Part 4: Large scale energy storage solutions

Improving energy storage on the electric grid (the grid refers to the infrastructure which provides electricity to homes in the UK) is key to improving the use of renewable energies. Figure 1 shows some of the components of the electricity grid.

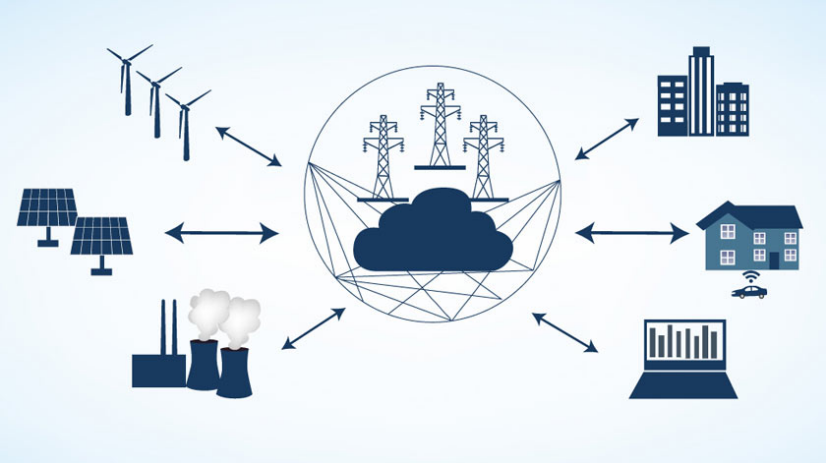

Figure 1. Components of an energy grid include: Renewable energies like wind and solar panels, and non-renewables like coal and oil to produce electricity. This electricity is delivered to industrial buildings/factories and homes through transmission towers.

Traditionally, hydroelectricity is used to store excess energy which does not get used up immediately, however this is geographically limited to a certain number of locations and not feasible everywhere. Renewable energies are highly variable such as wind turbines and solar panels, however relying on these technologies to provide energy 24/7 means we need to store the energy produced from solar panels during the day to use at night.
Typical batteries like the lithium-ion are only useful for small scale portable device usages. For more industrial solutions we look again to different electrochemical applications. One such application is the redox flow battery.

Redox Flow Batteries

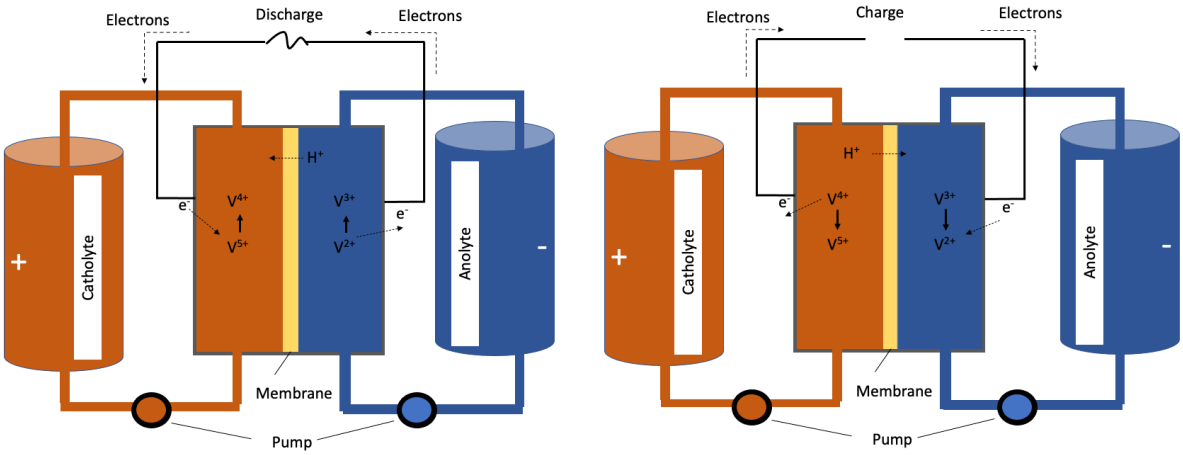

Figure 2. Schematic of a vanadium redox flow battery discharging(left) and charging(right).

A redox flow battery is a rechargeable energy storage device which relies on the electrochemical process known as redox (reduction and oxidation). The most common type is the vanadium redox flow battery as shown in figure 2. In the flow battery there are two tanks for the catholyte and the anolyte both consisting of vanadium. Previously, in lithium-ion batteries we have seen that the anode and cathode are electrodes where ions from the electrolyte pass into and out of to create a current. In the redox flow battery, there are two separate liquids which are stored in separate tanks externally. These liquids are pumped through a reaction tank in the centre of the drawings in figure 2, with a membrane in the middle. As the liquids are passed through, they are either oxidised or reduced. This means the metal vanadium in one liquid gains an electron while the other vanadium side loses one. With the help of the protons moving freely across the membrane, this generates an electron current producing electricity.

[As an aside the oxidation states of the vanadium are written as V^x. Where x represents the oxidation number. This numbers are a fancy way of showing how many electrons have been gained (-) or lost (+). So V^{3+} means the vanadium has lost 3 electrons. If you were to give an electron to V^{3+} it would become V^{2+}.]

These batteries are not constrained by the volume the battery is held in, as the catholyte or anolyte, once oxidised or reduced, can be stored in external tanks and pumped through to produce electricity from redox when needed. This allows the redox flow battery to be scaled up toward industrial sizes for large scale energy storage solutions. Figure 3 shows a redox flow battery storage in Germany next to solar panels.

Figure 3. Vanadium redox flow battery.

Sustainability

Vanadium is a useful element to use in redox flow reactions because having the same metal on the negative and positive side allows cross over of the vanadium ions through the membrane without contamination. However, vanadium is a toxic element which is also expensive due to the low abundancy.

Looking back at portable batteries, lithium is also a scarce material with 38% of the world's supply of lithium used up by 2015. Another material typically used in batteries is cobalt where two thirds of the world's supply is in Congo and instabilities in the country has led to questions about the ethics of mining cobalt. This is on top of the damage mining the toxic materials causes surrounding communities.

These issues have caused many researchers to consider more sustainable materials for energy storage solutions. Next generation batteries include organic flow batteries and zinc-ion batteries in the hope to provide a more sustainable future.