**Those of you that watch this channel regularly will know that there’s a bit of a global race on to find sustainable and cost effective ways to store energy so that micro and macro power generators can utilise intermittent renewables like solar and wind more efficiently and reliably.**

**It’s an absolutely crucial element of the transition away from fossil fuels in our struggle to keep our average atmospheric temperatures below two degrees Celsius above pre-industrial levels.**

**One of those energy storage options is a technology called Redox Flow Batteries, which is not something I’ve yet looked at on this channel. Redox Flow batteries represent a promising alternative to lithium ion batteries but the systems currently available on the market have a bit of an environmental Achilles heel – they all use a scarce and expensive metal called Vanadium in a fairly nasty toxic acid solution as the basis for their electrolytes, and most of them also use an oil based polymer called polyacrylonitrile for the electrodes. So, scaling the whole thing up to provide national grid level storage solutions could have potentially problematic environmental implications.**

**But in late October 2020 that hurdle looks to have been overcome by a team of researchers from Sweden’s Linköping University who claim to have designed a redox flow battery using all organic materials.**

**So, I guess now’s probably a good time to take a look at how it all works.**

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

**Redox flow batteries are a brilliant idea. They’re a kind of cross between a battery and a fuel cell and they’re very easily scalable.**

**The basic set up is two tanks of electrolyte liquid containing solutions of Vanadium. The vanadium ions in each tank have different chemical configurations so that one tank acts as a positive electrolyte and the other tanks acts as negative electrolyte. In between them there’s a cell stack. The solutions from each tank 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 the science bods call 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 on that side is known as reduction…you can see where I’m going here can’t you…**

**Yes, you guessed it, the Reduction and Oxidation processes are what gives Redox Flow Batteries their name.**

**Anyway, we haven’t quite finished the full cycle yet. The reduction process frees up positively charged Hydrogen ions which flow across the membrane to maintain the charge balance. The whole thing is completely reversible so that the system can be recharged.**

**Now if you’re thinking that that all sounds a little bit like what happens in a lithium ion battery then you’d be right. Lithium ion batteries have proved to be a transformational technology, not just for our modern electronic gadgets, but increasingly for domestic energy storage and of course for electric vehicles. So why don’t we just scale them up to use them as grid energy storage too? Well, you’ve no doubt already seen instances where exactly that is happening, the most famous of which is probably the Tesla installation at Hornsdale Wind Farm in South Australia. But that size of installation is really pushing the limits of what lithium ion can achieve in any kind of cost-effective way. They’ve got great energy density but they’re still pretty expensive and they’re only really good for about 4 hours of discharge to provide frequency regulation or grid balancing, and as anyone who’s ever owned a mobile phone knows, they also lose capacity over time. Plus we’ve got the well documented issues of lithium supply levels and cobalt sourced from appalling artisan mines in the DRC.**

**Redox flow batteries have a lower energy density but they can be really easily scaled up to theoretically unlimited energy capacity simply by using larger electrolyte storage tanks. They can also be left charged up or completely discharged for very long periods without degrading. They’re a lot safer than lithium ion batteries too – no chance of those inconvenient conflagrations that grid operators seem to find so irritating. If the electrolytes in a flow battery accidentally get mixed, there’s no fire or explosion and the battery doesn’t get damaged. They can be discharged down to about ninety percent or more, and they can be cycled between fifteen and twenty thousand times, which is way better than the four to five thousand cycles of lithium ion. All of that makes them cheap. And cheap is something that grid operators are quite keen on.**

**But that problem of Vanadium electrolytes and polyacrylonitrile electrodes is definitely a wrinkle that developers would very much like to iron out as these things get more and more integrated into large scale grids, not just to drive costs down still further, but also to avoid the environmental impact of drilling and mining for those materials.**

**Lots of research had already been taking place before the Swedish team published their findings, most recently in April 2020, from a team of Scientists at the University of South California, who published a paper in the Journal of the Electrochemical Society demonstrating a flow battery using an electrolyte solution combining iron sulphate, which is a cheap and plentiful waste product of the mining industry, with something called anthraquinone disulphonic acid, or AQDS, based on quinone, which is an organic material that the team reckon can be derived from any carbon-based feedstock, including carbon dioxide. They claim the material costs for their battery would be about sixty six dollars per kilowatt hour, which is less than half the cost of the vanadium version. That research already represents a big step forward for flow battery technology, providing an important boost to get this method of energy storage adopted on a much wider commercial scale.**

**But this latest research from the team at Linköping University over in Sweden has taken the concept a couple of very important steps further, not least from an environmental point of view.**

**If you watched our video about energy storage in bricks from a coupe of weeks ago, you may remember me talking about a conducting organic polymer called PEDOT. Well it turns out that PEDOT is proving a popular choice because that’s precisely what the Swedish team have used to coat the carbon electrodes in their flow battery system. They used chemical doping to manipulate the PEDOT into a state that will transport either positive ions or negative ions so you can effectively have a cathode and an anode like a normal battery, with both made from the same material.**

**And just like the USC team, they’ve also used Quinone molecules to form the basis of their electrolyte solution. It’s called ARS which their research paper refers to as**

**“a sulfonated anthraquinone derivative that becomes anionic in aqueous solution”.**

**That gives it the important distinction of being water based not acid based. Their principal research engineer Mikhail Vagin, says**

**“Quinones can be derived from wood, but here we have used the same molecule, together with different variants of the conducting polymer PEDOT. It turns out that they are highly compatible with each other, which is like a gift from the natural world”**

**That high compatibility has the advantage that the PEDOT electrodes improve the ability of the quinone molecules to switch between their oxidised and their reduced states, which in turn creates the flow of protons and electrons.**

**Vagin calls the process ‘ion-selective electrocatalysis’ and he points out that while the effect probably exists in other types of membrane storage devices like batteries, fuel cells and supercapacitors, it’s never been properly identified and deliberately exploited as an advantageous process before.**

**Now, one caveat is that their organic version of the redox flow battery does have a lower energy density than the existing vanadium versions, but just like the USC system, this new set up is extremely cheap. The Swedish battery is also totally recyclable and completely safe in operation.**

**That important safety factor will no doubt be a very attractive selling point for grid scale operators, but it also offers the potential for smaller versions of the system to be made commercially available to domestic homeowners who’ve got a bit of space in a garage or an outbuilding to use these things as a cheap alternatives to a power wall for their home and as a charger for their electric vehicles.**

**Another great step in a very positive direction. As always of course, we need it out of the laboratory and onto the market as quickly as possible, but one of the several countries already enthusiastically developing flow batteries, is flow batteries is China, and as well as funding from various Swedish foundations, this research also received a grant from China’s Scholarship council, so if you’re a big European or American tech investor with a bit of cash burning a hole in your pocket I suggest you get in touch with these folks pretty soon if you don’t our friends in The People’s Republic to gain yet another competitive advantage over the rest of the sustainable technology world.**

**That’s it for this week.**

**Do have a look at the Just Have a Think app if you get the chance. It’s not just a handy way to get to my videos directly from your phone’s home screen each week. It’s also a news aggregator bringing you daily news and articles from thousands of sources around the world on climate and sustainable technology. The part I really like is that you don't have to register any of your information to use it and there are no ads on the app itself, so what you get is a completely free to use platform that just gives you the content you want and nothing else.**

**I must also say a big thank you to our supporters over at Patreon who allow me to keep the channel ad-free and maintain independent content. And a special shout out to the folks who’ve joined since last time with pledges of ten dollars or more a month.**

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