**If you’ve been tuning into the channel over the past few weeks, you’ll know that I’m on a bit of a mission to review the progress of some of the most promising sustainable technologies that we’ve featured on the channel over the years.**

**One of those technologies is an energy storage system known as a redox flow battery, which we first looked at back in twenty-twenty.**

**Hang on Dave, didn’t you already do a review video back in September last year featuring all the most promising redox flow battery makers operating around the world today? And then didn’t you do another one only about three weeks later, highlighting a few more key players that you inadvertently missed the first time, in a sort of desperate retroactive mop up exercise to compensate for your own journalistic incompetence?**

**Yeah, I did. Thanks for noticing.**

**Thing is though, a few weeks ago, news of an alternative type of redox flow battery technology splatted straight into the middle of my radar screen, and although this one is not yet fully commercialised and mass produced, it does have a very distinct point of difference from every other flow battery we’ve looked at so far. Instead of using solutions of metal-based compounds as its energy store, it uses gaseous carbon dioxide captured from factory smokestacks.**

**And that definitely piqued my interest!**

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

**Those of you with a more focussed industry microscope than me will no doubt have already guessed that I’m referring to a Canadian electrochemical engineering company by the name of Agora Energy. And you will probably also know that Agora Energy is not a brand new twenty-twenty-four start up either – they’ve been developing their tech for several years now.**

**Back in twenty-twenty-one, the developers there published** [**this**](https://www.sciencedirect.com/science/article/pii/S0378775321002937) **research paper, with one of those really catchy titles that viewers of this channel have come to know and love over the years.**

**The bit that caught my eye, given the stuff I rant about so often in my videos, was the main description of a ‘Carbon Dioxide Redox Flow Battery’, which naturally made me want to know what happens to the carbon dioxide inside the battery, and whether any of it gets spat back out into the atmosphere at the end of the process. So, what’s the scoop then?**

**Well, it’s a redox battery first of all isn’t it, and we know from all our previous videos on the subject that that usually means the energy is derived from some variation of a metal-based solution held in large storage tanks that are completely separate to the electrochemical cells where the reaction takes place. We also know that the word ‘redox’ is a portmanteau abbreviation of reduction, which is when molecules gain electrons, and oxidation, when molecules give up electrons. If you can persuade the electrons to move from one side of that reaction to the other via an external wire, then you get yourself an electrical circuit that can do some useful work.**

**Redox Flow batteries don’t really compete with lithium-ion batteries for fast response, short duration frequency regulation duties, but they do fit quite snugly into the next slot up, providing longer duration storage, extending out to a few days. And that gives grid operators another option to help accommodate the rapidly increasing proportion of renewables connecting into their systems.**

**Difference number one with the Agora battery is that it doesn’t use any of the slightly troubling metals like vanadium or zinc or manganese that we’ve looked at in previous flow battery videos. It uses carbon dioxide, which the company plans to capture from industrial emission sources. That’s carbon dioxide that would otherwise be released into the atmosphere to do the nasty greenhouse gas thing that we hear so much about in the news these days. So, capturing that gas and doing something intelligent with it is definitely a good start.**

**So, the carbon dioxide comes into a storage container that sits next to the main battery set up.**

**Inside here, we’ve got a fairly typical, recognisable flow battery configuration, with two tanks of solution on either side of a cell stack, and a couple of pumps to keep everything constantly circulating. During the charging cycle the CO2 gets pumped into an aqueous solution on the cathode side of the battery where the charging current causes it to gain electrons to produce what the science bods call an ‘anion formate’ of formic acid . Meanwhile the tank on the anode side contains a solution of bromine. During the charging cycle the bromide ions give up their electrons, and that movement of electrons closes the circuit in the storage stage of the battery. The system can sit quite happily like that for relatively long durations with minimal self-discharge. When the stored energy is required, discharging does start happening and the whole process operates in reverse, allowing electrons to flow through an external circuit.**

**And that’s fine.**

**The bromide goes back to being bromine and the formate goes back to being water and carbon dioxide, and you can do that lots of times with negligible loss of performance. Or at least that’s how it would work in an ordinary set up, known as a ‘closed-loop model’. But the authors of this research paper discovered a potentially massive bonus reaction caused by running the discharge cycle on the cathode side at a significantly higher pH value than the charge cycle, in what’s known as an ‘open-loop model’. For reasons that, trust me, are way outside the scope of my little brain’s processing power, the team found that by doing this, instead of turning the formate solution back into water and carbon dioxide, they got water and carbonate instead. The carbonate, which has now essentially locked away the carbon dioxide gas into a solid material, can then be harvested and processed into commodities that are in great demand for all sorts of modern industrial processes.**

**Potassium carbonate, for example, can be found in a huge range of products from soaps and water softeners to animal feed, fire -extinguishers and industrial drying agents.**

**Sodium carbonate is more commonly known as soda ash. Its derivative, Sodium bicarbonate is what you and I know as baking soda. It’s used as a food additive of course, but also in glass and paper making processes, as well as soaps, and detergents and a whole host of other industrial chemical processes. About three quarters of the roughly fifty-five million tonnes of sodium carbonate produced today comes from something called the Solvay Process. That’s a whole video in its own right to be honest, but in very basic terms, it involves the reaction of sodium chloride and ammonia in water. Carbon dioxide is bubbled up though the briny solution to cause various chemical reactions that eventually produce the sodium carbonate end-product. It’s a bit more environmentally friendly than previous methods of production, but it’s still a pretty significant net CO2 emitter.**

**So, what the folks at Agora potentially have on their hands here is an energy storage system, plus a carbon negative method of producing an extremely valuable industrial commodity. On the face of it, that would seem to be a pretty compelling proposition.**

**Is it a good energy storage technology though? I mean does it have a decent energy density and low costs, and all that lovely stuff?**

**Well, let’s get the standard caveat out of the way first, shall we? You know, the one that generally causes the more cynical viewer to raise their eyebrows and start typing furiously in the comments section below, even before the video has ended… at the time of making this video we only have laboratory numbers available.**

**I know! I know! And you can probably switch off now if you’ve had your fill of that kind of bench test data.**

**But if you’re still watching then I can tell you that, according to the research paper, operating this reaction at room temperature resulted in a potential difference across the cell of 1.59 volts and a specific energy density of 284 Wh/kg, which is more than three times higher than a typical vanadium flow battery and right up there with Tesla’s 2170 battery cells. Although for fairly obvious reasons, it’s unlikely you’ll ever see one of these things strapped to the back of a road vehicle. Flow batteries are very definitely optimised for stationary energy storage!**

**As for costs? Well, that looks pretty encouraging too. A metric tonne of CO2 captured from industrial processes costs between $30 and $100 depending on its purity and how many processing stages it’s been through. That’s extremely cheap compared to some of the metals used in more typical flow batteries, which can cost many thousands of dollars per tonne.**

**And by the way, those carbonates and bicarbonates I mentioned earlier can be sold on the open market for anything between about $200 and $600 per ton, so there’s a pretty health claw back to be had there too.**

**Downsides? Apart from the fact that these things don’t yet exist at commercial scale?**

**Well, there’s acid on the cathode side, which obviously requires careful handling, and there’s bromine on the anode side which can be very harmful to health in large doses, so that needs to be managed properly as well, not least at the end-of-life disposal stage. So just like all fledgling technologies, there will inevitably be major hurdles to overcome along the road to commercial reality. Agora Energy have certainly received plaudits for their research work though. In twenty-twenty-one the company won the Keeling Curve Prize for Capture and Utilization, and the following year it won first prize in the**[**Hello Tomorrow**](https://hello-tomorrow.org/)**global deep-tech competition, beating five thousand entrants from a hundred and twenty-eight countries.**

**Prizes are great of course, but they don’t get you a new research facility or a demonstration prototype do they, much less a shiny new production line. That takes cold hard cash, and as far as I can tell Agora has so far struggled to secure a significant level of seed investment, possibly hindered by the two-year hiatus caused by the COVID pandemic. That sadly means we won’t be seeing the CO2 Redox Flow Battery in grid systems anytime soon, but I think it’s fair to say it does look like a very promising technology that green venture capitalists would do well to pay attention to and maybe get involved with in a meaningful, greenBACK kind of a way, if you know what I mean. I certainly wish them well. I’ll keep an eye on their progress, and I’ll keep you posted if I hear any news.**

**Now, if you’ve managed to get this far and you want to join other folks who may already be offering me the benefit of their wisdom in the comments section below, then do feel free to jump down there and leave your thoughts as well.**

**That’s it for this week though.**

**Thanks, as always, to our Patreon crew who keep me on the straight and narrow, and an extra special thank you to the folks whose names are scrolling up the screen beside me here, all of whom celebrate an anniversary of Patreon support in February.**

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

**See you next week.**