Introduction:	00:00	Are we recording? This is BP Technology Outlook. Focus on batteries. Podcast.
Angela Lamont:	00:07	I'm Angela Lamont, a technology journalist. This podcast is about battery technology. In the last one, we were looking at solar energy and one of the questions that we were left hanging with was where do you store renewable energy? One of the ways you can do that is with batteries. But frankly, batteries haven't always been up to the job. Now, it wouldn't surprise you that BP have their finger on the pulse and do their own research on battery development and technology, but they also listen to a huge range of experts from all over the world. Over the last few weeks, I've had the privilege of chatting to quite a few of them and wanted to share their insights with you.
Bogdan Gagea:	00:47	I was the first person with a battery electric vehicle on our Pangbourne Technology Centre. Unless you experience it yourself, it's very, very hard to have an informed opinion.
Angela Lamont:	01:00	Bogdan Gagea leads BP's research on energy storage.
Bogdan Gagea:	01:03	My role for BP is to listen to an extremely wide range of opinions and help the company make informed decision in terms of our long-term strategy.
Angela Lamont:	01:16	One of the things that struck me about the experts I interviewed for this podcast, was that every expert had their own passionate reasons for being involved in technology. Kurt Kelty.
Kurt Kelty:	01:29	So for me, batteries are a key element to get us off of fossil fuels.
Logan Goldie-Scot:	01:33	What appealed to me about the electricity sector, and then about energy storage in particular, was actually the speed at which things can change.
Angela Lamont:	01:41	Logan Goldie-Scot, head of energy storage at Bloomberg NEF.
Doron Myersdorf:	01:46	The vision that the streets will be quiet and clean really is something that drives me.

Angela Lamont:	01:53	Doron Myersdorf, CEO at StoreDot.
Doron Myersdorf:	01:56	Our children and our grandchildren, they will not believe that we polluted our planet.
Logan Goldie-Scot:	02:03	So what's been fascinating to see is that this market is gone from a relatively niche space, towards being much more mainstream. And this is really been driven by what we've seen on the electric vehicle side. As electric vehicle uptake has increased, we've seen billions of dollars of investment in lithium ion manufacturing capacity and we're actually just at the cusp of a huge expansion in capacity. We're in a pretty remarkable space in terms of the tipping point and the scale that we're about to observe.
Angela Lamont:	02:38	How long can that kind of growth go on?
Logan Goldie-Scot:	02:43	We expected this growth will have to continue at least for the next sort of about decade and likely much further because we're seeing demand for batteries grow very, very rapidly.
Kurt Kelty:	02:55	I'm concerned about supply.
Angela Lamont:	02:57	Kurt Kelty oversaw the battery technology at a critical time for Tesla.
Kurt Kelty:	03:01	So many companies are announcing their EV plans that are significant. I mean, really high volume. And where are those battery cells gonna come from? There's not nearly enough battery cells to meet the demand.
Angela Lamont:	03:15	I'm here at the University of Warwick to chat with Mel Loveridge at the Warwick Manufacturing Group.
Mel Loveridge:	03:20	We're going into an airlock to stop too much moisture entering the actual dry laboratory. Humans very selfishly emit moisture, which lithium ions don't like.
Angela Lamont:	03:32	Well, we're all for dry humour on this podcast.
		So, what actually makes a battery? A battery?
Mel Loveridge:	03:42	Well a battery operates on converting chemical energy into electrical energy. And so to do that it has to contain anodes and cathodes, which contain different types of material.

Angela Lamont:	03:56	So in the lithium ion battery, positively charged lithium ions shuttle from one electrode to the other inside the battery, while the negatively charged electrons flow through your device, your phone, your laptop, your electric vehicle, to power that device as they go.
Kurt Kelty:	04:14	If you look at the metals, the raw materials that go into batteries: Nickel, lithium, cobalt are the three primary ones you kind of have to look out for in terms of are we going to have enough supply going forward? And with the lithium it's just a matter of investment. We can do that. Nickel there is plenty of. Ultimately there may be an issue with nickel because we need battery grade nickel, and so if we really hit the growth plans of all these OEMs, then we'll develop a shortage the latter half of 2020s. But the shortage I'm referring to more is on the battery manufacturing capability, where there just are not enough factories around the world to produce all the battery cells that are forecasted.
Logan Goldie-Scot:	05:00	What we're beginning to see is companies move into space and many firms actually work on expanding facilities to bring that capacity online. You can expect huge change and a sort of unparalleled investment over the next few years. But I think that is something to be excited about rather than something to be scared about.
Angela Lamont:	05:23	And how does a lithium ion battery work compared to other kind of cells?
Mel Loveridge:	05:30	Well, the chemistries will be different. And the energy density, that's the exciting thing about lithium ion batteries, which were invented because Sony's camcorder needed more energy than typical batteries could supply. So the chemistry choice was much greater. But now obviously, with the interest in lithium ion technology and with it being the most likely contender to carry on electrification of transport, a lot of research has skyrocketed in this area.
Angela Lamont:	06:04	That camcorder battery is close to 30 years old now. So that's quite an amazing span of time to look at how things have changed.
Kurt Kelty:	06:15	In the electronics industry we have more Moore’s Law so, every 18 months or so you get a doubling of capability. Unfortunately we don't have that advantage in batteries. Batteries are chemistry as opposed to electronics. And so, it was always an

		incremental improvement that would double every 10 years or so. So it's a very different pace of improvement.
Bogdan Gagea:	06:37	I think the continuous evolution of standard lithium ion technology is probably going to be the biggest impact in the next 10 years. And there are many different technologies out there, but if lithium ion can deliver all the cost and technical requirements, does it matter?
Angela Lamont:	07:00	And because of course everyone is forecasting this huge demand for lithium ion batteries, but how about smarter more efficient? What's happening on that front?
Logan Goldie-Scot:	07:16	I see huge amounts of further potential, huge amounts of change within lithium ion more broadly. It's not just that batteries are getting cheap. It's also very much that batteries are improving in terms of their energy density, in terms of how long they'll last and how they'll perform. Beyond lithium ion there is a whole range of alternative chemistries, that the use of, to date, struggle to gain that scale and market acceptance that lithium ion has. And a part of the reason there is that they don't play in as many different industries as lithium ion does. So they're not able to benefit from that scale that lithium ion gets as a virtue of it's variety and versatility.
Kurt Kelty:	08:03	We're going to be approaching the theoretical limit pretty soon on lithium ion cells and as we approach the end of very incremental improvements, we've got to get something new out there.
Angela Lamont:	08:11	Any sign of what that might be yet?
Kurt Kelty:	08:14	Longer term, I think solid state chemistry is probably the next big jump.
Angela Lamont:	08:20	People are used to really fast charging their electric vehicles now. Can you fast charge solid state batteries?
Kurt Kelty:	08:27	That's a good question. Yeah that's one of the challenges that the chemistry faces. That's kind of the last compromise in the vehicle. The EV out performs internal combustion engines in every metric. Speed, handling safety, EV beats ICE in every category, so the one last one is charge time. Where you can fuel up so very quickly in a gasoline powered car and it just takes much longer in an EV. So that is an area that is going to see continued activity to increase the fast charge capability.

David Eyton:	09:00	I'm David Eyton, I'm BP's head of technology. As you get into the electrification of transport, you're going to have massive demand when a car turns up and wants to be charged up. You've got to be very smart about the way in which you manage the interface between that and either battery storage or the grid. We are already using batteries and we are very much beginning to look at more intelligent supply and demand management of power.
Dan Walker:	09:32	I'm Dan Walker. I lead the technology futures team at BP. Fast charging. Ultra fast charging is very important for an EV driver. A new battery chemistries such as that been developed by StoreDot could have a big role to play there.
Angela Lamont:	09:48	Doron Myersdorf.
Doron Myersdorf:	09:49	We are trying to make sure that as we transition to electric vehicles, the batteries in those vehicles would enable the same experience. So five minutes in and out from the charging station. We are reinventing some of the basic materials that are going into the lithium ion batteries. So for example, we are totally replacing graphite with some metalloids: germanium, or tin, or silicon. All of these materials or elements that are known to have very fast diffusion of the ions of the lithium.
Bogdan Gagea:	10:24	Silicon is one of the new analog materials that are being developed and it seems to be close to commercial maturity. Maybe today you can make a pure silicon anode battery cell that can fast charge in five, ten minute, but it's not going to last as long as the standard lithium ion battery technologies. And people are working very, very hard to mitigate that trade off.
Angela Lamont:	10:55	What does the continued popularity and growth of electric vehicles depend on? Is it that they need to come up with more efficient lithium ion, or is it that they need to crack this new technology?
Dan Walker:	11:10	Technologies in isolation of anything else will not disrupt. They will not transform. It's how you use those technologies, through what business models, they will disrupt. They will transform.
Mel Loveridge:	11:22	We refer to progress in battery technology as being about evolution rather than revolution. We believe there's still a lot of performance growth in lithium ion technologies. The more we

		are improving even current materials, both anode and cathode, the further we will see cycle life and durability.
Kurt Kelty:	11:47	In the future, you're going to end up with battery cells instead of getting a thousand cycles, they're going to get five or ten thousand cycles with the same performance benefits. So you're going to get vehicles that can last a heck of a lot longer. One of the other consequences of that is that the lifetime ownership of an EV becomes very, very small. And so, the concern about EVs being too expensive is suddenly much less relevant. As a result, I really think the percentage of EV versus ICE is going to increase pretty dramatically.
Doron Myersdorf:	12:18	Lithium ion batteries will be the dominant batteries or energy storage device that will be available in anything for the coming decade. What will change is the materials and the properties of these lithium ion batteries.
Mel Loveridge:	12:36	So the more research we do into larger format batteries, we have to demonstrate that we're making safety improvements.
Angela Lamont:	12:45	I now find that we're standing outside a label marked a 'Battery Abuse Centre.'
Mel Loveridge:	12:51	We do a number of abuse tests, so called, they can be anything from: nail penetration, crush, heating, overcharge. Because we need to know what is going to be the absolute worst case scenario. And this is why we typically would set up an abuse experiment, video it, close the door, and literally walk away. When you understand fully how something fails, can you then go on to make it better.
Angela Lamont:	13:24	So you can design it to be safer. You can design it to be longer lasting. But you could also design it for when it's not needed anymore and have strategies for that too.
Bogdan Gagea:	13:37	You need to design a battery with the end of life into consideration. Currently you can extend the lifetime of the battery so you don't have to replace it like you have to do it for your remote control. You can also design the battery with a second life application in mind, and that could extend the lifetime of the battery by another five to ten years. Ultimately, you will want to recycle the battery into the raw materials and potentially use them to make a new battery. The recycling part and reuse part is challenging at the moment, but what we see is the industry are clearly aware of this challenge and we see a lot of activity in the area.

Logan Goldie-Scot:	14:25	One of the things that we haven't really focused on is all the political momentum around decarbonization. This hasn't been at the forefront of sort of our work.
Bogdan Gagea:	14:37	Batteries require a lot of energy and raw materials to manufacture. And currently that comes with a heavy carbon penalty because of the current carbon intensity of the grid. As the grid decarbonizes globally, that CO2 penalty's going to get lower and lower. But power sector decarbonization is ongoing.
Logan Goldie-Scot:	15:00	What I see is happening, is just growing awareness and engagement with this topic that's new to people in the industry. Once things enter that sort of political consciousness and once this factor becomes more of a talking point, I think that'll make a pretty significant difference in that pace of change.
Angela Lamont:	15:20	An exciting point in the development of any technology is when everyone's talking about it and those changes come thick and fast. But for me, as a technology journalist, the most exciting time is when we stop talking about it and we're at the place that we wanted to be. The place that has devices that work all the time, a place where the cities are cleaner and greener and much quieter.
Conclusion:	15:51	This was a BP technology production. Focus on batteries. Podcast.