**This guy is called Donald Sadoway, and I’m guessing that’s a name that many of you are already very familiar with. Donald is a materials chemistry professor at the Massachusetts Institute of Technology, or MIT and for about a decade now he and his team have been developing a technology that he’s always claimed will revolutionise energy storage.**

**It’s called a liquid metal battery and Professor Sadoway is certainly not shy about extolling its virtues. He reckons its a zero maintenance, virtually zero degradation, high temperature chemistry that can outperform lithium-ion batteries on cost and performance.**

**The only slight snag is that it hasn’t.**

**At least not yet anyway.**

**Despite a thirty-five million dollar cash injection in 2014 from investors including Bill Gates and Total, Sadoway’s start-up company AMBRI struggled to reach the lofty goals it set for itself, with disappointing results in 2016 leading to the laying off of a quarter of the team.**

**But Sadoway has shown himself to be an extremely dogged and persistent innovator and he’s refused to give up on his quest, keeping the company going and pushing development as hard as possible in the four years between then and now.**

**And that determination and drive might just be about to pay off, because in November 2020 Ambri struck it’s first major commercial deal to supply a two hundred and fifty megawatt hour liquid metal battery storage system to a huge data centre due to start construction in Reno, Nevada in 2021.**

**Now, the tried and tested safe bet for Terra Scale, who are the company running the construction project, would have been to use utility scale lithium-ion batteries, but instead they’ve chosen to take a pretty big financial risk on a technology that has so far not been proven in a commercial environment.**

**So what is it that TerraScale have seen in Sadoway’s invention that’s convinced them to take the plunge?**

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

**In October 2020 the International Energy Agency published its World Energy Outlook report which states that global greenhouse gas emissions must be reduced by forty percent in the next nine years if the world is to reach carbon neutrality by 2050.**

**We’re miles off that of course. Not even close. 2020 was a bit of an aberration for obvious reasons, but once everyone’s had a couple of doses of vaccine no doubt we’ll all feel invincible again and much of society will return to it’s pre-pandemic, high consumption habits.**

**Meanwhile in the background, a herculean effort is being undertaken by grid operators all over the world to integrate low or zero carbon technologies onto their systems as quickly as possible in an effort to meet the challenge.**

**Bloomberg New Energy Finance projects that, by 2050, solar and wind will be producing fifty six percent of all power consumed globally, with hydro and nuclear providing a further twenty-one percent. And the remaining gas fired power plants and tiny number of coal plants, assuming they even exist at all by then, will be smothered in expensive carbon capture and storage systems.**

**To enable that volume of renewable energy to actually keep the lights on around the clock, three hundred and sixty five days a year, we’re going need a level of grid scale energy storage that makes our current provision look like a couple of double A batteries in the back of a radio.**

**That’s why we’ve been discovering and explaining so many different energy storage technologies on this channel over the past couple of years. We’ll probably need all of them and then some.**

**Right now though, the dominant technology is of course lithium ion batteries.**

**They’re doing a pretty decent job, and by dint of sheer economy of scale they are the cheapest option currently available. They’ve got pretty good energy density and can respond to frequency fluctuations on the grid within milliseconds. But they were never designed for very large utility scale implementation. They’re much better suited for use as single cells for laptops and phones. Once you start connecting them together in bulk they have to be quite carefully monitored and managed to keep voltages balanced across the cells and to keep temperatures down to safe working levels. And because the electrodes are made of solid material, they suffer tiny amounts of damage each time they get hit by lithium ions during the charge and discharge phases. That damage is permanent, and it accumulates over time, which leads to battery degradation. And then there’s the dreaded dendrites. You’ve probably heard about them. Essentially, they’re a build-up of lithium deposits on the anode which grow into long thin filaments that can eventually travel across the electrolyte separator and reach the cathode on the other side causing a fairly dramatic short circuit. So, although it’s still very rare in utility scale lithium-ion installations, risk of fire or even explosion does exist and has happened on several occasions.**

**Professor Sadoway reckons he’s got the answer to all these drawbacks with his liquid metal chemistry.**

**Not many metals are liquid at normal working temperatures, and the metals in Ambri’s system are no exception. Specifically they are Antimony, which melts at about six hundred and thirty degrees Celsius, and an alloy of Calcium, which has a melting point of more than eight hundred degrees Celsius.**

**Now you might think, given our experience of what can happen to a lithium-ion battery at very high temperatures, that deliberately heating up your anode and cathode towards their melting point is an extremely bad idea indeed.**

**But Sadoway didn’t start with lithium-ion batteries. He started with a nice crisp piece of blank paper on which he sketched out a fundamentally different way of constructing an electro-chemical energy storage device.**

**Admittedly there has been a massive amount of experimentation over the years to get to the optimal choice of materials, but the basic principle has never changed, and it’s this.. 5.57**

**The solid antimony and calcium alloy are combined at room temperature with a solid electrolyte 6.02 and put inside a sealed chamber insulated with a ceramic material. 6:05 Think of it a bit like a mini kiln. 6:08 The whole thing is encased in a positively polarized case 6:12 with a negative terminal sticking out of the top. 6:14**

**At room temperature you’ve got nothing more than an extremely heavy inanimate object. 6:19 In their solid states its impossible for the internal elements to react with each other to generate electricity. 6:25 That means the batteries are completely safe to transport. 6:29**

**Once they’re in situ and set up though, 6:32 an electrical current heats them up to five hundred degrees Celsius 6:35 which causes the metals and the salt electrolyte to move to a molten state, 6:40 and then gravity takes over, separating them out according to their density. 6:44 The antimony sinks, 6:46 the molten salt stays in the middle and the calcium alloy rises to the top. 6:50**

**At this stage the battery is charged and ready to go. 6:53 Antimony and calcium exist at opposite ends of the periodic table 6:57 and for reasons that are outside the scope of this video that means the antimony is much more electrically negative than calcium, which means there’s a potential difference between them. 7:05 So when a device is placed in the circuit 7:08 the calcium alloy breaks down into calcium ions and electrons. 7:13 The ions are attracted down to the antimony 7:15 and the electrons get there by flowing through the external circuit. 7:18 So, you may be thinking, that’s just a very hot version of a standard battery. 7:23 But discharging this system results in a completely new alloy of antimony and calcium, 7:28 with the molten electrolyte sitting on top. 7:31 And because it’s liquid there’s no permanent deformation or damage as the calcium ions hit the antimony. 7:37 And dendrites aren’t a thing either, because there’s no solid surface for anything to build up on. 7:43**

**To recharge the system you simply 7:46 use the electrical current from your renewable power sources to reverse the reaction 7:50 which causes the calcium alloy and the antimony to reform to their original positions. 7:56**

**After the initial input of electricity, the reaction generates it’s own heat, keeping the battery at optimum working temperature and eliminating the need for an external heat source. 8:07**

**Sadoway argues that the beauty of the system is in its simplicity. He points out that unlike lithium-ion batteries, these things actually like to be worked hard, ideally being fully charged and discharged every couple of days to maintain their constant high temperature. His teams research analysis showed an overall end-to-end efficiency of eighty percent, which is higher than pumped hydro. And Sadoway says operators can expect tens of thousands of cycles with negligible degradation or capacity fade. And because they have a self-maintaining temperature, the batteries will work just as safely and effectively in very cold climates like the arctic or very hot climates like for example India, where there’s an urgent focus on getting renewables onto the grid as quickly as possible. 8:51**

**If for some reason the battery gets tipped over 8:54 causing a short circuit between the metals, 8:56 then you will get a pretty big spike in temperature. 8:59 But still well within the insulating capacity of the ceramic enclosure. 9:03 After that the reaction simply stops and the whole thing cools back down to the inanimate lump you started with. 9:10 No dramatic fires or explosions like the ones we occasionally hear about with lithium-ion. AND you’re still left with a functional battery too. 9:18 Just stick a current through it again and the metals dutifully separate back out into their charged-up positions ready to go again. 9:26**

**The biggest challenge that Ambri faces is the economy of scale hurdle that all technologies face when they first get going. But according to Bloomberg New Energy Finance the cost of the electrode materials for Ambri’s battery are only about a third of the cost of electrode materials in a lithium -ion battery, and the kick start to scale production that Ambri so desperately needs may well come in the form of that deal with TerraScale that I mentioned right at the start of the video. The project is called Energos Reno. It’s a three thousand seven hundred acre site which will have its own micro grid comprising five hundred megawatts of renewable capacity powering a massive data centre that will likely be used by commercial clients and government agencies. If Ambri’s two hundred and fifty megawatt hour installation does what it says on the tin, then Professor Sadoway may finally see the floodgates open for the technology he’s dedicated himself to for more than a decade and history may come to record his contribution to energy storage on a similar level to John B Goodenough’s revolutionary lithium-Ion breakthrough several decades earlier.**

**Judging by the large number of people who asked me to take a look at this technology for the channel, I’m quite sure there will be some strong opinions on liquid metal batteries and the trajectory of energy storage in general, so…jump down to the comments section below and leave your thoughts there.**

 **That’s it for this week though.**

**Thanks to our fantastic Patreon supporters who help keep the channel independent and keep these videos ad-free, and a quick shout out to the folks who’ve joined since last time with pledges of ten dollars or more a month. They are**

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**Ryan Milakovitch**

**Amy Hemmeter**

**Mark Green**

**Colin Meier**

**John Comstock**

**and Colin Cochran**

**and of course, a big thank you to everyone else who’s joined since last time too.**

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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**