**I once worked for a guy who literally banned all his subordinate managers, including me, from ever using the phrase “we’re getting there” – he was one of those pedantic sticklers who would only accept a specific completion date for any given task, so that he could hold you fully to account each time you sailed passed that date without having achieved your goal. I did quite well, I lasted three months in that job!**

**Anyway, I mention that little anecdote because today’s video is the second of our twenty-twenty-four green tech PROGRESS reviews, and the green tech we’re reviewing today is solid state batteries. The developers of this particular technology have used the phrase “we’re getting there” so often since my first video on the subject back in twenty-eighteen that you could be forgiven for thinking that we are in fact not getting there at all.**

**So, is it time to give up on yet another green technology pipe dream, or are we nearly there yet?**

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

**We’ve investigated solid-state batteries on no fewer than three separate occasions on this channel over the last five years or so. It’s one of those extremely compelling technologies that, if it ever does hit mainstream mass production at an affordable price, really will revolutionise just about every sector of energy consumption for folks like you and me, most notably of course in the transport sector, where solid state technology promises significantly higher energy density than current lithium-ion batteries, with ultra-fast charging times and much longer operational lifetimes.**

**For the benefit of anyone who’s had better things to do for the last five years or so, here’s a quick recap of how it all works.**

**In a normal lithium-ion battery, like the one we looked at in last week’s video, you typically find a cathode made of a lithium-based material like lithium-nickel-manganese oxide for example, which is your NMC battery, and an anode typically made of graphite. Surrounding all that is a liquid electrolyte, usually made by adding lithium salts into a fairly nasty flammable solvent. To stop the whole thing short circuiting, you have a separator membrane in the middle of the electrolyte that will only allow ions to pass through. When you charge the system up, lithium ions rush across the liquid electrolyte from the cathode side, energised by the electricity flowing from the charging device. Those charged particles just happen to be small enough to be captured within the lattice-like structure of graphite in a process called intercalation. As the battery discharges, the ions flow back across to the cathode, and electrons flow back through an external circuit to do their useful work. And that’s fine. In fact, it works really nicely for myriad applications from very small stuff like smart watches and phones all the way up to very large stationary energy storage installations on electricity grids.**

**But then old Elon came along, didn’t he, and started putting lithium-ion batteries into attractive looking cars that people actually wanted to buy. The Tesla brand has turned the automotive industry completely on its head in the space of only a few short years, and now every auto manufacturer in the world is scrambling to get their ducks in a row before switching off all their internal combustion engine production lines sometime in the next decade or so. As a result, a concept that was essentially first proposed by Michael Faraday back in the early nineteenth century, has suddenly come hurtling back into vogue in the laboratories of battery chemists all over the planet, because it offers what most tech journalists, including this one, usually refer to as the ‘holy grail’ of battery cell technology.**

**Rightly or wrongly, one of the biggest perceived objections among prospective new electric vehicle buyers is the dreaded range anxiety. So, the alleviation of this ‘not really a real problem’ has become something of an obsession for all the major car makers, who are either making their batteries absolutely mahoosive, which strikes me as a rather self-defeating exercise, or who are looking for ways to produce batteries that can receive AND deliver energy far more efficiently. Which brings us to solid state technology. For the purposes of this video I’m going to ignore the so-called thin film solid-state cells which only store a very small amount of energy but which can last for a very, very long time and are already in use in things like pacemakers and IoT devices, and instead I’ll be focussing on what are known as solid-state bulk batteries which can store a lot of energy and are what the EV developers are interested in. There are currently dozens of different types of solid-state bulk batteries in development all over the world. Far too many to go through individually in a single video. But the basic theory, at least as far as this somewhat limited layman can understand, goes like this. The ‘solid’ in ‘solid state’ refers to the electrolyte as you’ve no doubt already worked out for yourself.**

**So why is that good then? Well, it means that in theory, if you can find a SOLID material like a ceramic or a glass or a solid polymer that lets ions through but that also effectively acts as a separator between anode and cathode, then you can get rid of the liquid electrolyte, reduce the volume of the cell, and effectively increase its energy density. You also theoretically eradicate the rather inconvenient problem of dendrite growth that presents a potential fire risk in current lithium-ion batteries. And because you get rid of the flammable SOLVENTS that liquid electrolytes are based on, your battery can now withstand far higher temperatures, which means you can really whack the charge in at a truly terrifying rate without causing damage to the cell.**

**But that’s not all.**

**Oh no! It turns out that solid state batteries may also facilitate the use of lithium metal anodes.**

**So why is THAT useful?**

**Well, apparently if you can ditch the graphite anode and replace it with lithium metal, then you potentially get yourself EVEN MORE energy density. The folks at BMW recently published this chart of test data based on twelve different next generation CATHODE materials, shown along the X-axis at the bottom here, and three different anode materials. You can see that changing the cathode doesn’t do a whole lot to the energy density when combined with graphite OR graphite / SILICON anodes. But when you combine them with a lithium metal anode, the performance jumps right up, almost doubling the best graphite / silicon energy density.**

**And here’s some more ham-fisted science by yours truly to try to explain why that is. You’re welcome!**

**Essentially, the clever science bods tell us that if you’re storing your lithium in a carbon-based material then it takes six carbon atoms to hold onto one lithium ion. But if you use an anode made of pure metallic lithium then you effectively do away with all that bulky carbon and get yourself an even lighter, even more energy dense battery cell.**

**The only slight snag, apart from the obvious worry about global supplies of lithium, is that lithium metal anodes are really, really good at building up those pesky dendrites that I mentioned earlier, which means they just don’t work in lithium-ion batteries with liquid electrolytes. BUT, if you can make a solid electrolyte robust enough to resist the growth of dendrites, while doing all the other stuff that you want it to do, then you’ve surely hit the jackpot, haven’t you? Which is why developers have been trying to find that solid material for the last four decades or so.**

**And that brings us rather neatly to a US start up called Quantumscape, which is a name that I’m quite sure most of you good folks out there will already know well. They are arguably one of the most vocal and most talked about solid state developers in the industry, and I think it’s fair to say they’ve had a bit of a rollercoaster ride since their inception back in twenty ten.**

**Just to really confuse the issue, they’re working on something called a semi-solid-state battery. There’s no anode at all in their system. Instead, you get a lithium-based cathode with an electrical contact below it, and a solid-state ceramic separator with an electrical contact above it. As the battery charges, lithium moves out of the cathode, through the atomic lattice of the non-porous ceramic separator, and deposits between the top of the separator and the upper electrical contact, effectively forming a new anode layer of pure metallic lithium. So, as this QuantumScape animation suggests, you get the same energy from a much smaller space compared to the standard lithium-ion set up on the left-hand side. Now here’s where the ‘semi-solid’ bit comes in. According to their own website’s FAQ page**

 **“QuantumScape couples this solid-state ceramic separator with an organic liquid electrolyte for the cathode. The [cathode] requires high conductivity, high voltage stability, and the ability to make good contact with the cathode active material particle. It is difficult to find materials that meet both these requirements and attempts to do so often result in a material that meets neither requirement well”.**

**QuantumScape’s original sales pitch, which is presumably what pulled in such impressive investment from VW, was that their technology would result in a fifty to eighty percent increase in the driving range of an electric vehicle, which translated to an increase from three hundred and fifty miles to as much as six hundred and THIRTY miles from the same sized battery pack. Despite some encouraging recent feedback from VW’s subsidiary battery testing company PowerCo, QuantumScape has struggled to achieve these numbers, or ramp its technology up to real-world production volumes, so it’s had to do a bit of expectation management in recent months. Its website now quotes a vehicle range improvement of between fourteen and forty three percent, which takes a three-hundred-and-fifty-mile range battery up to somewhere between four hundred and five hundred miles. A regulatory filing made by QuantumScape in October twenty-twenty-three to the US Securities and Exchange Commission clarified that the company had missed the commercialization milestones outlined in its deal with VW, and that the German automaker therefore had the right to terminate the joint venture if it chose to do so. And sure enough, according to this Reuters report from January twenty-twenty-four, VW has now put out the feelers to find alternative solid-state battery manufacturers, allegedly focussing on a well-established French outfit called Blue Solutions, which already produces solid-state batteries for Daimler electric buses. The challenge THEY bring to the table is that their batteries currently take four hours to charge up, which is fine if your vehicle is parked up in a bus depot overnight, but not so good if you’re on your way to your auntie’s 90th birthday party and you’re already half an hour late. A spokesperson for Blue Solutions told Reuters it was working on a passenger car battery with a charging time of twenty minutes, and that it was aiming to construct a "gigafactory" to build those batteries by twenty-twenty-nine. But everyone says that, don’t they?**

**Meanwhile, Japanese behemoth Toyota, fresh from waving bye-bye to long-time chief and arch EV denier, Akio Toyoda in January twenty-twenty-three, have now enthusiastically joined the race for EV domination. The company claims to have achieved a breakthrough in solid state battery technology, enabling a driving range of more than seven-hundred and fifty miles and a charging time of ten minutes, although anything approaching what you might describe as ‘detail’ has not so far been forthcoming. Anyway, having promised these batteries by twenty-twenty-one and then by twenty-twenty-three, Toyota now says they’ll be producing the cells at scale by twenty-twenty-seven or twenty-twenty-eight, which probably means twenty-twenty-nine or twenty-thirty.**

**South Korean car giant Hyundai are right there in the mix too, working with US based firm Solid Power on a solid-state battery set up that they say includes materials that can withstand not just high temperatures, but also very low temperatures, which I’m sure will be welcome news to those of you living in colder climes like Canada. They’ve also addressed one of the potential pitfalls of solid-sate technology, which is the tendency for solid materials to expand and contract with large temperature changes, which in turn can cause damaging cracks in the battery’s structure. Hyundai’s system uses a fluid to apply constant pressure to each cell during charging and discharging to prevent deformation and maintain good surface contact and conductivity between the electrodes and the solid electrolyte. Sensors within the battery monitor temperature, pressure and voltage, and an external controller regulates the whole thing and updates the vehicle or the charging device accordingly. Hyundai’s don’t give specific production timelines but their press release states that “Hyundai Motor Group accelerates development of next-generation batteries, including solid-state, aiming to produce 3.64 million EVs by 2030.”**

**Then there’s the CHINESE automaker Nio, which has been developing its own SEMI-solid-state battery with partner company WeLion for several years. In November twenty-three, Nio’s Chief Executive, William Li, live streamed a fourteen hour, six-hundred-and-fifty-mile road trip down the coast of China from Shanghai to Xiamen, in a Nio ET7 sedan, apparently powered by a one hundred- and fifty-kilowatt hour version of the new battery. To give a bit of context, a one-hundred- and fifty-kilowatt hour standard lithium-ion battery in the Rivian R1t pickup truck, gives a range of four hundred and ten miles. Li was apparently quoted as saying "This battery is currently the battery pack with the highest energy density in mass production in the world and has excellent safety performance,"**

**Nio reportedly received its first shipment of the batteries from WeLion in June twenty-twenty-three and will begin true mass production in April twenty-twenty-four.**

**You may also have heard of a company called ProLogium Technology, based just across the water from the Chinese mainland, in Taiwan.** **ProLogium has been focussed on solid-state battery research, development, and manufacturing since two thousand and six and the company is arguably closer to market than any of its competitors. It has patented technologies that purportedly enable full charging in around twelve minutes and a driving range of up to a thousand kilometres, which again we’ll just have to take on face value until we see the real thing. That might not be all that far away though. ProLogium already has an automated pilot production line that has produced nearly eight thousand solid-state battery sample cells to global car manufacturers for testing and module development. In January twenty-twenty-two ProLogium struck a multi-million Euro deal with Mercedes Benz with a view to getting solid state batteries into their vehicle range by the second half of this decade. And in twenty-twenty-three the company announced a five-point-two billion Euro investment in a new purpose-built manufacturing facility to be built in France, with mass production expected to start there in twenty-twenty-seven.**

**Staying in Europe, a German company called High Performance Batteries, or HPB was also blowing its own trumpet in October twenty-twenty-three, unveiling what IT described as the world’s first PRODUCTION-READY solid-state battery. According to the company’s very slick website, their batteries have been independently evaluated to achieve more than ten thousand charging cycles with minimal degradation, represent a fifty percent reduction in environmental impact compared to current lithium-ion technology, and maintain a higher conductivity at minus forty degrees Celsius than conventional liquid electrolytes can achieve at THEIR optimum working temperature of plus sixty degrees Celsius. No doubt the good folks just down the road at Volkswagen will be beating a path to their door very soon, eh?**

**There’s a whole host of other companies around the globe working tirelessly to come up with their own solutions to the solid- state battery conundrum, as you can see by all these logos that I’m rather unhelpfully scattering across your screen.**

**One notable absentee from the frothy world of solid-state battery development though, ironically enough, is Tesla Motors. I wonder if that tells us something.**

**I’ll leave that open ended question with you, and as always if you’ve got news and views or actual industry experience of this particular technology, then why not jump down to the comments section below and share your thoughts there.**

**That’s it for this week though. Thanks, as always, to our Patreon supporters, who enable me to keep ads and sponsorship messages out of all my videos.**

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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.**