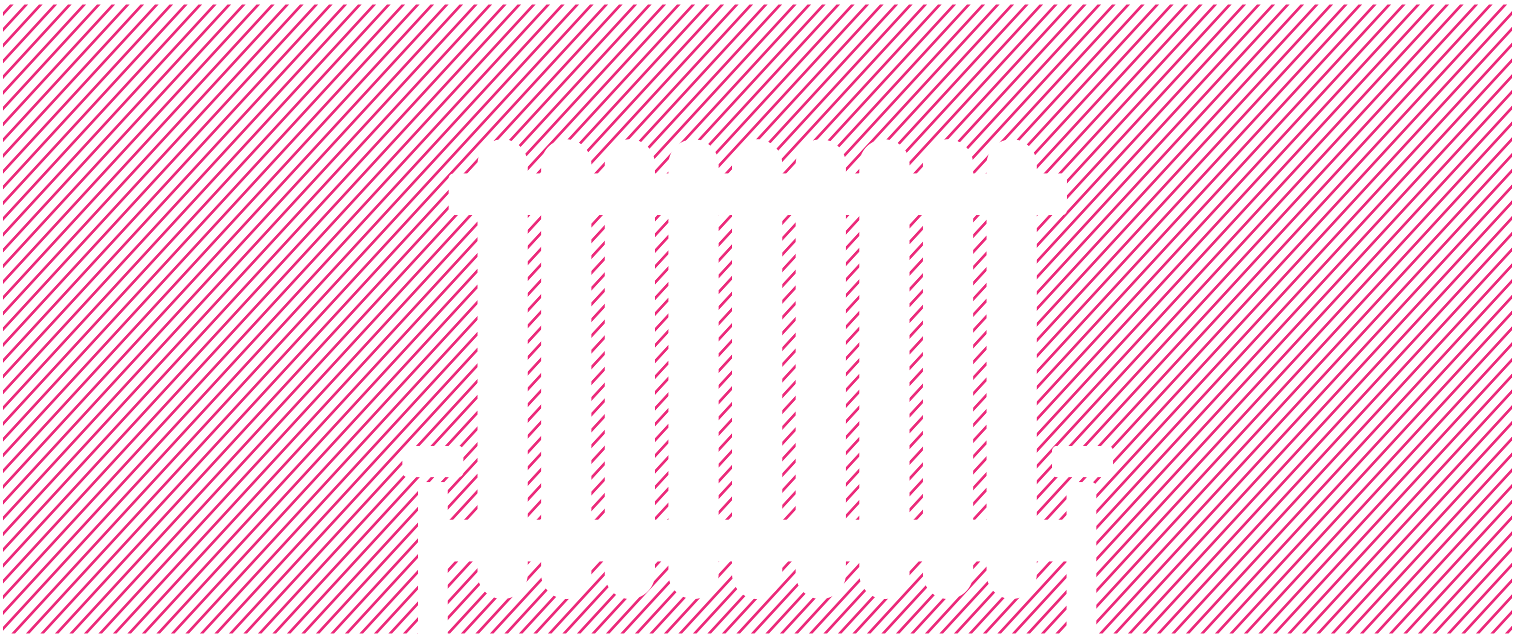
ENERGY FOR
HUMANITY_

STORAGE

Rick Jefferys
Nov 2016



If seasonal heat storage can be deployed widely, heat pumps may provide a massive dispatchable load to balance renewables and effectively electrify a lot of our heating.

Oil and coal are easy to store, while natural gas is a little more difficult. In contrast, electricity must be generated at the rate it is consumed, to maintain grid frequency within tight limits.

Conventionally, this is achieved by ramping power station output up and down; rate of change is limited, and generation output cannot go negative. Stations are started and stopped as required; Some types of generation, particularly conventional nuclear, are slow to restart after stopping and all incur costs when cycled. Hydro power is particularly flexible and reversible pumped hydro schemes are excellent energy stores but sites are limited and flooding the countryside is not always popular. Wind and solar power cannot be switched on at will, and cost nothing at the margin, so it appears wasteful to switch them off. For all these reasons, energy storage schemes which can consume power when it is in surplus and return it when needed are desirable - especially if they can be built at sufficiently low cost and display round trip efficiency of (say) 70% or more.

If electricity consumers can be persuaded to vary their demands to fit available supply, this looks like storage - and it is often much less expensive to store 'demand' than to store electricity. 'White meters' which provide low cost power during fixed hours have been available in UK for many years and encourage usage, often for storage heaters, during the night time trough in demand. Modern electronics makes it simple to switch individual loads off and on when this would be valuable, but still provide the services we need. Heat and cold are relatively easy to store for periods ranging from minutes upwards, so storage heaters, immersion heaters, refrigerators and air conditioners are prime candidates at domestic and commercial scale.

> Electric vehicles may soon provide another significant controllable load.

Electric vehicles may soon provide another significant controllable load. Some industrial processes are also flexible, but need additional investment to enable them to 'catch up' when power prices are low. If seasonal heat storage can be deployed widely, heat pumps may provide a massive dispatchable load to balance renewables and effectively electrify a lot of our heating. But this only solves part of the problem - we would like more controllable and deployable storage, to smooth out variable wind and solar generation and variable demand.

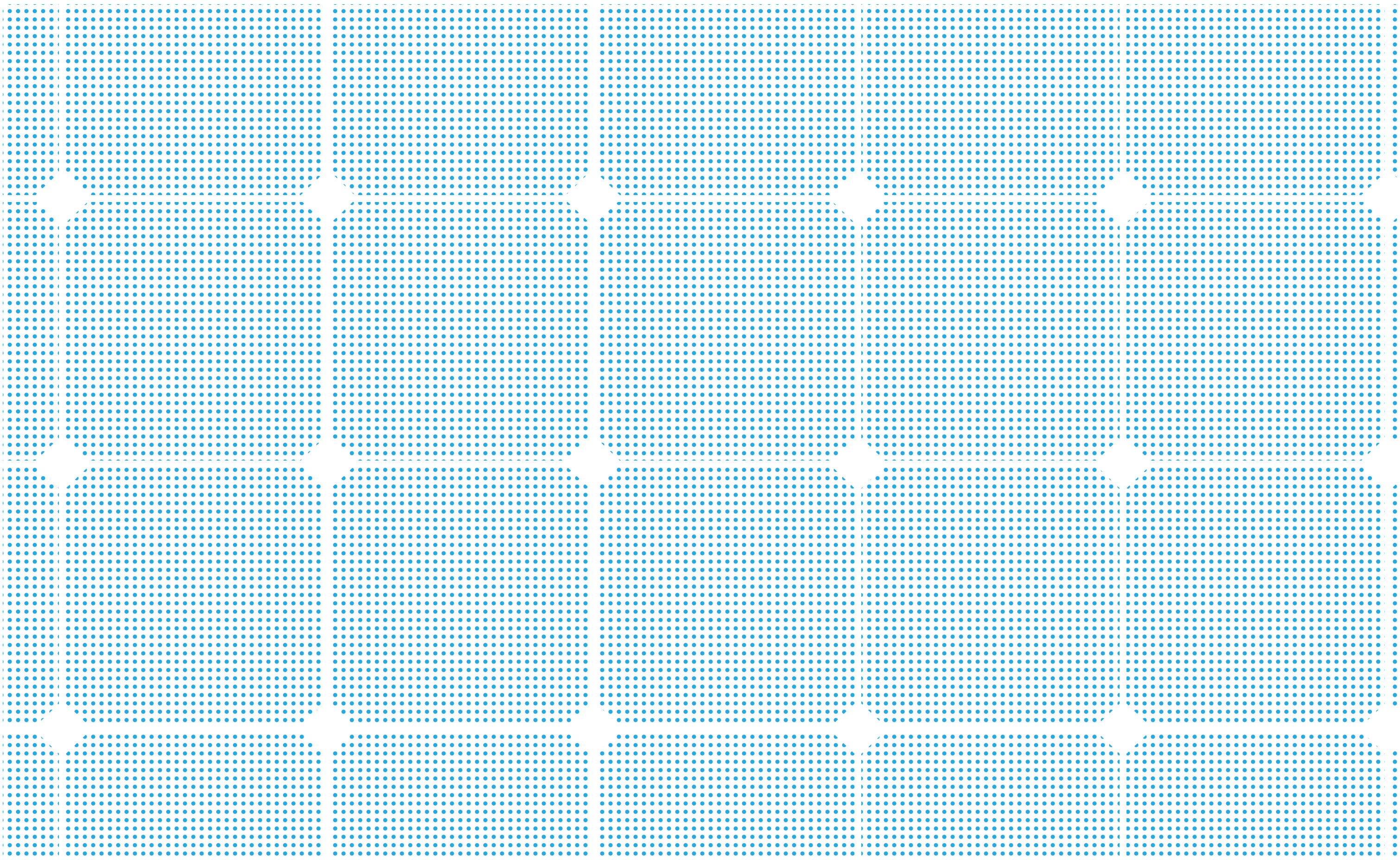
Most of the energy storage in action today is pumped hydro electricity. Turbines pump water from a low reservoir to a higher level one when prices are low and reverse to generate. About 80% of the input energy is recovered and such schemes can run in one direction for 5-20 hours, depending on the size of the reservoirs. Unfortunately, there are not many good sites and they are not always where they are needed. Conventional hydro electricity can be an excellent fit with variable renewables; many hydro plants do not receive enough water to run all year, so it makes sense to run them when RE production is low, throttling back when supply is generous.

Compressed Air Energy Storage (CAES) shows considerable promise. Air is compressed by electrically driven turbines and stored in salt caverns of the type used for short term gas storage. Re-expansion through a turbine, typically with gas burnt to replace the heat rejected during compression, returns energy to the grid. Two projects (Huntorf, Germany and McIntosh, Alabama) have operated reliably for many years but economics has been marginal to date. CAES has the potential for very low cost longer term storage, perhaps 25+ hours, and modern concepts eliminate gas combustion by storing and re-using the heat of compression during expansion.

Liquid air energy storage uses electricity to refrigerate air until it condenses into a liquid which can be stored in cryogenic tanks. Electricity is recreated by compressing the liquid and vaporising it with ambient temperature heat or waste heat from other processes, before expansion through a turbine. While the ideal round trip efficiency is at first sight unappealing, the system effectiveness is greatly improved by integration with other heat sources such as the exhaust of peaking gas turbines,

Many other **mechanical storage ideas** have been proposed such as flywheels (15 minutes storage), trains hauling weights up hills, large weights moving up and down shafts etc, but tend to be pricey / impractical. A promising pumped heat technology was under development by UK based Isentropic, now in administration, which may yet become competitive, particularly for longer duration applications.

Batteries store energy chemically and have no moving parts but have historically been too expensive to store grid power. Costs are now reducing steeply and there are a wide variety of technologies, commercial and in development, competing for the grid storage market. These include Lithium-Ion as used in iToys, electric vehicles etc (Panasonic, LG Them and others), Lithium Sulphur (Oxis, PolyPlus) Sodium based (Fluidic, Aquion, Faradion), Zinc-based (Eos), Solid state (Sakti3), Liquid Metal (Ambri), Flow Batteries etc. Conventional batteries can be charged and discharged in 2 to 4 hours, with some risk of damage at faster than recommended rates. Flow batteries can supply energy until the liquids which store the energy run out and need to be recharged; these are good for longer periods since only costs are bigger tanks and more active liquid - but costs are not



> Wind can blow (and not blow) for days at a time. No power storage technology appears economic for scales of several days.

We need 8 or more hours of storage to smooth out solar power, which peaks at mid-day, typically before peak demand, and goes to zero by sundown. This is substantially more than is offered by conventional batteries. Wind can blow (and not blow) for days at a time, and no power storage technology appears economic for scales of several days - although seasonal heat storage driven by heat pumps holds promise. Northerly and southerly locations see greatly reduced solar generation during winter (1/9th the summer generation in UK) and long lived anticyclones can cover the UK for weeks every few years, zeroing out wind power.

None of the storage technologies listed here, other than seasonal heat storage, can provide a solution for such long term and seasonal variation, so we need a combination of flexible fossil fuel (with Carbon Capture and Storage) and nuclear to provide generation capacity to get us through such events. These will be available at all times and in most scenarios reduce the need for renewables and storage.