HOUSE OF LORDS

Science and Technology Committee

Corrected oral evidence: The role of batteries and fuel cells in achieving net zero

Tuesday 25 May 2021

10 am

[Watch the meeting]

Members present: Lord Patel (The Chair); Baroness Brown of Cambridge; Lord Hanworth; Lord Holmes of Richmond; Lord Kakkar; Lord Krebs; Baroness Manningham-Buller; Lord Mitchell; Baroness Rock; Lord Sarfraz; Baroness Sheehan; Baroness Walmsley; Baroness Warwick of Undercliffe; Lord Winston.

Evidence Session No. 11 Virtual Proceeding Questions 121 - 128

Witnesses

Professor Magda Titirici, Chair in Sustainable Energy Materials, Imperial College London; Professor Richard Herrington, Head of Earth Sciences Department, Natural History Museum; Dr Paul Anderson, Reader in Inorganic and Materials Chemistry, University of Birmingham; and Principal Investigator of ReLiB project, Faraday Institution; Dr Evi Petavratzi, Senior Mineral Commodity Geologist, British Geological Survey.

USE OF THE TRANSCRIPT

This is a corrected transcript of evidence taken in public and webcast on www.parliamentlive.tv.

Examination of Witnesses

Professor Magda Titirici, Professor Richard Herrington, Dr Paul Anderson and Dr Evi Petavratzi.

Q121 **The Chair:** Welcome to today's session, particularly our witnesses. Thank you for very much for making time to talk to us today. We are looking forward to hearing you and your comments.

My question relates to the materials we require for the production of batteries and fuel cells. What are the crucial materials that we require and where are they mostly sourced from? How good is the United Kingdom at securing their availability? Two questions in one.

Dr Evi Petavratzi: Good morning. I work for the British Geological Survey as a Senior Mineral Commodity Expert. My background is actually in engineering, so I am not a geologist. Please ask Professor Herrington any hard geological questions. My research interests are primarily in the sustainable and responsible supply of critical raw materials.

To your question, the materials that we will need for batteries are primarily lithium, nickel, cobalt, manganese, graphite, copper and aluminium. For fuel cells, we will need platinum, and potentially cobalt, and nickel zirconium for electrolysers. We will also need copper and aluminium for our electricity networks.

The quantities in which they are found in nature is not really an issue; we are not running out of any of these materials in the foreseeable future. We have enough in the earth’s crust to satisfy our needs. The issue is really how we can gain access to these resources. Access can be influenced by a variety of different factors, including the economic situation of the producing country, the political stability of the country, commodity markets, environmental issues associated with the locality of the deposit, social issues, and in some cases technology and supporting infrastructure as well.

In general, there is a tendency to use the terms “resources” and “reserves” to understand the geological availability in future mineral supply bottlenecks. However, most of the time these terms are not used correctly. The mineral resources do not represent everything that is in the ground; they are working inventories, and they are bad indicators of the future availability of minerals.

The world's total reserves of cobalt, for example, are currently about 6.9 million tonnes. The DRC dominates—about half of them, found in sediment-hosted deposits there—followed by Australia and Cuba. Obviously the majority of production at the moment comes from the DRC.[1]

[1] Further information is available at: https://www2.bgs.ac.uk/mineralsuk/download/mineralProfiles/BGS_Commodity_Review_Cobalt.pdf

In the case of lithium, the majority of the resources are found in the lithium-triangle countries of South America: Argentina, Chile and Bolivia. Obviously lithium is found in a variety of different deposits. It is found in hard rock deposits—Australia is the primary producer from hard rock deposits—and in sedimentary basins, although there is hardly any production of lithium from sedimentary basins at the moment. It is found across the globe; Africa, for instance, has a significant endowment,, and it is found elsewhere in South America (apart from the Li triangle), central America, and so on.[2]

Extraction methods are very much determined by the ore deposit's characteristics, and they are defined during feasibility at the exploration stages of a mine project development. A lot of factors define which way the extraction method will go; economic, environmental and social factors can play quite a role in how we go about extracting some of these resources. Surface mining and underground mining are the key primary techniques for extracting materials, but in certain cases, for instance for lithium, we pump out the brine from the ground. There are other techniques such as in situ leaching, which is used commonly for copper extraction, for instance, but also in rare earths mining.

If I remember correctly, you also asked me about UK's access to materials. We have domestic resources in the UK, but at the moment we are not utilising them. They are very limited, so when it comes to security of supply for the UK, domestic resources won't be sufficient to utilise our needs.[3]

The Chair: We will come to security of supply issues later on. Professor Herrington, do you have anything to add to that?

Professor Richard Herrington: Yes, thank you for the chance to speak. I am an economic geologist, as Evi kindly said, with 40 years' experience in industry and as an academic. I am currently at the Natural History Museum, where we have a research group focused on looking at where metals are located in rocks and minerals, specifically researching the properties that enable us to locate where new resources are, and find ways to extract them in a way that is less damaging for the planet.

Part of what we are working on is looking at the whole issue holistically. As Evi was saying, it is not a problem of running out; it is a question of developing diversity of supply. We are very much looking into that so that we can then make an holistic choice about where those metals and minerals can be resourced.

Moving on to the question, Evi said most of what needs to be said. But to bring it home to the UK, every battery and electric vehicle has specific metal needs. Every single car will need 75 kilograms more copper than an internal combustion car, and it will need rare-earth metals, 8

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[2] Further information is available at: https://www2.bgs.ac.uk/mineralsuk/download/mineralProfiles/lithium_profile.pdf

[3] Further information about UK resources of materials is available in reports found at the end of the following webpage: https://www2.bgs.ac.uk/mineralsuk/statistics/rawMaterialsForALowCarbonFuture.html

kilograms of lithium, 7 kilograms of cobalt and about 25 kilograms of graphite.

Currently those materials, as Evi said, are not sourced in the United Kingdom; they have to come in from outside. There is potential in the UK—particularly with lithium, which hopefully we will talk about later—but it is a question of identifying and making sure that we understand that we have a diverse set of places where we can obtain these metals. That is the biggest burning issue. We are not going to run out, but we have to ask the question: can we access those metals and minerals in the timescale that we need to introduce the technologies that will reduce—

The Chair: We will come on to access questions later on. Professor Titirici, do you have anything to add?

Professor Magda Titirici: I am Professor of Sustainable Energy Materials at Imperial College London in the chemical engineering department. I am also the director of research there.

I am not a mineralogist, but I am very passionate about energy, sustainability and critical materials. A lot has already been said, but I would like to point out, and I am happy to send it to you, a very nice paper called *Addressing the Terawatt Challenge*. It was published in 2012, but I think it is still valid.

The paper classifies materials according to their availability—as high volume, low/medium volume, very low volume and extremely low volume. This is based on the availability of what we can extract, so high volume means at least one Megatonne per year, low/medium means 33 kilotonnes to 1,000 kilotonnes a year, and so on. This is not only about the abundance; it is also about how concentrated materials are in the ore, because a material can be very abundant but actually very diluted within the ore crust.

Also, in the paper, there is a formula that relates the market price to the product, which is in dollars per kilogram, in relation to the ore concentrations. That is very important to take into account.

A lot has been said about batteries so will move on to fuel cells. In order to use fuel cells we also need hydrogen and electrolysers, and for that we need iridium, which is a by-product of platinum extraction. Most of the platinum resources are in South Africa. Iridium is one of the elements that are very scarce, so it is classified under extremely low-volume availability.

Talking about batteries, if we want to produce hydrogen with PEM electrolysers, we will need between 1.5 and 2 milligrams of iridium per square centimetre. That does not seem a lot, but when you upscale it to terawatt hours it becomes quite a lot. You also need platinum in electrolysers, but very little; you could do it with as little as 0.0025 milligrams of platinum per centimetre square and it would work equally well.

In a PEM fuel cell, you need more platinum; you need quite a lot of it in the cathode. It is estimated that in a fuel-cell vehicle, for example, you would need about 25 grams of platinum per car. In the catalyst that we use in a regular vehicle today we only need 3 grams, so there will be a huge increase in platinum demand there.

In terms of availability in the UK, I do not think anything has changed. The last time I checked, the UK did not have a strategy for critical materials. Every other country seems to have one. The European Union definitely has one high on the agenda, as do Germany, France, Spain and the USA. It would be nice if Defra did a report addressing the very important issue of where the UK will get the supply of critical elements in future. That is just my view on things.

The Chair: Thank you. We probably have the paper that you mentioned, but if we do not, Simon will probably ask you to send it. Dr Anderson, do you have any further comments on this?

Dr Paul Anderson: Good morning to everyone. I am from the School of Chemistry at the University of Birmingham. I am Director of the Birmingham Centre for Strategic Elements and Critical Materials. I am also principal investigator of the Faraday Institution ReLiB project on the recycling and reuse of lithium-ion batteries.

I would just like to draw the committee's attention to a report that we published last month from Birmingham. It is a CrEAM—Critical Elements and Materials—commissioned report as part of an EPSRC-funded network, and is entitled *Securing Technology-Critical Metals for Britain*[4]. It looks comprehensively at many of the issues for four important industrial sectors, one of which is lithium-ion batteries. Another important one that I do not think has been mentioned is rare earths, which are common to fuel cell vehicles and electric vehicles as they are important components in the electric motors.

So at the moment I'd just like to bring to the committee's attention the report, which deals with quite a lot of these issues in detail from a UK perspective.

The Chair: I think I have covered the question that Baroness Blackwood might have asked, so we will move on to Baroness Brown.

Q122 **Baroness Brown of Cambridge:** I want to explore further the opportunities for the UK in this mineral supply chain. I would like to understand a bit more of the structure of the mineral supply chain for the manufacture of batteries, fuel cells and electric motors. How much of that supply chain is based in the UK, and how much of it could be? Our focus on this comes partly from the fact that one of our earlier witnesses pointed out to us that a gigafactory is about 20% of the cost of a battery, but 80% of the cost is in the supply chain. So we are interested both from a strategic access perspective and an economic opportunity perspective for the UK.

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[4] Report is available at https://www.birmingham.ac.uk/research/energy/research/centre-strategic-elements-critical-materials/securing-technology-critical-metals-for-britain.aspx

Dr Evi Petavratzi: A supply chain normally consists of six broad lifecycle states. You start with the exploration of the raw materials and then the extraction, the processing, the manufacturing, the use and end of life, and within each one of these lifecycle states there are a lot of sub-stages and processes taking place.

The material supply chains are very complex and global, and they involve multiple actors and locations; materials travel across the globe via several different locations before they reach the manufacturing plant where products are produced, and you have to take that into account. We have become more intelligent in producing complex products over the years, so we have also increased the complexity of the supply chains. So we are now in a situation where we can no longer track the journey that materials undergo. This is something that we seriously need to research properly, especially if the UK is looking at building new manufacturing such as the gigafactories.

We have limited UK actors in the supply chain at the moment. Maybe that will change in the future, but the current situation is that the number of actors in the UK is very limited. Obviously if we are successful with the UK battery gigafactories, maybe we will be able to build up a supply chain around them, but at the moment that is not the case.

In terms of UK mineral resource availability, it is hard to say what the resources are. There is not enough evidence out there for us to say that there are sufficient domestic raw materials to utilise as primary sources for our battery construction. Overall, though, these resources are likely to be small, so our import reliance on external sources will not go away.

Baroness Brown of Cambridge: Thank you. Professor Herrington, can I ask you about Cornish Lithium?

Professor Richard Herrington: Yes. Obviously you have seen a lot of that in the press. We have just heard about the supply chain. One way would be for us to get indigenous supply to feed local factories. There are two consortia working in Cornwall. The Natural History Museum has been involved with one of them, Cornish Lithium, in looking at characterising raw materials, because obviously it is important to characterise them precisely. The other is a company called British Lithium. Each of those has published aspirational production figures. Cornish Lithium thinks that it could contribute up to 10,000 tonnes of lithium per year to the UK, and British Lithium around 21,000 tonnes. That is probably about half of what Britain would need, which is 75,000 tonnes.

To take the example of what China has been doing, basically it secures the processing of most of those commodities. That is where Britain needs to get involved. Evi was talking about the different parts of the supply chain. It is in this processing area where we need to build capacity. With lithium we have the opportunity for raw material and then perhaps to build the next stage of the refining. It would then be logical to build a manufacturing facility next to it, which is exactly the route that China has gone; even if it does not mine the raw materials, it looks at controlling the production of the refining capacity.

So, partly for lithium, we have an obvious example in Cornwall, and potentially in north-east Scotland. Other parts of Europe could supply the other metals, so even though they might not be indigenous to the UK, there is great potential in the work that we have been doing to suggest that Europe could provide the cobalt that we will need, and there is no reason why Britain could not get involved in securing the processing part of the supply chain for that metal, and indeed for some of the other metals. There is an opportunity for us to get involved in that part of the supply chain.

Baroness Brown of Cambridge: Graphite is another of the key components where we have the needle coke, but we do not do the processing. Is that something that we should also focus on?

Professor Richard Herrington: Exactly. I know that we can recover graphite from some of the petrochemical refineries; indeed, that is a raw material. But the raw material can also be mined in places like Norway, and perhaps the UK could secure the immediate downstream of processing that type of material. We have the mineralogical and chemical expertise to build that capacity, but we currently do not fulfil any of that. Our refining capacity for different metals has actually declined in the last 20 years. We have moved out of being a country that processed and smelted metals, and we could look at re-establishing that as a business for the country.

Baroness Brown of Cambridge: Presumably this is done in areas where the levelling-up agenda could be very important. Is this something that would be done in the north-east or north-west of England?

Professor Richard Herrington: Indeed. The old Capper Pass smelter was in the north-east, and there was a smelter in Avonmouth. Both are obviously coastal areas where materials are brought in, and one could aspire to locate the new capacity for such processing facilities in some of those areas.

Baroness Brown of Cambridge: I want to hear from our other two witnesses. We have a very strong message there that it is not perhaps so critical that we have the source of some of these minerals, but that processing is absolutely key. Professor Titirici, is that your view as well?

Professor Magda Titirici: Again, I am not a geologist or expert on how many resources the UK has. If we have the resources, processing is definitely a critical issue. It would be easier to address that if the resource availability is there. Of course, if we think about making synthetic graphite from petrochemicals, which are available in the UK, we need to consider costs. That would require at least 3,000 degrees centigrade to produce graphite, which is potentially huge energy consumption at a very high cost. With energy going greener and renewable energy getting cheaper, perhaps there is the potential for that, but it would be extremely expensive at the moment. It would be competing with natural graphite from China, and the price of UK graphite would probably be 40 times higher.

It is also interesting that the EU imported about 10,000 tonnes of primary cobalt in 2012, which is about €227 million. I think the UK imported about 6,000 tonnes of cobalt in the same year, so we are still relying a lot on imports. We also need to consider that the battery market is growing rapidly. Between 2010 and 2018, the battery market grew by 30%, and it is estimated to reach 2,600 gigawatts in 2030. Out of this, China has 43%, so it will be very difficult to compete. As a fun fact, China is of course much bigger, but at the moment it has almost 400,000 e-buses, whereas Europe and the UK combined have only about 1,000.

Baroness Brown of Cambridge: Presumably the main value in this supply chain is not in the extraction of the minerals but in the processing stage. Is that the case?

Professor Magda Titirici: Yes. There is a very nice report by the World Economic Forum on battery sustainability, which looks across the whole life chain on a battery. Indeed, processing is the one where there is most value chain, but if you look at the life cycle assessment it is also responsible for most CO_2 emissions.

The Chair: Thank you very much. We need to be slightly briefer in answers, please, because otherwise we will not get through the questions.

Q123 **Viscount Hanworth:** What are the environmental and safety impacts of extracting and processing these minerals? How might these impacts be mitigated? The answer is presumably specific to the localities where the minerals are located predominantly, such as cobalt from the Congo, lithium from the Atacama Desert in Chile, and platinum and iridium from South Africa. Who might answer this? I suggest that Evi Petavratzi should begin.

Dr Evi Petavratzi: As you said, the environmental impacts can be a wide range of things, from mine waste all the way to particulate matter emissions, deforestation, soil degradation, water abstraction, et cetera. Obviously, every commodity is unique and every mining project is unique. The environmental challenges are very much influenced by the locality, the climatic conditions, the mining methods utilised, the infrastructure used, and so on and so forth.

The way in which we assess environmental impacts at the moment is very much at the project level, so we develop environmental impact assessments and have monitoring systems in place. These are confirmed by national law and regulations that define how these impacts are managed and mitigated.

The issue with the decarbonisation agenda is that it sets very high goals and aspirations for sustainable development. The environmental management systems that we have in place are not really fit for purpose. The reason is that we are now asked to make sure that there are no trade-offs between mining and the downstream supply chain, or the life cycle of the material further down the supply chain, and to do that you need to start assessing mining projects as part of a wider system. This is something that we have just started doing. For instance, we are doing quite a lot of work on South America in the Lithium Triangle at the moment. There is a perception of harm related to water abstraction there, but the scientific evidence to justify these assumptions is not there. There are huge data gaps.

We have to look at the salars not just as a mining project but as part of the wider ecosystem, including what sort of direct and indirect impacts they have, what the cumulative impacts are, and how they compete with other sectors and areas, such as tourism and agriculture. This is something that we have not done in the past at great scale.

Viscount Hanworth: I was thinking of the social circumstances of the countries in which these minerals are mined.

Professor Richard Herrington: I just wanted to talk about the biodiversity impact of minerals operations, which has been so poorly considered in the past for mining operations. It is quite clear that we should be developing metrics to measure that. That should be part of the analysis of any project moving forward, particularly in light of the Dasgupta report this year, which talked about the value of biodiversity.

We should put a value on that. It is not only the environmental and people impacts but the impacts on the ecosystem. Some parts of the world have a higher biodiversity intactness, and we should be a bit more careful about allowing mining in those regions versus those where biodiversity is not intact. That would include Europe, where we have disturbed biodiversity for many years. Perhaps that is part of the metrics.

Viscount Hanworth: Thank you for that. As I hinted at before, I think the social circumstances of some of the places where the minerals are mined should be taken into account. For example, the mining conditions in the Congo are appalling. Can anybody comment on that?

The Chair: Viscount Hanworth, if there is time, I will come back to you at the end to expand on your question. Can I go to the noble Lord, Lord Holmes? Please be brief in your answers, because I need to keep to time.

Q124 **Lord Holmes of Richmond:** Thank you, Chair, and good morning to the panellists. What steps is the mining industry taking to address human rights issues in the jurisdictions where some of these precious metals and their minerals are mined, not least cobalt in the DRC?

Professor Richard Herrington: That is a very important consideration. To take the example of DRC, in 2019 specific legislation was brought in to look at the artisanal mining supply because, as we know, up to 20% of the material coming from there was from an artisanal source. A partnership is in place between Pact, an NGO working there, and the Trafigura Foundation, one of the big metal trading companies, to focus particularly on reducing child labour in mining. It is quite apparent that artisanal mining is extremely important for the local economy. One solution would be to walk away from those countries and cut out artisanal mining completely, but that would cut the lifeblood out of the community, so legislation was brought in, as I say, in 2019. These are things that are definitely making a difference, but it has taken legislation to do it.

Similarly in the Philippines, where there have been social issues, the UK Government have just invested £10 million in a programme of sustainable mineral supply. Research is being done on how we can embrace working with local communities as well as the mining companies and academics to develop a way that is more sustainable not only for the mine but for the communities around it.

So things are moving, and I think people are aware of it, but it needs intervention, and this is where legislation and interventions of international groups are critical.

Dr Evi Petavratzi: I endorse what Richard said. A huge volume of standards and guidance is coming out regarding responsible sourcing. The OECD due diligence guidance has been accepted as the international standard and is used by a variety of Governments and agencies. It has also become part of legal frameworks in several African countries. There are standards specifically for cobalt too. As Richard said, there is the responsible cobalt initiative, which the Chinese are involved in as well. The DRC has recently published its Entreprise Générale du Cobalt standards on responsible sourcing. The Cobalt Institute has developed the Cobalt Industry Responsible Assessment Framework.

What is obvious is that the downstream supply chain, especially the OEMs, are really taking stock of these and starting to utilise them within their processes. They also have their own initiatives to track supply chains. For instance, we know that Apple is tracking cobalt. Equally, BMW is using tools such as blockchain to track cobalt within its supply chain.

So things are happening, Obviously, it is a start. One of the biggest issues in all this work is data. Again, that comes back to the complexity of supply chains and the difficulty of tracking material flows within them. Very often, those supply chains are not transparent. That is definitely a big challenge. Another big challenge for OEMs is the responsible sourcing standards that ask them to connect to tiers of the supply chain that normally they do not engage with. They ask for convergence across a supply chain, which is positive, but it will take time.

Lord Holmes of Richmond: Thank you. Do either of the other two panellists want to add anything, briefly?

The Chair: It does not like it, Lord Holmes.

Q125 **Lord Kakkar:** I want to revisit the question of the other materials that are required for the manufacture of batteries and fuel cells beyond minerals and metals, particularly elements such as electrodes, binders, solvents, additives and so on. I want to understand better what challenges these materials pose with regard to the UK supply chain in the first instance, and then how we might solve these issues.

Professor Magda Titirici: First, batteries are not only about lithium, cobalt and nickel. The chemistry is there for lithium-ion batteries. We have many other options as well.

It is a threefold problem. First, how do we access the minerals so that we can continue the development of lithium-ion batteries? Secondly, how do we start recycling? I guess Paul will talk about that in a bit, because it is the next question. Thirdly, how do we produce locally-sourced new materials in the UK for these technologies?

This is where the UK has an amazing opportunity to produce new materials that are not necessarily based on critical materials, with a locally available supply chain in the UK, and to diversify the battery market. We do not need to use only lithium-ion batteries. We can also make an alternative catalysts in fuel cells without platinum. We do not need to use platinum; we can use enzyme-inspired materials and even things that we make from our local bio waste—this is something that my research addresses a lot.

It is the same for the binders. The binders that we use in batteries at the moment are PVDF, which is extremely reprotoxic and carcinogenic. We have the potential to use, for example, biopolymer-based binders from cellulose and lignin, which are widely available in the UK in any biowaste. Electrolytes are mainly carbonate solvents, but we have the potential to make greener solvents locally in the UK, potentially even from recycling CO_2 into these carbonates.

This is an area that I am very passionate about. The UK has a huge potential for manufacturing new materials for batteries, fuel cells and electrodes. It could move to different technologies and source the other parts—electrolytes, binders and so on—from locally available supplies, making them greener.

Lord Kakkar: That is very clear. You rightly identify "we could have". What capacity do we have at the moment? Is there a strategy to take us from our current position to a position that would provide us with greater security and greater-value generation opportunity?

Professor Magda Titirici: The UK is leading in the production of advanced materials worldwide. That has always been there. Production of advanced materials in the UK represents about 17% of our GDP. It is just a matter of greening a little the chemical industry that is already available here and trying to maintain this leading position.

Professor Richard Herrington: Professor Titirici is better placed than me to answer, but I would comment that these mitigating technologies always have a longer lead time. With the agenda that we have and short supply, those things will probably take at least 10 years to come in. That is my understanding.

What we are not talking about is the need to provide the energy for all these technologies. It is not only batteries. We will need to generate 20% more energy to fuel them if we change all our cars in the UK from diesel and petrol to battery. It is about looking at the infrastructure of energy and making sure that it is renewable.

There is a metal cost of that too. There are the infrastructure metals to build the networks—the aluminium, the copper and things like zinc—and then the materials for solar panels, the silicon and so on. It is beyond the critical minerals for the batteries, because, by moving to this new structure, we need a new infrastructure to go with it. That needs to be considered as well.

Lord Kakkar: We have heard that in previous sessions too, thank you. But in terms of these other materials, just to be clear, when it comes to current technology—batteries and fuel cells—are we content that we have the supply chain for those in a way that means our jurisdiction remains competitive and attractive for those who wish to manufacture batteries and fuel cells at substantial capacity?

Professor Richard Herrington: We can get those materials, but we do not have that supply chain secured because it is largely outside our control. China secures the materials that it needs for its industry by securing that processing. We can get those on the open market, but there is always the issue of whether we can guarantee the supply chain. That would be my warning in that regard.

Lord Kakkar: Would the creation of downstream processing facilities to deal with all this make it more attractive and better secure the raw materials for us to proceed in this direction?

Professor Richard Herrington: For the automotive industry there is the danger that if we do not produce the batteries locally, the manufacturers will move to where the batteries are produced, because then they can guarantee that they can produce the vehicles because they have that supply chain secured. There is always the issue that if you are not controlling the parts of that supply chain, you will not be able guarantee the supplies in future. That is the warning that I would raise.

Dr Paul Anderson: The extent of the EV revolution and the speed at which it needs to be carried out—we will not be able to sell internal combustion engines in nine years—means that there will be an enormous scramble to deliver this industry and the number of vehicles that will be needed. So, whether we like it or not, we are in a competition—a friendly one, I hope—to secure supply chains. We will need to invest quite extensively in UK processing to maintain the UK's position in the vehicle manufacturing market, and that will be expensive.

My other point, which might have been mentioned previously, is that in the terms of the EU withdrawal agreement there are stringent targets for the number of components, and indeed battery components, in manufacturing vehicles that must be sourced locally—rising, I think, to 50% as early as 2024. We currently export about 80% of our vehicles to the EU market and they will attract a 10% tariff if we do not meet those requirements. So this is existential for the UK electric vehicle industry.

Q126 **Lord Krebs:** My question picks up on something that Professor Titirici touched on a few minutes ago. I want to ask whether new battery technologies and/or alternative sources of materials might help us to avoid some of the current issues of supply and hazards that we have already touched on. So far, we have focused largely on lithium-ion batteries, but I believe that Professor Titirici is interested in sodium batteries and alternative sources of materials—for example, plant-based carbon.

Professor Magda Titirici: I think I partially answered this in response to the previous question. The battery market is very diverse: there are electrical cars where you need a high energy density, there are stationary energy needs where you do not need such a high energy density, and there are electronics where sometimes you need high power.

So it is not that we will completely replace lithium-ion batteries—they will exist for a long time—but it is very healthy to diversify the market and create new alternative batteries. In particular, if we look for the green solution, sodium-ion batteries have the potential to locally deliver much cheaper solutions in the UK. We do not need any critical elements; sodium is way more abundant than lithium, and in particular you could make cathodes for sodium-ion batteries that had absolutely no cobalt or nickel. So this is an opportunity.

Then there are other multivalent ion batteries such as magnesium, calcium and aluminium-ion batteries. Magnesium is very abundant, but almost 80% of it is in China and it is considered a critical element by the European Union for that reason. Then there is aluminium, which is the most abundant metal and is also the most recyclable. However, these technologies are nowhere close to lithium, so a lot of investment in R&D is necessary to try to accelerate the development of these new alternative technologies.

It is the same for fuel cells. PEM fuel cells are the most voltage efficient if we compare them with traditional alkaline electrolysers. How do we secure better catalysts? How do we discover new catalysts to replace iridium in these PEM electrolysers? Similarly with fuel cells, how do we discover new catalysts to replace platinum? The US Department of Energy, for example, launched a massive project on alternative catalysts US-wise, and it has made quite a lot of progress in non-critical metal catalysts for fuel cells and electrolysers.

On the previous question, I should add that you do not need to change the infrastructure. The way that you manufacture sodium-ion batteries is exactly the same as you manufacture lithium-ion batteries, so the battery producer will not have to change a thing.

Dr Evi Petavratzi: I have a couple of points to make. One is on supply risks. We have to understand why supply risks occur. They occur when the supply chains are out of tune. That is what we are experiencing at the moment. The expectations and demands of the downstream supply chain are not met in a timely manner by the upstream supply chain. That is due very often to not understanding properly the lead times needed for different states of the supply chain to develop. For instance, the extractive sector needs huge lead times to bring new materials to stream.[5]

[5] On 3 June, Dr Petavratzi sent the following update: We have reviewed Tier 4, which embraces namely the deposit discovery, development and production of raw materials and it is clear that there are long lead times, often exceeding 30 years, to bring a new mine into production following the deposit discovery. Consequently, to ensure adequate raw material supplies for the anticipated ramp up in EV production there should be new mines in the pipeline now, based on discoveries made some decades ago. However, we are not currently in this position, rather many new projects are in the early stages of

I endorse what Magda said about supply diversification. That is extremely important. We cannot just rely on domestic resources or on recycling; we have to rely on a lot of different things such as trade, recycling and domestic as well as finding new resources.

My last point is about the lack of sufficient intelligence regarding raw material flows at the moment. We do not know what the UK picture is in the world, and we really need to understand that better. We need to get much better at having mineral intelligence and understanding where our materials will come from in future.

Professor Richard Herrington: Feeding on from what Evi just talked about, we need to be proactive about understanding where the future demand might come. We must make sure that we invest in understanding where all new commodities are coming from and research some of the minor metals that might be needed in future, so that we do not get out of sync where there is a demand because someone discovers a technology but we do not know where the raw material is.

We need to make sure that we invest well enough in unlocking things like our national mineral collection. You can unlock all the understanding about what metals are where, and then as soon as someone comes up with the technology you can be along that path. I would definitely be more proactive in looking at new materials that might be used in future.

Lord Krebs: Dr Anderson, could we have one sentence from you?

Dr Paul Anderson: I echo what Magda said earlier about us not having a national strategy. We need to have a single focus in government to look at these issues rather than the responsibility being spread, as currently, around several government departments. Whether it is articulated publicly or simply stays in Whitehall, we need a national strategy on these elements. That was a very long sentence, so apologies for that.

Lord Krebs: But it was a very clear steer. Thank you very much.

Q127 **Baroness Manningham-Buller:** Dr Petavratzi touched on recycling, and I would like to ask some questions about that. We have heard evidence in earlier sessions about the importance, if we can do it, of recycling some of the minerals and components of batteries, but we have had differing views on the practicality and plausibility of doing it at scale.

Dr Anderson, to what extent does recycling currently feature and at what scale, and what do you think about the possibility of it being a good source of components for the UK?

Dr Paul Anderson: We do not recycle EV lithium-ion batteries at all in the UK currently. As for the more global picture, there are varying reports and it is difficult to verify information, but it is estimated that the figure for cobalt and nickel is quite high, maybe 70% to 80%, whereas that for lithium is much lower, perhaps only around 10% or less.[6] It is absolutely

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exploration and their future is not assured due to continuing market uncertainties for most of the technology metals needed by the EV industry.

[6] The amount of lithium recycled varies by region, which goes some way to explaining

the case that, as the industry grows quickly, we will have to rely on primary resources for a considerable time, but again it is estimated that, by around 2040, we might be able to source somewhere between 25% and 35% of our lithium and cobalt from secondary sources.

We had a brief discussion earlier about the environmental consequences of the extraction of some of the primary materials. In some cases, although not all, it should be possible for us to recover materials from secondary sources with much less environmental impact than is the case for primary materials. So we should not necessarily allow profitability to be the only factor that we take into consideration with regard to that.

Professor Richard Herrington: Building on what Paul has said, at the moment, for lithium, around 1% of the demand is coming from recycling, and it is really important that we build that recycling strategy. Some EU projects are building that, and the UK needs to be a part of that. If we can get into the recycling, that effectively gives us a raw material. Recycling could come from industrial wastes, and there are wastes around Europe that could supply quite a bit of what we need. We estimated that up to 50% of the cobalt that Europe needs could be being put on to the waste dumps of existing mines in Europe, so that is something that we can work at. The UK is really well placed to help with that, unlocking resources in waste materials, characterising where they are and extracting them.

At the moment, it is cheaper and easier to go back to raw materials than to recycle. We may need some intervention into the value chain, because people will go to the raw material before they go to recycling because, ironically, it is cheaper and more efficient. If we had a different way of valuing, perhaps we could stimulate the recycling industry to go more quickly. As Paul said, and my article published yesterday in *Nature Reviews Materials*[7] pointed out, about 35% of the cobalt could be recyclable once we have a mature battery market, because at the moment we do not have those batteries to recycle and there is that long lead time before we get recycled metal into the supply chain.

Baroness Manningham-Buller: If we got to the stage where we were able to recycle on the scale you think is possible, what would the UK Government in particular need to do to get us there?

Professor Richard Herrington: It is about creating the legislation to make sure that when manufacturers build things, we are then able to unlock those resources for future technologies. It is about some standardisation of knowledge about what the recyclable materials are like, so that, at the end of life, it will be easy to unlock those minerals and metals and get them back out of the technologies. We have seen too much that materials are so difficult to recycle they go to waste and new materials are needed instead. That is where the British Government and

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the discrepancy with the much lower figure of 1% quoted by Professor Herrington in this session.

[7] Link to this paper published on the 24th May 2021: https://www.nature.com/articles/s41578-021-00325-9

legislators can be involved: in making sure that products are able to be used and recycled after their end-of-life.

Professor Magda Titirici: I agree with Paul that recycling is key. It would be nice to see more initiatives in the UK. It is not a lot, but I know of four companies in the EU that operate at some sort of scale and there is nothing currently in the UK.

Beyond recycling, we could also repurpose batteries so that, for example, when you take a battery out of an electric car it would still have about 80% of its life and you could put it into the grid for stationary storage. This is a widely known technology. The stadium in Amsterdam is powered by such batteries. So it is not only about recycling; it is also about re-use and repurposing.

If we are to manufacture batteries in the UK, it would be nice to make them smarter than most people have done by designing for disassembling and clear labelling to make known what metals are in the battery so that you can track them down and recycle them. Current recycling methods are not the nicest and the greenest. If you knew what you had in there, you could do direct recycling. Paul knows much more about that than me.

Dr Evi Petavratzi: First, in terms of things happening in the UK, we have the Circular Economy Network+ in Transportation Systems, which has been going on for over a year now. Today, we also have the external launch of our Circular Economy Centre in Technology Metals, so there is quite a bit going on in the UK. Obviously, none of this will solve the problem, but some money is going into research to address some of the knowledge gaps.

People have touched on the regulatory side of things. The EU’s proposed new regulation for batteries and waste batteries is very important. It will influence the whole world, because it changes the requirements for producing, repurposing and recycling batteries. There are mandatory requirements within these regulations for collection rates up to 2030 and recovery rates of elements—lithium, cobalt and nickel are mentioned—as well as mandatory carbon footprint declarations. There are also requirements for what recycled contents we will have in the new batteries. This is key. I bet that the next set of critical raw materials will have secondaries—recycled lithium, recycled nickel—in the list.

Baroness Manningham-Buller: Is that change imminent?

Dr Evi Petavratzi: Yes. They have set a target of 2027 to 2030.

Baroness Manningham-Buller: Thank you.

Dr Evi Petavratzi: It is quite imminent.

Professor Magda Titirici: There is something to learn from lead acid, which is in the battery recycling directive. Lithium batteries are not, currently, so I agree that this is key.

The Chair: Viscount Hanworth, I stopped you because I thought the question you were going on to was about social conditions in some areas where we could source these materials. Lord Holmes was going to ask that, which he did. Do you want to come back to any of your question?

Q128 **Viscount Hanworth:** I think it is obvious that there are difficulties in places that I mentioned. One thing I would like to raise is that there is an abundant but very dilute source of lithium, which is sea water. Is this source under consideration?

Dr Paul Anderson: One thing we have not really said with regard to recycling but which is really important is that it is part of the overall CO_2 emissions of the vehicle’s life-cycle. The companies I speak to in all parts of the recycling process are very keen to avoid wherever possible high-temperature processes that use a lot of water and solvents. The thrust of our research in ReLiB is to reduce that. I anticipate that sourcing this from sea water would probably take quite a lot of energy for the amount of lithium that we would get from it. Perhaps some of my colleagues have a different view.

Viscount Hanworth: I am keen to advocate for plentiful energy from nuclear power, but there seems to be some resistance there.

Dr Paul Anderson: As a chemist, it must be said that all these problems would be solvable if we had infinite supplies of green energy, because many of the processes require energy, and if it is not green energy it rather undercuts what you are trying to achieve with zero-emission vehicles in the first place.

The Chair: On that thought of a plentiful supply of green energy, I am afraid that I have to bring this session to an end because we have just hit the time. I thank all four of you very much for the session today. It has been extremely interesting and very helpful. If, on reflection, you feel that there was something else that you might have said or you have more material, please feel free to send it to us. You will get a transcript of today’s session, and if there are any corrections to be made, please feel free to make them. For today, thank you very much indeed. I am very grateful.