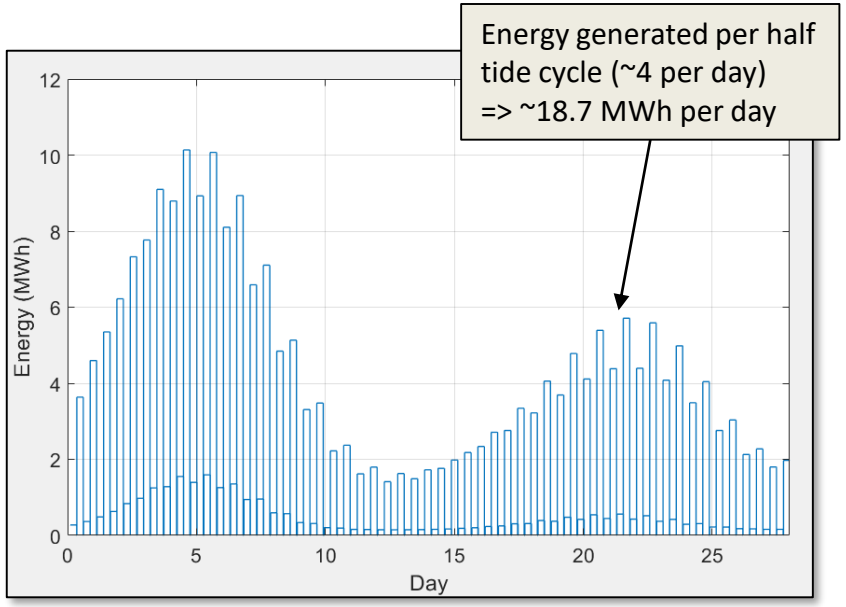
turbine diameter (m)

velocity (m/s)

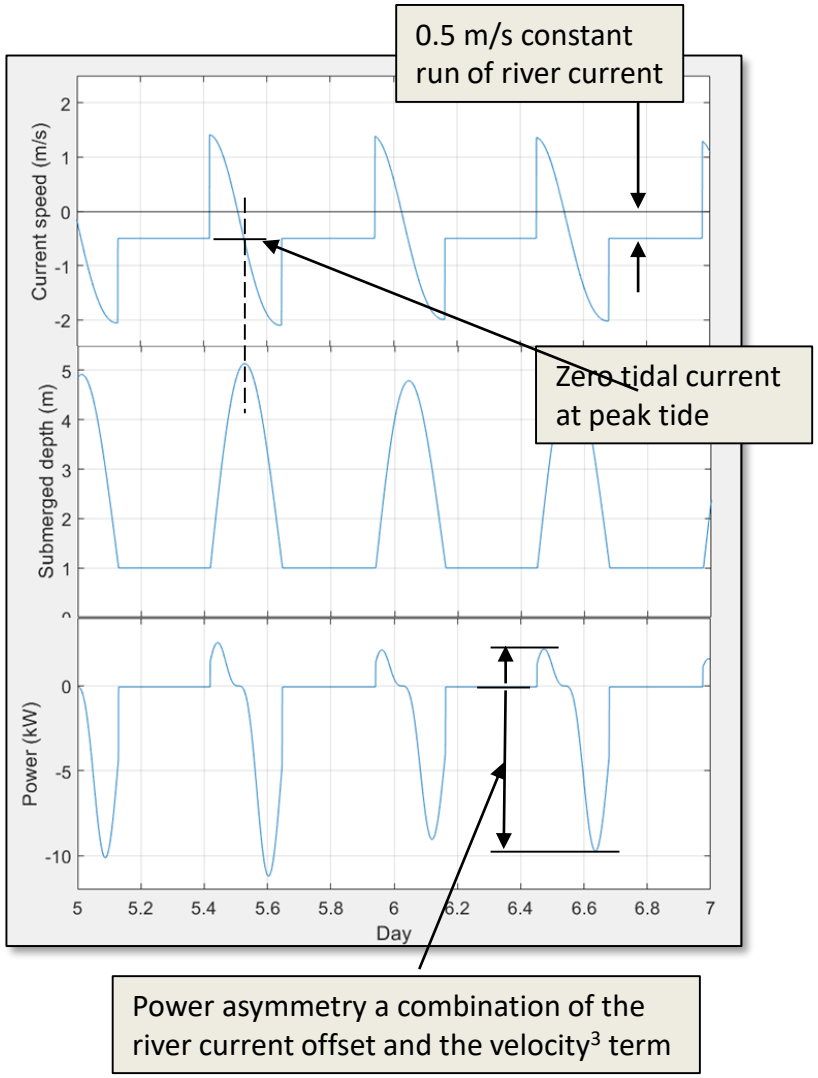
power coefficient < 0.6

submerged depth (m)

∅ = 2m, d = 2m, v = 2m/s => 8 kW



The current at Arnside is a combination of tidal and river flow



Hydrokinetic: vertical axis turbine

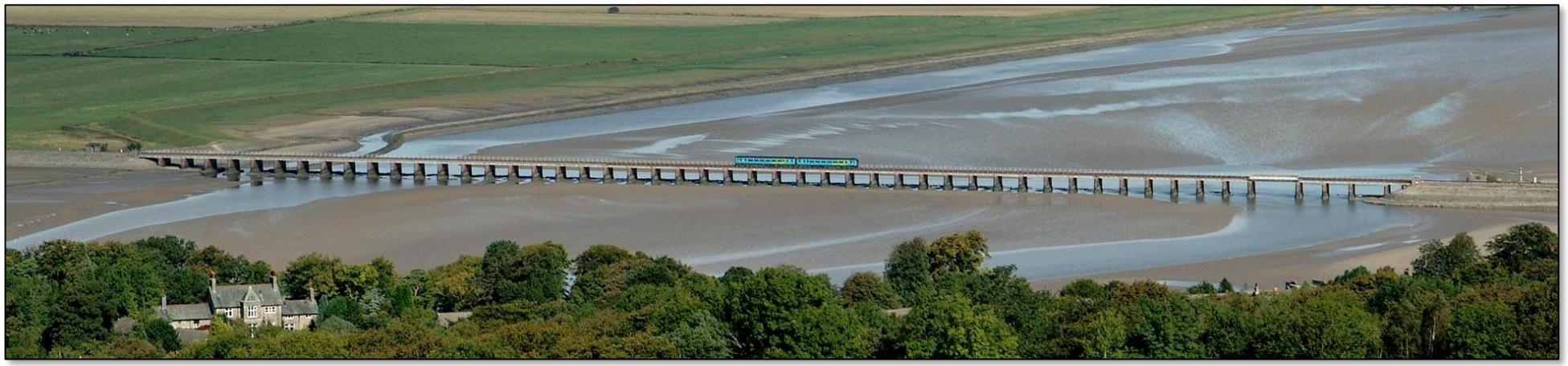
https://www.networkrailmediacentre.co.uk/resources/dsc04091

http://www.nepalenergyforum.com/small-river-hydro-turning-the-lights-on-in-nepal/

- Scope for multiple units
- For run of river would need to follow the channel

https://en.wikipedia.org/wiki/Arnside_Viaduct#/media/File:Arnside_Viaduct_-_geograph.org.uk_-_324585.jpg

lower cost and modest energy ☑



https://www.networkrailmediacentre.co.uk/resources/kent-viaduct-dscf7451-small-3

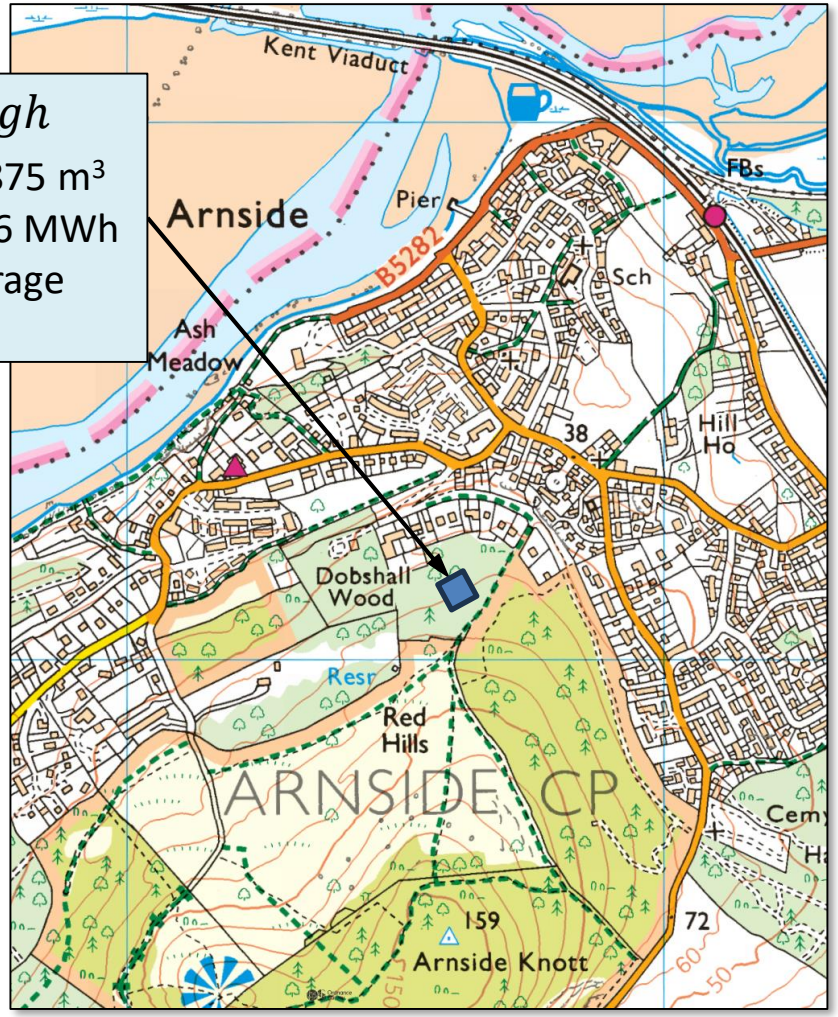
Pumped hydro storage (PHS)

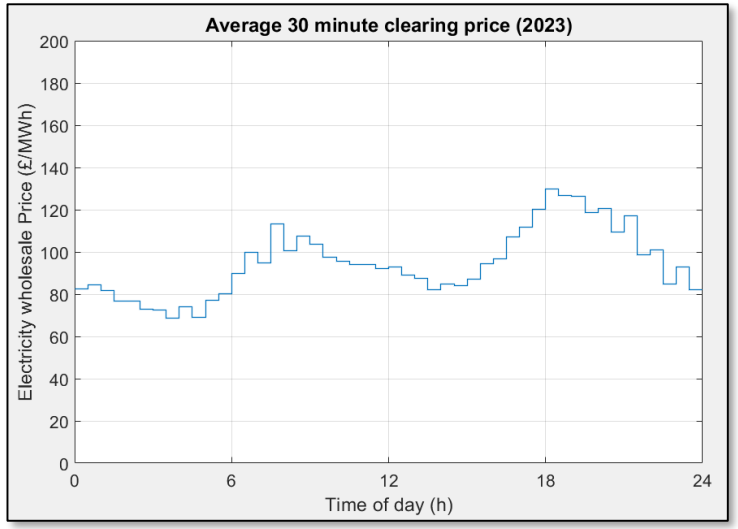
Pumped hydro storage uses cheap electricity to pump water uphill and releases it to generate electricity at times of high demand

$$PE = mgh = \rho V g h$$

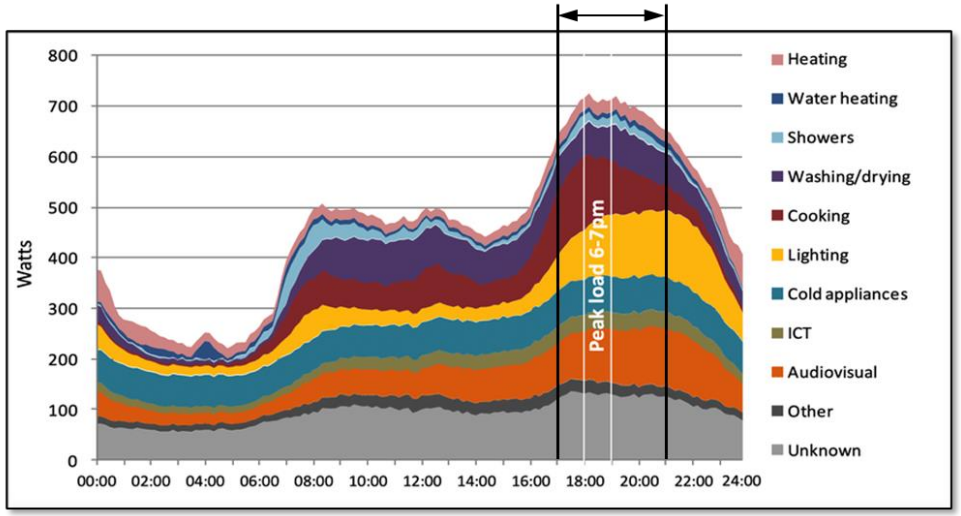
25m x 25m x 3m => 1,875 m^3
@ 70m elevation => 3.6 MWh
(~350 homes daily average consumption)

mass and height ☑





4 hours of generation at 90 kW => 3.6 MWh



Palmer, J.; Terry, N.; Firth, S.; Kane, T.; Godoy-Shimizu, D.; Pope, P. Energy Use at Home: Models, Labels and Unusual Appliances; Further Analysis of the Household Electricity Survey, Reference 475/09/2012; Loughborough University: Loughborough, UK, 2014.