**Those of you who’ve been following the progress of renewable power integration onto our global electricity grids will no doubt be only too aware of their biggest achilles heel – something called intermittency. In other words the obvious problem that the sun doesn’t shine at night and the wind doesn’t always blow. There are various ways to get around that challenge, including ambitious projects like intercontinental distributed smart grids that can share electrons from where they’re being generated to where they’re needed in the blink of eye, even over distances of thousands of miles. A grid like that is already being built out here in Europe, but even so the world is probably decades away from any kind of fully integrated system, so in the meantime we have to find ways of storing any excess energy that renewables produce so that we can use it when those renewables are dormant. Pumped hydro does a good job in some parts of the world, and we looked at that in a previous video, but its limited by geography and it’s hardly something you can just stick on the back of a truck and deliver to a new site. Lithium-ion batteries are currently being embraced in large volumes by grid operators all over the world. They work well in principle. They’ve got relatively high energy density and efficiency. They provide instant frequency response and can discharge their stored energy into the grid for about four hours at a time. But they’re still relatively expensive due to the scarcity of lithium metal resources and the sophisticated internal protection systems they use in order to prevent dangerous overcharging and combustion. And four hours is not a particularly long time either. So, a great deal of research and development has been going on to find cheap, reliable and long duration energy storage solutions that also use abundant, safe, reusable and sustainable materials.**

**And now, after a long period in stealth mode, a Massachusetts company has put their head above the parapet to announce to the world that they’ve developed a storage solution using one of the cheapest and most abundant elements on earth and which can discharge power not for hours but for days at a time. So, will this be yet another one to add to the cynics list of ‘somewhere over the rainbow’ technologies, or could it turn out to be a realistic disruptor in the grid scale energy sector?**

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

**The company that nails the long duration grid scale energy storage challenge on any kind of economically viable level is likely to become a very large and very wealthy entity indeed. So, it’s hardly surprising that furious research and development activity is going on in laboratories all over the world.**

**Form Energy Inc. have been quietly working away on their own solution for about four years, and they reckon they now have a product that’s ready to ramp up to megawatt levels of production by 2023.**

**The main two ingredients of their technology are nothing more fancy than good old iron, and fresh air. Both extremely abundant, easily accessible, and dirt cheap. Good start.**

**The iron-air battery is actually a technology that’s been known about for decades, but until now there’s never been a market force strong enough to attract funding for development, partly because the batteries are very large and very heavy.**

**You certainly won’t be seeing iron-air batteries in smart phones or electric vehicles any time soon – they’re far too heavy for that, and lithium ion has pretty much captured that market already. But for stationary utility scale long duration energy storage, Form’s iron air technology looks like it could be an ideal solution.**

**The basic principle of the technology is breathtakingly simple. It’s something that Form refer to as ‘Reversible rusting’.**

**Each individual battery is a unit about the size of a washing machine containing between ten and twenty stacks of cells, each of which has an anode consisting of pebble-sized pellets of metallic iron on one side, and an air breathing cathode on the other side, all immersed in a water-based, non-flammable electrolyte, much like what you’d find inside a standard double A battery.**

**As oxygen from the air floods into the battery cell, it reacts with the iron via the liquid electrolyte. That reaction reduces the air to hydroxide and oxidises the iron firstly into iron-hydroxide which releases electrons, and then into iron oxide or rust which releases more electrons, all of which can then be harvested to provide electrical energy.**

**As the battery discharges, that rust builds up at the cathode.**

**To recharge the battery, an electrical current can be passed through the cells which reverses the reaction, liberating the oxygen from the rust and turning it back into iron.**

**One of the biggest challenges was to find a cathode material that was impermeable to water but was still able to breathe oxygen. In 2020, Form Inc found that material at an Arizona based battery company called Nant Energy Inc.**

**They’d spent about ten years developing just such a membrane for a similar technology using zinc instead of iron.**

**Form bought all the patents and an inventory of thousands of cathodes from Nant Energy. That provided them with the last piece of their development puzzle and enabled them to greatly accelerate their program.**

**According to this twenty-nineteen article, the theoretical energy density of iron-air batteries is around seven hundred and sixty-four watt-hours per kilogram. That’s several times greater than the best lithium-ion batteries on the market today**

**Lithium-ion batteries use a process called intercalation. Lithium ions move back and forth through an electrolyte and fit into empty spaces inside the crystal structures of the anode and cathode. That means the capacity of a lithium-ion cell is limited by the physical volume of the two electrodes.**

**Iron air batteries don’t move ions between the electrodes, so they’re not limited by intercalation in available spaces in electrode lattices, they use an electrochemical reaction that simply deposits rust onto the surface of the cathode, so they’re only limited by the cathode’s surface area. That greatly reduces the mass requirement of the battery and leads to that much higher theoretical energy density.**

**At scale, Form reckons their batteries will store energy at about a tenth of the cost of lithium ion. The nickel, cobalt, lithium and manganese minerals used in existing lithium-ion batteries translate to a cost of between fifty and eighty dollars per kilowatt hour.**

**Form say that using iron instead will mean spending less than six dollars per kilowatt hour, and even when it’s all packaged up into a full battery system, the price will still be less than twenty dollars per kilowatt-hour. At that level, the general industry consensus seems to be that renewables plus energy storage could fully replace traditional fossil-fuel-burning power plants.**

**And when I say ‘at scale’, I’m talking about warehouses full of tens of thousands of washing machine sized batteries, all hooked up together to provide enormous quantities of energy storage. Form say their least dense configuration would get one megawatt of capacity into about an acre of land, with the high density configurations reaching three megawatts for the same amount of space. By 2023, Form plans to deploy a one-megawatt demonstration battery capable of discharging continuously for more than six days, and they’re already in talks with several utility companies about potential battery deployments.**

**The system can be sited anywhere where there’s a need, even in urban areas, and the idea is not to supersede lithium-ion batteries, which already provide a very useful function for short bursts of frequency regulation and grid stability, but to compliment them by delivering about a hundred and fifty hours of continuous discharge. That’s a combination that, according to Form’s CEO Mateo Jaramillo, could completely displace gas power on electricity grids, and enable wind and solar to provide low-cost renewable energy that can work alongside existing nuclear and hydropower plants to provide reliable, carbon-free electricity all year-round.**

**Jaramillo himself has a pretty good pedigree, having spent seven years at Tesla Motors, initially working in powertrain sales and site acquisitions and then spearheading Tesla’s move into stationary energy storage. His industry knowledge is complimented by a team of highly experienced and very technically qualified colleagues including Professor Yet-Ming Chiang from MIT who started working on long-duration batteries back in 2012 as part of an Energy Department collaboration and who co-founded a pioneering lithium-ion battery company called A123 Systems Inc.**

**Form is backed by Bill Gates’ renewable energy investment company Breakthrough Energy Ventures, and also by the steel making giant Arcelor Mittal, who are one of the world’s largest producers of iron-ore and who are leading a two hundred-million dollar funding round to get Form energy’s technology into full production and to establish collaborative links with all the major regulators and electricity generators across the United States.**

The reverse reactions represent charging the half-cell. The discharge reaction at the air electrode also involve 4 electron**There’s a saying in the building trade that the three most important factors for any project are for it to be fast, cheap, and good quality – the saying goes that you can have any two of those factors, but you can’t have all three.**

**There’s a saying in the building trade that the three most important factors for any project are for it to be fast, cheap, and good quality – the saying goes that you can have any two of those factors, but you can’t have all three.**

**It’s a similar problem in the energy sector. The three crucial factors there are affordability, reliability and the absence of carbon in the process. Most electricity generation can deliver any two of those factors, but long-duration energy storage like the Form battery looks set to help renewable energies like wind and solar deliver all three of them and actually move the world towards the sustainable future we’re all hearing so much about in the media these days.**

**If you’ve got some experience working in this field of technology, or if you have views on how you think utility scale energy storage should be rolled out in your part of the world, then why not jump down to the comments section below and leave your thoughts there.**

**That’s it for this week though.**

**A big thank you, as always, to the folks who make these videos possible by supporting my work via Patreon. They allow me to remain completely independent, and they enable me to keep all my videos completely ad free. And I must just give a quick shout out to those people who joined recently with pledges of ten dollars or more a month. They are**

**LH King**

**William Gregor**

**Michal Prause**

**Owen Evans**

**John Sawdon**

**Lemmi**

**Dave Palmer**

**Marrie Lionel**

**Romain Dubois**

**Sabine Behrmann**

**John Foster**

**Broom**

**and**

**Angry Abacus**

**And of course, a big thank you to everyone else whose joined since last time too.**

**You can join the team at Patreon and get the opportunity to exchange ideas and information with like-minded folks, plus watch exclusive monthly news updates from me and have your say on future programs in monthly content polls by visiting**

[**www.patreon.com/justhaveathink**](http://www.patreon.com/justhaveathink)

**And you can hugely support the channel absolutely for free by subscribing and hitting that like button and notification bell.**

**It’s dead easy to do all that, you just need to click down there or on that icon there.**

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