**So, lithium-ion batteries then. They’re an astonishing piece of technology, developed back in the eighties by the legend that is John B. Goodenough, who by the way is still working on new energy systems today, at the age of one hundred.**

**Without the breakthrough that John and his colleagues achieved more than forty years ago, it’s probably fair to say that most of the technology we use today would not exist. No MP3 players, no smart phones, no life-saving medical implants or portable hospital devices, no electric vehicles and no energy storage to compliment intermittent grid scale renewable technologies like wind and solar, without which the transition away from fossil fuels would be even more impossible than it seems right now.**

**So, thank you Mr Goodenough for everything you’ve done for humanity. Happy belated birthday greetings and congratulations on reaching the century mark.**

**But fantastic as they are, lithium-ion batteries do have their drawbacks. Despite rapid cost reductions over the past decade, they’re still relatively expensive, and although there are versions now that don’t use any cobalt or nickel, most do STILL contain those problematic commodities, along with lithium itself of course, all of which are in short supply in today’s troublesome global market. There’s also the problem of self-combustion, which while VERY rare, is nevertheless a potential eventuality in every single lithium-ion battery on the planet, as those pesky little dendrites gradually form inside the battery until they cause a short and ignite the volatile electrolyte. Chances are you’ll never witness such a conflagration, but when they do happen, they’re pretty dramatic. And in extreme cases they can shut down sections of a power grid or even threaten lives.**

**So, a great deal of work is going on all over the globe to develop cheaper, more reliable, more efficient and more environmentally friendly solutions to our rapidly growing energy storage requirements, and now a world record breaking zero emissions energy storage facility has stirred into life which doesn’t contain a single lithium-ion battery. So, what is this eco-friendly behemoth, and does it represent another step change in how we power the sustainable societies of the future?**

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

**Before I dive into today’s topic, I’ve just got a slightly unusual request to make of you good folks. Several of you have told me recently that despite having your YouTube notifications switched on for this channel, you haven’t been receiving any notifications from YouTube for some time and, as a consequence, you’ve missed some of the weekly videos. I’ve spoken with YouTube about it and although they have visibility of everything that goes on inside their platform, they have asked me to provide evidence that these notifications are not happening. So, if you HAVE hit the notification bell below in the past but haven’t been receiving weekly pings from YouTube, could you let me know? Either by leaving a comment below this video or by emailing this address here?**

**Cheers.**

**Now then, let’s get back to the interesting stuff.**

**It might not come as a total surprise to you to learn that the new installation I mentioned earlier is over in China. It seems like just about every new energy initiative they embark upon these days has some sort of record-breaking dimension to it. This one’s called the Zhangjiakou Power Plant and it uses nothing more complicated than compressed air to store energy. Now I’m sure many of you, especially in Germany and the States will be yelling at the screen that this is nothing new and you’ve had compressed air energy storage for decades. But HANG ON! Don’t click away just yet! Because this new technology is big leap forward from those existing systems, and don’t worry if you ARE in North America, OR Europe or Australia, because there ARE similar projects in development in your part of the world as well. We’ll come to those a bit later in the video, but first of all, lets take a look at why the installation in China is such a step forward. And to do that we first need to have a look at how a traditional utility scale compressed air energy storage system works.**

**The basic principle is dead simple really. When excess power is being generated on the grid, often from intermittent renewables like wind and solar, that power can be diverted to drive an industrial scale air compressor which draws air in, compresses it and shoves it into a large storage chamber, which is typically either a huge pressurised vessel, or something like an underground salt cavern or an aquifer.**

**The laws of thermodynamics tell us that gases get hot when they’re compressed, so to ease the process, that heat has to be somehow drawn away from the air. That’s a very important step which we’ll touch on in more detail in a moment.**

**When there’s a demand for extra grid power, the cold compressed air is heated up to help it rapidly expand so that it can be directed across a turbine to drive an electrical generator.**

**The world’s first Compressed Air storage system was the Huntorf Power Plant, built way back in nineteen-seventy-eight in Lower Saxony, Germany. It had a generating capacity of two hundred and ninety megawatts which it dispatched with an efficiency level of around twenty nine percent. A few years later, in nineteen-ninety-one, the McIntosh Power Plant was opened in Alabama, USA with a capacity of one hundred and ten megawatts and twenty seven percent efficiency.**

**So how do these plants deal with that heat generation that I mentioned a moment ago? Well, they both use a process known as diabatic compression. Diabatic is one of those sciency words that you and I are unlikely to come across in our everyday lives, and it sits alongside two other sciency words… adiabatic and isothermal. All three of them describe how the temperature of a gas changes as it’s compressed or expanded.**

**Adiabatic compression usually happens very quickly, with the gas getting hotter and hotter as it gets compressed. It’s what happens as a piston pushes air into a cylinder inside a diesel engine for example. In that case you WANT the air to get EXTREMELY hot so that it ignites atomised diesel fuel inside the chamber, which then causes an explosion that pushes the piston back up to rotate the crankshaft.**

**At the other end of the thermodynamic scale is isothermal compression where the temperature of the gas remains constant as it gets compressed. To achieve that you have to find a way of REMOVING all the heat AS the gas is compressed, either by going incredibly slowly so that the temperature gradually equalises with the ambient surrounding air, or by using some kind of non-compressible thermal mass right next to the gas that’s being compressed, to very quickly absorb the heat and keep the gas as close to a constant temperature as possible.**

**In between those two extremes is the diabatic compression technique used by the Huntdorf and McIntosh plants. Diabatic compression is generally achieved with huge intercoolers, which are specialised heat exchangers specifically engineered to cool a gas after it’s been compressed. Most of us probably know of intercoolers in the context of turbocharged vehicle engines. The intercooler dumps most of the heat straight into the air, essentially throwing away the energy used to compress the gas.**

**The result of this method is a large amount of cold air that’s been compressed down to as small a volume as possible and stored in underground caverns. The stored air is VERY cold, which is why the warming step is required to cause rapid expansion ahead of the turbine, and I’m sure you’re at least one step ahead of me here… yes, you’ve guessed it, the easiest way to heat up cold air is in a burner powered by fossil gas, which means the Huntdorf and McIntosh plants generate large quantities of those pesky greenhouse gas emissions.**

**They’re like everywhere aren’t they? They’re really irritating!**

**But this new ADVANCED compressed air energy storage facility in Zhangjiakou uses no fossil fuel combustion at all. Instead, they’ve developed a technology that draws the heat off the gas as it compresses and instead of releasing it into the atmosphere, they divert it into an insulated thermal storage facility. Then when the grid demands extra power, that stored heat can be put back into the air to accelerate the expansion before it goes over the turbine.**

**The facility has a generating capacity of a hundred megawatts, releasing up to FOUR hundred megawatt HOURS of energy. Capturing heat in a thermal storage tank increases the system design efficiency to over seventy percent, which completely eclipses the efficiencies of the fossil fuel combustion technology used at the existing Huntorf and McIntosh plants. It’s enough to generate more than a hundred and thirty-two million kilowatt hours of electricity a year, serving around sixty thousand households during peak electricity consumption.**

**According to the Institution of Engineering and Technology, or IET the Zhangjiakou plant will prevent the burning of about forty-two thousand tons of coal and reduce carbon dioxide emissions by a hundred and nine thousand tons every year.**

**But China isn’t alone in diving into this very promising technology. I promised you earlier that we’d talk about opportunities in other parts of the world, and one of the frontrunners in the field is a Canadian company called Hydrostor.**

**They’ve been on the go for eleven years now and, in that time, they’ve developed a very similar non-combustion system to the one being used in the Zhangjiakou plant, with a compressor, generator and thermal management system that can capture the heat from the air as it’s being compressed. Hydrostor combines all that with a closed loop water reservoir providing what they describe as hydrostatic compensation to maintain the system at near constant pressure during operation. That means the reservoir water is sent down into these purpose-built subterranean air chambers where it gets pushed back out again by the compressed air coming in the other side. Once the chambers are full of air and the reservoir is back at full level, the system is fully charged and can stay that way for days if necessary. Then when there’s a power demand, the reservoir water is pushed back down into the chambers to force the air back up to the surface under pressure where its temperature is rapidly increased by the stored heat in the thermal management system before being sent across the turbine.**

**Hydrostor has had to overcome a range of pretty challenging obstacles to get their technology to market, not least of which is the very long payback timeline that venture capitalists and other investors have to accept. Those folks are used to getting a return on their money in about ten months on average, but Hydrostor projects can cost as much as five hundred million dollars overall, and have a payback time that’s more like ten years, which is longer than some investment funds even run for! Company Chief Executive Curtis VanWalleghem has shown himself to be a very dogged and determined operator though, and the company now has several projects on the go in various parts of the world, ranging from a ten-megawatt hour facility, already in operation in Ontaria, Canada and a UK project converting a disused gas storage site, to some very large installations under active development in Australia and the USA that’ll have generating capacities as high as five hundred megawatts.**

**Additional competition comes from an Israeli technology company called Augwind Energy that’s developed a slightly different solution to the heat loss and efficiency challenge. Their system also uses water and air, but instead of pushing air down into deep underground chambers, they use a series of modular air tanks which they tell us are made of unique polymers that reduce production and maintenance costs. The tanks are cemented in just below the surface, with installation taking just a few days. Then they use renewable energy to run water pumps to compress the air into the tanks. That has the secondary advantage of removing a bit of heat from the air as it’s compressed. But Augwind run their system extremely slowly too, which means they stay very close to the isothermal compression we looked at earlier. Then when there’s an energy demand, the compressed air is used to push the same water over a hydroelectric turbine to produce the electricity. It’s just a different route to the same end result, and Augwind claim a very similar efficiency rate to the Zhangjiakou plant. They’ve been developing their Air Battery technology for about twelve years now, and they’ve secured more than two hundred megawatt hours-worth of projects in Israel that they hope to get up and running over the next few years.**

**But in typical fashion, China isn’t resting on its laurels either. There are apparently at least nine compressed air energy storage plants there that are either under construction now or have already entered into service. The total combined capacity of those plants is six hundred and eighty-two megawatts. And there are another nineteen projects in the planning stages, with a combined capacity of five point three-eight GIGAwatts.**

**By twenty thirty, China expects to have more than forty-three gigawatts of non-combustion compressed air storage facilities in service, representing about twenty-three percent of the country’s total energy storage capacity.**

**There will no doubt be pitfalls along the development pathway for this fossil free energy storage technology, especially in western democratic countries. Getting one of these projects off the ground entails securing the land and interconnections, seeking community engagement and applying for all sorts of permits and regulatory approvals. But the prize for patient investors could very large indeed. According to a recent Mckinsey report, long duration energy storage has the potential to deploy as much as two and a half THOUSAND GIGAWATTS of power capacity by twenty-forty to become the vital key to unlocking twenty-four seven clean grid energy in a more sustainable future world.**

**So, what’s your view? Do you think this advanced compressed air solution could be a market disruptor that displaces the dominance of lithium-ion batteries? Maybe you work in the industry and you can share some insight with us all. If you do, then why not jump down to the comments section below and leave your thoughts there.**

**That’s it for this week though. Don’t forget to subscribe and turn on those notifications if you want YouTube to tell you when we’ve posted a new video, and if you enjoyed this one then giving us a like is always a massive help to the channel too.**

**Thanks to all our Patreon supporters out there who allow me to keep these videos free of ads and sponsorship messages. A special thank you to the long-term supporters of the channel scrolling up the screen over here, all of whom reached an anniversary during October. And I must just give a quick shout out to some new supporters who’ve joined recently with pledges of ten dollars or more a month.**

 **They are**

**Ann J. Storm**

**Henk Werner**

**Seth Hall**

**Ryan G.**

**Radoslav Kirilov**

**Kimberley H**

**Alberts Appens**

**Aaron Ruscetta**

**Eduardo Da Costa**

**Xander Marjoram**

**John Novinson**

**and**

**Zvi Miller**

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

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