Battery Caffè - Batteries in AI

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Welcome everyone to this new episode of the Battery Caffè, focusing on AI for batteries. I'm Nikoleta Piperidou from the Clean Energy and Infrastructure team at Innovate UK Business Connect, hosting today's episode alongside my colleague, Neelam Mughal.

Hi everyone. My name is Neelam Mughal, and I look after advanced materials at Innovate UK Business Connect. It's great to be here today on the Battery Cafe and looking forward to the conversation. So, a quick reminder, the Battery Cafe is an initiative of the Cross-Sector Battery Systems Innovation Network, a community co-funded by Innovate UK Business Connect and the Faraday Battery Challenge. The Innovation Network aims to open new markets for the battery industry, promote innovation in batteries and help decarbonise a wide range of sectors. Over to you. Nikoleta.

Thanks, Neelam. Today, we are lucky enough to be joined by three guests. Richard Hewitson, CEO at Lion Vision, Dr Mona Faraji-Niri, Associate Professor Battery Modelling at WMG, and Steve Kench CTO at Polaron. Could each one of you please briefly introduce yourselves and explain your current work in relation to battery technology and AI? Perhaps, Richard, we'll start with you.

Hi. I'm Richard Hewitson, founder of Lion Vision. We specialise in leveraging advancements in AI and vision systems to help the waste recycling sector detect, visualise and extract batteries and other critical items from the waste stream. Our mission is to use AI technologies to develop more efficient, sustainable solutions that address the growing demands of the recycling sector and support the circular economy.

Thank you so much, Richard. Mona, over to you.

Hello. I'm Mona Faraji-Niri and I'm Associate Professor of Battery Modelling in WMG, Warwick Manufacturing Group, University of Warwick. I have a PhD in control systems theory and about 13 years of experience in modelling control algorithms and AI for energy systems, with about seven years of that specifically on batteries. Currently, I'm leading the battery modelling team in WMG, and that looks at manufacturing process, product modelling, battery cell, module to pack representation for improved performance, safety and longevity.

Thank you very much, Mona, and last but not least, Steve over to you.

Hi. I'm the CTO and co-founder of Polaron, where we characterise and optimise the microstructure of battery electrodes, with the goal of trying to understand how we can tweak battery manufacturing parameters to try and get the best possible performance out of the batteries that we're making.

Thank you very much, Steve and thank you all for those introductions. And to our listeners, please make yourselves a coffee and join us. Today we're talking about artificial intelligence and machine learning and their application to batteries.

Why don't we start by introducing today's topic to our listeners. Mona, when we're talking about AI and batteries, what do you think the key application areas are, and why do you feel it's such a big opportunity for the battery industry?

Generally, artificial intelligence or AI is a very broad term, and even when we narrow it down to an area like batteries, there's still a lot to fit in a few sentences. But generally, I see four key application areas for AI. It is about multi-objective design and optimisation of battery material components, form, factor. A big area is around modelling battery management systems, which is around understanding the complex behaviour of batteries under different use conditions, and eventually to control that in real time. It's about agnostics, predictive maintenance, which for batteries, mainly means remaining useful energy, remaining useful life, the ability to quickly identify faults, failures, abnormal behaviour, and ideally to control and mitigate their impacts. And probably eventually it's around manufacturing, the scale of acceleration, the process product optimisation, because of the nature of the complex nature of these processes and the multi-step nature of the process. There is huge potential for AI to play a role in here. It's generally because this is a multi-physics, multi-scale domain, and needs every aspect to be taken care of at the same time.

Thanks, Mona. I think that really helps provide some context for our discussion today. So we know that you've been working on Faraday Institution’s Nextrode project over the last few years. Would you like to share some of the key findings that have come through from this project?

Yes of course. So Nextrode is next generation electrode manufacturing, and it's about smart manufacturing and to understand and optimise and also scale up new technologies by the power of digitalisation on AI. So, the battery manufacturing process has between 600 to 1000 control variables to it. It has about 130 small and bigger steps, such as mixing, coating, drawing, calendaring. These have a lot of complex interactions. There are multi-physics processes in here, thermal, mechanical, electrochemical aspects. These are multi-scale, starting from particles at the microscale to the components at the mesoscale, and also the cell itself at microscale. And looking at all these together is the scope of the Nextrode project and understanding the causal effect of them in general. Understanding these processes is a little difficult by just physics-based or first-principle models, and that is where AI and data-driven approaches could really play a role. We looked at how we could leverage machine learning models, deep learning models and explainability techniques to use that data to understand the process, to optimise those processes, and to use that for a little more sustainable, low-cost manufacturing process control and optimisation. There were some interesting findings, some correlations that weren't really understood before we looked at them from this data-driven approach, data-driven and AI-based, causal effect type and correlation type of understanding. And some of them really were matching to the physics-based understanding, and some were pretty new. Some of the processes were very predictable, and that means that we could use these models to help us develop better electrodes with lower cost and lower energy and a lower footprint.

So that was really interesting hearing Mona's view, I think we work at one of those specific scales, which is the microstructure, trying to understand, if you take an electrode, you cut it in half and cross section it, and then take an image of it, how we can use that information and images of that electrode to understand how it behaves. And just like Mona was saying, there are loads, like hundreds, of decisions you have to make when you manufacture a battery, lots of different manufacturing parameters you can tweak. And before I started this company, I was working on my PhD looking at how we could try and understand how those manufacturing parameters affect that microstructure of your battery. And I was basically taking machine-learning techniques that we'd seen in industry developed for these really big machine learning models to try and generate images of cats and dogs, and try and take all of that technology and transfer it into the space of material science, so that we could understand, instead of images of cats and dogs, images of electrodes and different types of materials. And so yes, my PhD was working on not just understanding those microstructural images, but linking this to those hundreds of process parameters, so that if we could understand those relationships between how we manufacture something and how it looks on a micro scale, then we could predict how we could potentially change those parameters to make our batteries perform even better. And the reason that's so important is that that micro structure of your batteries has a massive influence on how your battery actually performs. It affects things like how fast you can charge your battery, the cost of your battery, the lifetime of them, and even things like recyclability. So, we were looking at how we can essentially optimise everything from a broad perspective, but looking at specifically the influence of those microstructural aspects. And so, we were doing this research, we spoke at some conferences, and we got a lot of interest from different commercial partners who were coming to those conferences and also collaborating with us. And we realised that the tools we were building could be really useful in industry, and we wanted to drive them into industry so that we could actually help with some of the challenges that our commercial partners were facing, specifically around trying to make a commercially viable cell. We've seen the challenges in industry over the last few years with developing new gigafactories and building manufacturing plants that can make reliable and high-performance batteries. And we've seen that across Europe especially. I think this kind of leads into the commercial opportunity. Obviously, over the next five years or so, we're going to have to double our battery manufacturing capacity to about five terawatts. And what that means is building lots and lots of battery manufacturing plants that can make reliable and long-lasting batteries. And that's really where we see these commercial opportunities to help the companies that are trying to do that to provide that renewable energy storage systems, help those companies to build those manufacturing plants.

Thank you, Steve, it's really helpful to understand your drivers and motivations there and to get a view into the future trajectory that we could expect. Richard, moving to you, you're working in a complementary space, still in the battery sector, but not looking at manufacturing, but on the other side of the value chain in recycling. So would you mind telling us a little bit about the battery recycling market, what you're seeing at the at the moment, and what you see as the commercial opportunities for AI.

Absolutely. Whilst manufacturing, beside the battery industry, is crucial, the end process of the end-of-life phase of a battery is really equally important, especially as the demand for batteries continues to grow. Exactly what Steve just saying, the move from what we're currently utilising now. We're seeing an exponential rise with the batteries that we're seeing through the recycling centres, but unfortunately, in recycling centres, what they receive in mixed recycling waste is a mixed bag of waste. They don't actually know how many batteries are being processed until they see the tonnage at the end that are all shredded. So what's really interesting and important for me to be hearing today is what Mona and Steve are saying about the complexity of what we can see inside, because some of that information they have can assist us to help identify the battery at the end of its life so it can be segregated within the recycling sector. It can then be compartmentalised into maybe the cobalt, the nickel, and the lithium ion, so those can be then directed towards certain specialties of recycling centres, so that product can then be utilised, and the extraction of the minerals can be reutilised, and that adds to the circular economy. So, what we're talking about today, you know, AI holds an enormous potential to transform the recycling space. Where we sit, from a Lion Vision perspective, is that if we can understand the complexities of the battery itself during its manufacture, we can assist ourselves to help the recyclers identify those contaminants that are in the waste stream at the moment, because majority of these batteries are currently going to landfill, which isn't great, because they can't identify what they're seeing, and they're relying on labour-intensive processes to extract those batteries from the waste streams. So, looking ahead, I see significant opportunities in automating and sorting process and recycling plants, improving safety, because batteries that are going through those hazardous plants are going through mechanical systems that are agitating the battery and ripping them apart. And every battery was born to hold its own energy so when those batteries get ripped apart, they sort of explode, and it's very, very difficult to put out a lithium-ion battery cell. You can't use just standard water, you've got to use specific, and you've got to cool that battery over a period of time. So, you know, we're going to play a major crucial role in ensuring that batteries can be fully reused and safely disposed of, closing the loop in a circular economy.

Thank you very much, Richard. And this is indeed a very important point that whilst battery manufacturing is increasing and projected to increase even more, battery recycling will need to equally match the opportunity. And currently we don't have that many battery recycling facilities in the UK. So yes, it is a space that needs to be further looked at. Would you like to tell us a little bit more about the SWEEEP project as a practical case study? We know you've been working on this.

Sure. You know SWEEEP's one of the largest waste recyclers in the UK. So, I didn't know this before we got into waste recycling, we think that we've got a green bin, a grey bin, a black bin, and you segregate your waste, but that waste then goes to multiple different streams of recycling centres, whether it be wood waste or general waste or waste electronics. And even the general waste people, where you put your bin bags into the black bin bag waste, those recyclers then segregate out certain electronics waste, and then they move it on to people like SWEEEP, who then take that electronic waste and mangle it all up and start to then recycle the gold elements, the lithium-ion batteries out of there and segregate all that waste. So what we've been doing, starting from scratch really, is that SWEEEP deal with around about 6000 different batteries every single day, from mobile phones, toys, laptops, power tools and various other devices. So when we kicked off with SWEEEP, we always start with an exam question, and that exam question that SWEEEP gave us, was how do you detect, visualise and extract batteries from a waste stream moving at one meter per second on a conveyor? What we did was, from a Lion Vision perspective, we initially deployed to support the first-use case, detecting cylinder batteries, because in every power pack, for instance, that goes on a power tool, there's not one battery in there, there are 50 batteries in there. One electronic device, when it's ripped apart, goes from being one incendiary device to 50 incendiary devices. So we created, and installed the initial system to identify how many batteries they were seeing within their waste stream, so they could provide data for their teams to put more labour in place, for them to pick those products from the waste stream. Then what we did, once we'd optimised that system, we then deployed a second rig to identify what the pickers weren't identifying or were missing during the picking process, because what AI can't do is see what the human eye can't see. So for instance, if a battery is underneath a piece of waste, AI can't see it. We wanted to make sure that when we are taking the data of how many batteries we're seeing then looking at how many batteries the pickers are collecting out, we want to be seeing how many units are passing through that picking station and then we can make a decision on what we do with those remaining batteries. Do we put an extraction system in place? And the second challenge that SWEEEP challenged us with is now we can identify 98% of the batteries within their waste stream, right guys, we want you to extract them now. We don't want our pickers any longer to be picking these batteries by hand. We want your automated AI system to tell us where they are, find a matrix and extract them. So, we've now created an air jet system that works online and we're now extracting, I'd say, around about 70% or 80% of their batteries that the pickers don't actually have to look at extracting by hand, which is fabulous for them, because it becomes more automated. We can then use those pickers to take out valuable elements, rather than contaminants, such as batteries, from that waste stream. So yes, it's been a brilliant collaborative approach that creates a really strong relationship, and we're excited to build on that foundation and integrate that AI-powered vision into electronic waste management in the future.

Thanks, Richard, and thanks to everyone else for your insights so far. I think we've been talking quite clearly about those market opportunities and you know, it's all sounding really promising so far. I am curious though, whether any of you see any barriers to adoption from wider industry and from stakeholders within the value chain. So, Steve, if I could go to you first on that point.

Yeah, absolutely. I think the battery manufacturing industry is a really strong case for adopting AI, because, as Mona was saying earlier, and also Richard, it's a really complicated process. You know, there are lots of manufacturing steps, the scale-up process is really difficult. Going from a lab up to manufacturing is a really challenging process to attain consistency. And this means it's a really promising place for AI to come and help us, because it's so hard to model those processes, that data is a really appealing alternative. But in order to actually use data-driven approaches, you need to be collecting the right data. And what that means is that manufacturing plants need to scale up the amount of imaging they're doing, the sensors and the data that they're collecting, and generally be characterising and understanding that process in much more depth than they currently are. And I think that presents one of the biggest limitations. We need to collect the right data in order to gain useful insights into how those processes are working. One of the major challenges around this is also that manufacturers are incredibly secretive about the data that they do generate, because that constitutes all of their core IP right there. You don't want to share all that information with your neighbours who are trying to do the same thing. So unlike, you know, ChatGPT, where you have these large language models trained on the whole of the Internet, what we need is really specific data that describes one specific process and these challenges that manufacturers are facing. But the ability to collect those data sets is much more limited in the space of manufacturing because of that secrecy. And I think getting around that basically means a lot of innovation around data efficiency and developing new algorithms and models that use much smaller amounts of data and are still really useful. And so I think that's one of the biggest challenges that we face going forwards, developing these models that work across different industries using just really small amounts of data.

Thanks Steve. Mona, have you got anything to add there, perhaps on interoperability or standard issues as well?

Yeah, Steve mentioned a very good point. So now we know that AI needs data, not any data, good data, and also we know that data is gold, but collecting that data is really challenging. It’s very good to mention that it's about confidentiality. There are a couple of factors that could really address this. We need forward-thinking management. We need forward-thinking people to adopt technologies that could collect data without breaching confidentiality and share it, so we could use it. AI developers, scientists could use it for advancement of AI technologies. So this is one aspect to that data, but also it is about how we could collect that data without interrupting the line, without people having to shut lines and give us that data. Minimise the dependency on offline and offline data capture technologies. These are the things that we could really try to raise awareness around and capture investment around. Inline data collection is really key, especially in manufacturing. If we can collect data by inline sensing mechanisms without interrupting the lines, that's perfect, that's critical, and that could really help us to use AI techniques to their full advantage. Another aspect to this limitation, I would say is a little bit around cultural factors. Every technology needs some time to find its place, its home, and get developed, so we need some of those management business strategies to have a little bit of open mindedness and patience so these technologies find their ways into these areas, costly areas such as battery manufacturing. That cultural factor is really a thing, and providing some good example cases on this could really help the situation. One of the key limitations that is still there is the trust in those AI algorithms and AI models, that we leave them to perform standalone. Do the decisions that they make really make sense to the domain experts who are electrochemists, thermomechanical modelling people, and I'm just looking at that from the modelling aspect, so that trust is a limiting factor, really. And probably turning to explainable AI techniques, interpretable AI modelling techniques where you really make it a little bit more transparent about how your model, how your algorithm works, and if they are making a particular decision, making a particular prediction, that really makes sense because it is based on this and that collection of the factors features. If you can explain that to the end user, being the business owner or the scientist in the domain, then there is a better chance that these AI models can be adopted in an area like battery manufacturing or battery development.

Thanks, Mona. I think no one mentioned cost so much yet. I mean, Richard, AI-driven recycling is still quite an emerging area. Do you think cost is one of the most prohibitive barriers there?

I can totally understand where Steve and Mona are coming from, from data collection. But once you've got the data collection, what we're having to deal with is the waste stream, which is totally and utterly unpredictable. And because we're not seeing a homogenous battery that goes through the waste stream, because the system is quite archaic in its format, it's very much of a conveyor-based organisation where they rip things apart and try and make them as visible as possible. But you can imagine the waste is horrible. It's dirty. There are things have been mangled during that process. So cost is a massive consideration. Initial setup, from our perspective, means wanting to get lots of images and putting those into data sets, and then quality controlling those images. What's really important is good quality images going in, great response and detection and visualisation coming out. It's not just about throwing lots and lots of data and then just processing that data, because we're trying to see something that's unique within a very broad waste stream. And, I suppose, like I said before, the initial setup cost and optimisation system, that is the time-consuming part. That's where the cost comes in, and that can provide barriers to entry for other organisations, either wanting to buy into the technology, or specifically smaller recycling centres. And from a wider point of view, you know, you've got to employ a lot of data scientists. You've got to employ a lot of people that are imaging and quality images need to be put into the system. So, you know, batteries come in different shapes and sizes, different compositions, they're sort of hidden within and underneath materials and reliable detection is very, very difficult. One challenge that we've got is the complexity of the training model. Each recycling centre is slightly different. Their backgrounds are different, their foregrounds are different. What are you trying to identify? You know, there was one instance where we knew that one of the major wholesalers up in the Northeast had a massive offer on cheap, low-cost batteries that were being sold through their retail outlets, because one of the sites where our deployment was located at saw maybe 10 or 15,000 batteries over a month period with the same branding on the outside of them. So we can actually identify the type of those batteries, and we can then relate them back the retail outlets that have actually sold them in the first instance. And what we want the industry to really try and do, is link with the manufacturing. We can identify them, we can extract them, and what we want is for the manufacturer have some level of responsibility for the recycling of those products, rather than them keeping on going to landfill. So that's from a cost prohibitive point of view. Batteries aren't something that recyclers can sell at the moment. Whereas they can sell gold, they can sell silver, they can sell metal, they can sell plastics. What they can't sell and reuse are batteries. So it's a problem for the industry itself. But we are going to end up consuming massive amounts more of them. I hope I answered the question, and I probably went off topic there.

No. Thank you so much, Richard. Actually, it is a complex topic that we could be talking about this for ages. And I know we were just now talking about limitations and challenges, but there's so much more coming on the horizon in terms of innovations, both in the UK and globally. And I'm sorry we won't have a chance to discuss this today, but possibly in a future podcast episode, so just for today, I would say a big thank you to all of you, to our brilliant guests, and to all of you for listening. And we hope that you enjoyed this discussion as much as we did. Don't forget to visit our online hub on ukbatteriesnetwork.org, and register to receive our updates and participate in the networking area of the hub. Bye for now and thank you all.

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