**Regular viewers of this channel will know that over the last five years or so we’ve looked at literally dozens of different ways to store electrons and release them again when they’re needed. Those electrons can make a vehicle go from A to B, or enable you to cook your evening meal using free stored energy from the sun or, at the larger end of the scale, they can stabilise our national electricity grid systems in a process known as frequency regulation. All in all, energy storage is proving to be a jolly useful piece of technology that’s becoming more and more ubiquitous as society continues its rocky path towards decarbonisation. One of the most promising but arguably less well known of all the energy storage options is something called the Redox Flow battery. It’s not a new technology by any means, but it’s one that is approaching that exciting steep section of its market adoption S-curve, as grid operators around the world increasingly demand longer duration energy storage solutions, which redox flow batteries are especially well suited for.**

**So, I reckon it’s high time we had a look at the movers and shakers in what is rapidly shaping up to be an extremely lucrative global market.**

**Hello and welcome to Just Have a Think.**

**So, as usual, first things first. What are Redox Flow batteries, and why do we need them?**

**Well, in theory, they’re sort of a bit like a cross between the traditional battery set ups that we’ve looked at countless times here at Just Have a Think, and a fuel cell. The most common system configurations involve a couple of large tanks filled with solutions of Vanadium. There is one very notable exception to that, which is a company called Redflow in Australia, but we’ll come back to them a bit later in the video. Anyway, in most cases you’ve got these Vanadium solutions, and the key thing to note here is that the Vanadium ions in each container are chemically manipulated so that one tank can effectively act like a positive electrolyte and the other tank can act like a negative electrolyte. Between those two tanks is a stack of cells, which is where the magic happens. The different solutions of Vanadium are pumped into the cell stack where they’re separated by a thin membrane. As the system discharges, the ions in the negatively charged solution release an electron in a process called oxidation. Those electrons move towards an electrode in the cell stack and go out through a circuit to do their useful electrical work before returning to another electrode on the other side of the stack. That electrode feeds the electrons into the positively charged solution which is happy to receive them. The process of ADDING electrons on THAT side is called reduction, hence the name Redox Flow.**

**The reduction process frees up positively charged Hydrogen ions, or protons as the scientists prefer to call them, which flow across the membrane to maintain the charge balance. The whole thing is completely reversible so that the system can be recharged.**

**Advocates of Redox Flow batteries point to several significant advantages to this set up over something like lithium-ion batteries, at least for stationary energy storage applications anyway. They’re reckoned to have a longer cycle life than Lithium-ion, which makes them ideal for applications that need frequent charge and discharge cycles without significant degradation over an operational lifetime. They can be discharged almost completely to zero without harming their performance or lifespan, which means they’re well-suited for scenarios where full energy utilization is important. If you want to change or scale up your configuration you don’t have to go out and buy a whole bunch of new batteries like you would if you had a lithium-ion set up, you can just put bigger tanks in, containing more electrolyte fluid. That flexibility makes them ideal for large applications that demand longer-duration energy storage to smooth out fluctuations in renewable energy sources over extended periods of eight hours or more, and the modularity of the design also simplifies maintenance and repair because individual components can be replaced without affecting the overall system.**

**The solutions themselves are non-flammable, which means redox flow batteries can operate very happily at higher ambient temperatures with minimal risk of thermal runaway. Redox Flow chemistry generally has a low self-discharge rate too. In other words, these things can store energy for very long periods of time with minimal losses. That makes them ideal for moving electrons from one time of year to another and it means they’re an ideal candidate for backup power applications. And when they do finally get to the end of their operational life, all the components are very easily recyclable.**

**Despite all that though, no-one’s suggesting that Redox Flow technology represents a potential replacement for lithium-ion technology. The energy and power densities are both typically quite a bit lower than lithium-ion, which means there are many applications where they simply won’t be the best choice. We certainly won’t be seeing redox flow batteries in cars or planes anytime soon, and for rapid-fire day-to-day tasks like frequency regulation, lithium-ion is likely to remain the most competitive and effective option. But if power and space restrictions are not your main concern, and you want something that can discharge electrons for a relatively long period of time, then flow batteries might be a better choice.**

**So, what about the comparative Levelised Cost of Electricity, or LCOE of each technology then?**

**Well, in twenty-twenty-two some boffins from the University of Sheffield here in England did quite a lot of leg work and crunched an awful lot of numbers to try to get an accurate picture of how that comparison is panning out. Using a model based on a commercial solar PV installation in California, and assuming round trip efficiencies of ninety four percent for lithium-ion batteries and seventy-eight percent for redox flow batteries, the researchers found that both configurations achieved an LCOE of less than twenty-two cents per kilowatt-hour. They also found that in hotter locations the redox flow system has a distinct advantage over lithium-ion because of its better operational suitability to higher ambient temperatures.**

**There’s obviously a great more detail than that in the paper itself, so if you want to scrutinise the minutiae then I’ve left a link to it in the description section below. And it’s open source too, so you won’t be confronted by a paywall.**

**In terms of the global market, well… busy, busy. China being China, they have of course got the largest grid connected redox flow battery system IN THE WORLD, with a capacity of a hundred megawatts delivering four hundred megawatt hours of energy into the electricity grid of China’s Dalian region. A second phase of the project is expected to double that capacity to two hundred megawatts and eight hundred megawatt hours of energy discharge. Next door in South Korea, there’s H2 Inc. who have a vanadium redox flow battery product that they call Enerflow, made in a factory with an annual production capacity of three hundred and thirty megawatt hours. In December twenty-twenty-one they started work on a twenty-megawatt hour energy storage installation at an existing gas peaker plant in California.**

**And while we’re in America, there’s Invinity Energy Systems. They reckon themselves to be the global leader in utility-grade energy storage. As of August twenty-twenty-three they had more than sixty-five megawatt-hours-worth of vanadium flow batteries deployed at sites all over the world.**

**Another big player is VRB Energy, originally founded in Australia and now with a North American HQ in British Columbia. They currently have thirty megawatt-hours of installed redox flow batteries boasting a total of more than eight hundred-thousand hours of proven performance time.**

**Cell Cube is another competitor. They’re based in Austria, but they’ve been involved in projects all over the world with an emphasis on grid independence for applications as diverse as industrial parks, construction sites and even remote off grid villages in very hot climates like Africa and South America.**

**That brings us back around to Redflow, who I mentioned earlier. They come at the redox flow challenge from a slightly different angle. They still have two separate tanks containing solutions that get pumped across a stack of cells, but instead of using vanadium, they use a zinc bromide solution. When the system is being charged up, the bromide gives up an electron in a process that converts it into bromine, which is then deposited on the electrode. Meanwhile the zinc ions on the other side GAIN a COUPLE of electrons each and the resulting zinc metal gets plated out on the electrode on that side. During discharge the reaction is reversed, and all those lovely electrons can be shuttled back to their original position via an electrical circuit where they can do some useful work. But here’s the thing – because each zinc ion can capture TWO electrons at a time instead of just a single electron in a vanadium set up, you effectively get twice the bang for your buck. In other words, say Redflow, each of their ten-kilowatt hour modules only needs to be half the size of an equivalent version using the Vanadium tanks that we looked at earlier. Redflow have been supplying rudimentary versions of their flow batteries to places like off grid homesteads in the Australian outback for many years, but more recently they’ve really tidied up their modules and started focusing on the global market. They recently announced their most significant project to date… a twenty-megawatt hour system to back up a large solar installation commissioned by Faraday Microgrids in California. When it’s completed in twenty-twenty-four, it’ll be one of the largest flow battery installations in the US, helping California reach its target of about fifty-five gigawatt hours of long duration energy storage by twenty-forty-five.**

**Redflow are based in Brisbane, which is not somewhere I’m ever likely to get to. Luckily, two of my favourite YouTube colleagues, Rosie Barnes from Engineering with Rosie, and Robert Lewellyn from the Fully Charged Show have both visited Redflow’s factory, and I’ve put links to both their videos on the end screen of this one, so if you’re on a PC or tablet you’ll be able to click on the thumbnail images to jump straight over to either one of them.**

**There are other flow battery manufacturers around the world of course, so apologies to any of those that I haven’t mentioned today. And there are loads of very interesting flow battery installation projects happening too. They’re far too numerous to look at in a single video, but I’ve left links in the description section to as many of them as I could find.**

**So, all in all, an extremely lively and competitive market for a technology offering yet another solution to the challenge of storing and releasing energy over several hours or even a few days, which many industry analysts regard as the final link in the renewable energy chain and the final nail in the coffin of the fossil fuel industry’s global monopoly.**

**Not ALL analysts agree on that assessment though, and you may have your own views, or direct industry experience to share as well, so as always, if you do, then why not jump down to the comments section below and leave your thoughts there - and I’ll be very interested to find out what you know.**

**That’s it for this week though. Thanks, as always to our Patreon supporters, who help me keep ads and sponsorship messages out of all my videos. If you feel you could support us in that way, then head over to Patreon dot com forward slash just have a think to find out about all the exclusive stuff you can get stuck into there.**

**You can also support us for free by subscribing to the channel here, and most importantly by simply hitting that like button, which apparently induces the dreaded algorithm to put this video in front of more people…which would be nice!**

**As always, thanks very much for watching! Have a great week, and remember to just have a think. See you next week.**