Storing energy: look to the future

THE INCREASING PENETRATION OF VARIABLE ENERGY SOURCES IN SOME PARTS OF THE WORLD IS MAKING IT MORE DIFFICULT TO MATCH PRODUCTION WITH DEMAND. SO MORE ROBUST ENERGY STORAGE OPTIONS WILL HAVE TO BE PART OF FUTURE ENERGY SYSTEMS. **BENT SØRENSEN** REPORTS.

Renewable fuels as backup

One of the simplest potential "energy storage" options sees **fossil-fired power back up periods of insufficient renewable energy production**.

But as we move forward and increase the penetration of renewables, one solution could be to replace such back-up use of fossil fuels with renewable energy fuels that can be stored - think **biomass, synthetic hydrocarbon fuels** or **hydrogen**. But there is a caveat to this: While the use of hydrogen in fuel cells (or for conventional combustion) does not emit CO_2, biomass combustion or the use of synthetic hydrocarbons does, unless carbon-capturing devices are part of the system.

So what about away from biomass?

There are indeed more intricate systems that can be used to convert excess solar or wind energy into fuels. **Hydrogen - produced by electrolysis** - is an obvious choice, if a demand for hydrogen can be made viable, in the transportation sector for example. And if electricity has to be re-generated from hydrogen itself, hydrogen stored in underground reservoirs may be possible.

Alternative fuels, or rather fuels closer to those we have become accustomed to during the last 100 years, containing carbon can only be produced from solar or wind if there is a source of carbon. This could be found in the form of CO_2 capture from current fossil fuel operations; direct solar thermal; or electrochemical conversion of atmospheric CO_2.

However, a lot of technical development is required to make these options viable. In the medium-term, there may be more modest energy storage challenges that can be solved with technology that exists already.

Storage with compressed air

One example is **compressed air storage**. The basic idea of CAES (Compressed Air Energy Storage) is to transfer off-peak energy produced by base nuclear or coal fired units to the high demand periods, using only a fraction of the gas or oil that would be used by standard peaking machines, such as a conventional gas turbine.

Excess wind or solar power in the form of electricity is used to compress air. This is usually done in several stages, in order to minimise the associated heating - heat energy gets lost after prolonged storage. Compressed air then passes through a turbine when needed to generate power. This expansion of air a produces a strong cooling effect, and heat has to be added in order to release the air at near-ambient conditions.

So far, there are only 2 CAES plants in the world: the 290 MW plant belonging to **E.N Kraftwerke**, Huntorf, Germany, built in 1978, and the 110 MW plant of AEC (**Alabama Electric Corporation**) in McIntosh, Alabama, USA, commissioned in 1991. Huntorf uses a 0.3 million cubic metre underground cavern. AEC's plant recuperates heat from the compression process and stores the heat for the turbine stage of new power production.

The storage cycle efficiencies are typically 40%-50%, and the facility was originally used as a peak-load plant (charging the store at night, and discharging during peak load hours). But the longer storage times needed for integrating a larger percentage of renewable energy will lower the round-trip efficiency, due to larger heat losses.

Storage using water

Previous articles in this series have dealt with storage methods that have the potential for long-term storage (*see box – **Click through***). **Elevated water stores** for example work in several ways:

- The system pumps water upwards and then regenerates power by letting the water

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down to the lower level through an ordinary hydro turbine;

- Alternatively, there is no upward pumping, rather a coordinated operation of the reservoir-based hydro system together with the wind or solar electricity system requiring storage. So hydropower covers customer demand when there is no wind or solar production, and hydro production is reduced when wind/solar production exceeds demand. This second type of operation requires strong transmission links between the two subsystems. Only a few locations in the world are blessed with hydro installations that have such large (seasonal or annual) reservoirs, and they were typically built a long time ago, when issues such as flooding heritage-level mountain landscapes didn't raise the opposition witnessed today.

Batteries and underground storage

Other storage techniques that have potential are **reversible chemical reactions with high levels of energy input and output**, but none of these ideas are close to commercial reality. The scaling up of advanced battery technologies from the smaller-scale applications that are already in place is a new development, but will need further price reductions to really become commercially viable.

Hydrogen storage is, in principle, also technologically feasible. But it is expensive, and requires fuel cells to become more readily available – for two reasons:

- The roundtrip efficiency when using 1) either reversible high-temperature fuel cells to convert electricity to hydrogen and hydrogen to electricity; or 2) conventional alkaline fuel cells (electrolysers) to produce hydrogen and advanced fuel cells to regenerate electricity; is higher than using conventional combustion-based turbines to regenerate electric power;
- In future, hydrogen may ultimately gain traction as an energy carrier - for use in vehicles for example. Therefore energy stored after conversion to hydrogen would not need to be converted back to electricity again, rather be used directly in vehicles or stationary fuel cells. The most likely technology in an energy system with hydrogen widely available as a carrier would be battery/fuel cell hybrids, as a natural replacement for the battery/diesel hybrids expected to dominate the near future.

CHP and the fuel cell

The stationary use of fuel cells for storing energy has the advantage that the heat generated in all of the conversion processes can be used to satisfy heat demands too. This could take place in district heating systems (for central stores) or in individual buildings where fuel cells operate in a decentralised environment (in which case low-temperature fuel cells such as Polymer Electrolyte Membrane (PEM)-cells will be used). Waste heat generated at all of the conversion steps could allow low-temperature heat needs to be met without dedicated heat plants.

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He has written several books on the subject of energy storage including:

Renewable Energy (3rd ed., Elsevier 2004);

Hydrogen & Fuel Cells (Elsevier 2005).

Renewable Energy Conversion, Transmission and Storage (Elsevier 2007).