HOUSE OF LORDS

Select Committee on Science and Technology

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

Tuesday 23 March 2021

10 am

Watch the meeting

Members present: Lord Patel (The Chair); Baroness Blackwood of North Oxford; Lord Hanworth; Lord Kakkar; Lord Krebs; Baroness Manningham-Buller; Lord Mitchell; Baroness Rock; Lord Sarfraz; Baroness Sheehan; Baroness Walmsley; Lord Winston.

Evidence Session No. 4 Virtual Proceeding Questions 49 – 59

Witnesses

Tony Harper, Industrial Strategy Challenge Director, Faraday Battery Challenge at UKRI, Innovate UK; Dr Lucy Martin, Deputy Director of Cross-Council Programmes and lead for Net Zero, Engineering and Physical Sciences Research Council (EPSRC); Dr Bob Moran, Deputy Director, Head of Environment Strategy, Department for Transport; Professor Paul Monks, Chief Scientific Adviser, Department for Business, Energy and Industrial Strategy (BEIS).

Examination of Witnesses

Tony Harper, Dr Lucy Martin, Dr Bob Moran and Professor Paul Monks.

The Chair: Good morning all, and thank you to our witnesses—Dr Harper, Dr Martin, Dr Moran and Professor Monks—for joining us today. Thank you very much for making time to help us. There is a time constraint for committee members and witnesses of about eight minutes for each question, so I ask for brief questions and brief answers, and I do not need all the witnesses to answer all the questions. Viscount Hanworth will ask the first question.

Q49 **Viscount Hanworth:** I should begin by saying that I have no interests to declare.

The first part of the question is: which aspects of battery and fuel cell research and development is the UK focusing on, and why? Perhaps Paul Monks could answer that one.

Professor Paul Monks: Good morning, I am the chief scientific adviser at BEIS. I will hand this question over immediately to Lucy Martin, who is in a better position to answer it than I.

Dr Lucy Martin: I am deputy director of cross-council programmes at the Engineering and Physical Sciences Research Council, in UK Research and Innovation, so I am responsible for activities focused on decarbonisation and environmental sustainability, which includes our contributions to net zero. I will cover the fuel cells research and development activities, and then I will hand over to my colleague Dr Harper to talk about batteries specifically.

We have a long history in the UK of research strength in fuel cells, and as a consequence quite a number of companies have emerged from the UK's research base specifically focused on the commercialisation and exploitation of some of our fuel-cell research discoveries. The predominant focus of our research activities at the moment is hydrogen fuel cells: how we can reduce the cost of those fuel cells and increase their manufacturability, and how we can incorporate them into the hydrogen economy in the UK and globally, thinking both about internal UK opportunities and wider global opportunities. I will hand over to Tony to give you an overview of battery technologies.

Viscount Hanworth: I have a quick question. Are ammonia fuel cells more or less equivalent to hydrogen fuel cells, or is that a completely different technology?

Dr Lucy Martin: That is a very good question. Hydrogen and ammonia are two viable and important energy sources that will really have a role to play as we progress towards net zero. Ammonia and the use of ammonia-based fuel cells have opportunities primarily for application in the shipping and maritime applications domain. We certainly see that as a huge opportunity for the UK to exploit going forward.

Viscount Hanworth: Thank you.

Tony Harper: As the committee may know, we have very focused activity on research, development and scale-up for batteries in the UK, funded through the UKRI. That is the Faraday battery challenge, which I run. The aspects the challenge focuses on are centred mainly on all the performance targets that need to be improved for the mass adoption of batteries in electric vehicles. Today we have electric vehicles that are just good enough for some people in some circumstances. We need to move to a position where we have electric vehicles and the batteries that go in them that are very good for all people in all circumstances.

We have distilled those performance requirements down into eight specific technical targets, which have been agreed by government, academia and industry. They relate to such things as: cost; energy density, which relates to range; power density, which relates to charging; temperature resilience, which relates to usability; et cetera. Those targets are clearly laid out for where we are today, where we need to be in 10 years' time and where we need to be by 2035. Those targets are driving all the research, development and scale-up activity in the UK.

We often talk about this just in the sense of battery cells, but actually the R&D is concentrated not just on cells but on modules, which are the sub-assembly of cells that go into cars, and Packs , which are the big assembly of cells that go into cars. We concentrate on that, because some of the targets we need to achieve can be and are being achieved through detailed research, development and engineering at the module and pack level.

Viscount Hanworth: Are we fully abreast of the automotive applications of fuel cells, or have we neglected that? Perhaps I should ask Lucy Martin.

Dr Lucy Martin: One feature that we are likely to discuss during this session is that what has driven a lot of the move to lower-emission vehicles, particularly in passenger cars, has been the need to reduce CO_2 emissions, which has been driven by regulation. I will hand over to Bob or Tony to speak about that in particular. We are aware of the opportunity presented by fuel cells, but the greatest opportunity for them is predominantly in heavy goods vehicles and different applications beyond passenger cars where range and charging time will be critical. There has not been as much of a regulatory push for that industry to evolve at this point. I will hand over to Bob to speak in more detail about that.

Professor Paul Monks: To reinforce Lucy's point before I hand over to Bob, it is quite important when we discuss fuel cells versus batteries to reinforce the context driving this. It has a lot of industrial pull; the Government legislated that in 2030 we will stop selling internal combustion engines in order to reduce the amount of CO_2 emitted from them. That has led a rush into development of battery technologies in particular to meet the goal of the electrification of vehicles in the decade beginning 2030 or so. That will be a real driver for what you see in technological development. I will hand over to Bob to answer the questions about the transport sector.

Dr Bob Moran: I think we are abreast of the potential for fuel cells as well as batteries across automotive applications. They are a kind of figurehead application within transport, and I think we have seen battery electric vehicles, certainly in the smaller vehicle weight categories, come through far more quickly and in higher volumes than fuel cells. They have both been around for the last eight or nine years, comparatively speaking, in which fuel-cell passenger cars have been available for people. I think it will be in heavier vehicles and heavier applications within transport—planes, ships and trains—where fuel cells will come into their own.

Viscount Hanworth: Thank you, that has been very informative. I pass over to the next questioner.

Q50 **Lord Winston:** To start with, I would like to come back to something that Lucy Martin just referred to. You mentioned that we have done pretty well with exploiting the fuel cell technology in the United Kingdom, but I think we are still behind Korea and Singapore, for example. Do you think we are really competitive in this area of the market?

Dr Lucy Martin: That is another very good question. One of the main features that needs to be overcome in thinking about fuel cells and their potential application areas is bulk production at volume and how we scale up that manufacturing capability to drive down cost. That is something that we need to consider: how and whether we pursue that in the UK at scale. We have been able to do that with batteries because of such a co-ordinated and focused national effort. Given that a priority for the UK is the transition to hydrogen as another fuel source going forward, that leads to the question of the role fuel cells will play in that and whether we wish to secure a large-scale industry to support that within the UK.

Lord Winston: Perhaps I should just return to the battery technology, because it is very clear that the automotive industry has undoubtedly made a massive difference to our interest in batteries, but batteries go much further than just motor vehicles. I wonder whether one of you, perhaps Tony Harper, might like to say where you think the deficiencies are. We accept that the research is doing pretty well in Britain, but we do not seem to be doing much in the way of production of batteries. Can you comment on that, Tony?

Tony Harper: Yes. I will comment on both aspects: the world beyond automotive and production. It is four years now since we did the target work on mainstream automotive. In the past year, we have worked with aerospace, marine, stationary storage and rail to define the technical targets for the other sectors. You are quite right: the targets driving our programme right now for mainstream automotive are one set. There are three other sets of targets that would cover all those other applications. We are well aware of them, and we are starting to drive our research according to those targets as well.

You are also quite right that our research, as is typical in the UK, is world-leading. Our mid-scale development is also very strong. We have seen through the programme a great velocity of technology maturation,

from technology readiness level 3 through to technology readiness level 6. However, as you rightly point out, that is all very well and good, but we need the mass manufacture, the supply chain et cetera.

We must not forget that we have been making volume automotive batteries in the United Kingdom since 2012. This is not new to us; a plant in Sunderland has been doing that and was for many years the leading plant in Europe for so doing. However, the rest of the world is catching up to us and starting to overtake, which is why we are putting a lot of effort not just into research and development but into the capital and other incentives that we need to attract the inward investment for manufacturing, not just of cells but of all the active cathode materials and the supply chain that we need.

That is part of the Government's investment in the automotive transformation fund, which is starting to attract some of that investment. You will have seen some of it with Britishvolt in the north-east, and there is quite a bit more in the pipeline as well, but we must be under no illusion that the international competition for landing these investments is not fierce. The continent of Europe is treating this as very strategic geopolitical problem or opportunity, and it is being addressed at that scale.

Professor Paul Monks: Perhaps I might add to that by talking about gigafactories. The £500 million ATF is part of that. Britishvolt in Blyth is at the forefront. Tony has described the strategic drive for that. The Prime Minister has set up the Office for Investment, led by Lord Grimstone, to focus on the opportunities driven by this. As Tony rightly points out, it will be a competitive area. It is about getting that match between government ambition and industrial pull to deliver the right form of gigafactories. One is already seeking planning permission and a second is in the advanced stages of negotiation.

Lord Winston: Paul, are we going to have enough gigafactories in the United Kingdom, and how soon?

Professor Paul Monks: That is a very good question. We probably will, moving quickly. I think the automotive transformation fund is a way of doing that—by getting government investment behind delivering it. We have to be on the point here, which is why I think the Office for Investment was set up. I am positive, but, as Tony said, there are difficulties and dangers.

Lord Winston: Why do you think we have been slow with exploitation? Is it a lack of people or a lack of chemical engineers, or is there a particular deficiency that we have in the United Kingdom which we should address?

Tony Harper: I am not entirely sure that we have been slow. The selection criteria that companies use for investment are: whether there is a clear and large addressable market; whether there are capital incentives to help them to set up; whether there is a supply chain: whether there is a workforce; and whether there is a technology base in the country that can support what they are trying to do.

The very early investments in Europe, by the Far East manufacturers, went into Poland and Hungary, because they saw those territories almost as a sort of cheap Germany—they were on the continent and near the market, but labour costs were low, et cetera. The selection criteria are becoming more nuanced, because companies are much more interested now in a stable labour force. They are also interested in low-CO_2, low-cost energy. They are also interested in technology and not just the sheer scale of the market. So a lot of the initial investment went to eastern Europe, but I think we will see that shift for a number of reasons and play to the UK's strengths.

As the committee will know, we have a low-CO_2 grid today and it is getting lower. We have stable labour relations and stable wages, and we have the technology. With the automotive transformation fund there as well, that puts us in a good place to attract the next round of investments, as Paul was hinting at, and of course we have some homegrown capability too. However, again, I caveat all that with the fact that it is a very competitive international battle at the moment.

Q51 **The Chair:** We know that the Faraday challenge has three different arms to it, and you might tell us what those arms are. How successful has the strategy of choosing three different sectors for the challenge been? Also, you might comment on what kind of companies, or scale or size of companies, are involved. Are they from the United Kingdom or are they international? Could a similar model be applied to fuel cell technology? How sure can you be that the funding will remain in place?

Professor Paul Monks: I will deal with the funding question. I think Tony is in a much better position to describe the Faraday Institution, as he runs it.

The Faraday challenge is funded in its current form until 31 March 2022. It was originally for four years and was extended for another year with the one-year SR this year. We have funded it to the tune of £318 million so far. We are entering another SR period next year and the next phase will be negotiated as part of that. I think the Secretary of State has recently said in evidence to various Select Committees that he recognises that the Faraday battery challenge has delivered and will be at the forefront of the SR thinking as we develop.

So the funding will run out next year, but it is very much in the SR thinking for the coming years. I will hand over to Tony to answer the first part of your question on the R&D arms.

Tony Harper: The Faraday battery challenge overall was conceived between a wide coalition of industry, senior academics and government. My background was as research director of Jaguar Land Rover previously; at the time, I was in industry. It was recognised that a co-ordinated approach was required for the sheer scale of the opportunity and the need for batteries in particular. That speaks to the demand that was touched on in the last question; Lord Winston asked whether we had enough capability to match the need. The need was quantified at the time as: "We currently make two gigawatt hours a year in Sunderland; we

need to make 100 gigawatt hours a year by 2035 for our car industry alone". It was that kind of "oh, my gosh" moment that spawns the need to do something.

The consensus at the time among industry, academia and government was that a co-ordinated approach that invested heavily in our core scientific capability was needed, building on our existing strengths. Our business-led R&D elements pulled that research through into proof of concept and the provision of an open-access gigafactory, in effect to allow our industry to develop its technology at manufacturing scale. It is those three arms that make up the Faraday battery challenge.

The Faraday Institution has now committed well over £100 million across nine projects in co-ordinated science activity at scale against the same eight targets that I talked about earlier.

We have 124 companies—all of them, by the way, have R&D in the UK; whether or not they are UK companies, they need to have R&D in the UK to qualify for the programme—and 64 projects happening at scale. We have just got to the point where we are finalising the commissioning of the UK Battery Industrialisation Centre, which was designed and built in two years. We have had some commissioning delays because of Covid; all the equipment comes from places where you really would not want it to come from in a global pandemic, so we have had some delays in installation and commissioning.

I think that answers some of the questions. On the question whether you can stand up big science, big technology, and then instantly have flow, as you can imagine the minute you stand up a collaborative R&D programme and they turn to the scientists and say, "What have you got? We want to start commercialising it", they reply, "We haven't started yet". So there is a timing issue.

However, we have found that the mid-TRL R&D programme has done a lot of commercialisation work on battery technology that was spun out of universities prior to the Faraday Institution. For example, we have built a lot of strength in next-generation chemistry, sodium ion, lithium sulfur and solid state. A lot of the companies—they are small and medium-sized UK companies—that are involved in that and have grown through that process were spun out of universities between 2010 and 2015, which is quite interesting. That is how we have had very high velocity of that kind of technological maturation through the programme.

Getting nine major scientific programmes off the ground in three years, including four fast-start programmes, at about £10 million each, each involving five or six universities, has taken some time; we have had the first four and now we have the second five. We now have 450 of the best scientists in the country working together at scale on all these problems, and already we are starting to see some highly commercialisable breakthroughs from that activity involving very large companies being interested in putting significant amounts of money into taking those discoveries forward.

Hopefully that describes the dynamics a bit. Now that we are commissioning the UK Battery Industrialisation Centre, we also understand its likely pipeline of activity for the next 24 months and—surprise, surprise—that involves taking at scale some of the technologies that I have talked about which have come through the collaborative research and development programme as well as attracting inward investment from some of the gigafactory folks we talked about earlier.

The Chair: Do you feel confident that in the current climate of R&D funding the funding will be maintained in the longer term? Dr Martin might like to comment on whether this can be applied to fuel cells.

Tony Harper: Yes, of course. I will probably need to defer to Paul Monks on the question of confidence. However, those of us who are involved at the sharp end of all this would say that to a large extent the answer to that question will depend on how well we do in this programme. Can we demonstrate very clearly that this approach of co-ordinated, targeted, cross-TRL, mission-oriented research and development really produces the growth, jobs and outcomes that we all think it needs to? That is our job.

Professor Paul Monks: I will not repeat what I said earlier, but I will expand a little on the question of confidence. In the House of Commons on 1 March the BEIS Secretary of State stood up and praised the extraordinary progress made by the Faraday battery challenge in the past two to three years and its role in the industrial strategy. Again, I will say that it is to the fore of thinking. We are in a one-year SR and that is the nature of the game in town. The battery challenge will be to the fore, but as you well know there are no promises around funding at the moment, although I think its record will speak for itself in an SR bunfight.

Tony Harper: On the fuel cell question, speaking from a personal perspective, I came out of a very large corporate research directorship role into UK Research and Innovation, because I fundamentally believe in the approach of co-ordinating our science, our R&D and our industrialisation at a major lead-in opportunity. That has worked over the last four years, and I absolutely believe that that approach is appropriate and required for fuel cells.

Dr Lucy Martin: Last year, we worked through the forward strategy for the UK research and innovation energy programme, so I thought I would bring it to your attention that one of the highest priorities in our forward plans is hydrogen and how we support a co-ordinated research and development programme, looking across the production, distribution, storage and usage of hydrogen across application domains, which would include fuel cells as part of that. One of our leading ambitions is to drive that in future years, and obviously that will be part of our forward plans approaching the next spending review.

Q52 **Baroness Walmsley:** We are hearing that battery research currently receives greater public funding than fuel cell research. If that is correct, can you say why that is? Does the difference reflect the expected contribution of each technology to decarbonisation, or does it reflect the

difference in the level of technical challenges that need to be overcome?

Dr Lucy Martin: Looking at the current research investment levels, battery technology receives about 10 times the amount of funding that fuel cells do. That is due to the existence of the Faraday battery challenge and the fact that the opportunity arose because the convergence in academic strength, the industrial need for the UK automotive sector, and the policy driver due to the need to reduce CO_2 emissions created a strong case for increased investment and a significant co-ordinated national programme. That is the real reason for the difference. Historically, prior to the Faraday battery challenge, investment levels in both areas were fairly equivalent.

Professor Paul Monks: There are two clear factors here. The first, as Lucy has just said, is the industrial pull question. The second is that fuel cells are just at an earlier stage of development as we have not backed that technology to the same extent. To put some colour on that, for a grid fuel cell you will need something like 40,000 hours of performance, whereas for a transport fuel cell you need 5,000 hours of performance. In some senses we are just not there yet.

I am positive about the future. As Lucy said, we have the £1 billion net zero innovation portfolio over the next five years to promote new technologies, and hydrogen is very much to the fore in that. The 10-point plan clearly says that we will look to generate 5 gigawatts of hydrogen by 2030. We will see a driver growing and fuel cells being part of that.

On the fuel cells and hydrogen piece, which we talked a bit about earlier, there are also very interesting applications in transport and aircraft. One of the innovative places for fuel cells in aircraft is the Aerospace Technology Institute, which is funding projects to look at using hydrogen fuel cells in aircraft to drive new-short haul aviation.

So there is a gap in the stages of development of fuel cells, but I think there will be a greater draw now, particularly in the hydrogen piece, given the increasing focus on hydrogen as a fuel for decarbonising our industrial energy and our economy.

Q53 **Baroness Walmsley:** Despite the disadvantage in funding, obviously a lot has been going on in the fuel cell world. What are the big advances that have been made in fuel cell technologies, not just here in the UK but around the world?

Dr Lucy Martin: I am happy to speak about the advances that we have made in fuel cells. There have been advances in the UK and globally. Some of the UK advances have been driven through the H2FC SUPERGEN hydrogen and fuel cell hub, which we invest in as EPSRC, looking at the development of catalysts for fuel cells, the safety of fuel cell operation and manufacturability. A notable output of that work is the formation of Bramble Energy, a spinout that emerged from Imperial College London, which is looking at printed-circuit-board-based fuel cell systems that reduce the costs associated with manufacturing. That has been a major development.

A number of different projects in the UK are applying fuel cells to different application domains. One major advance to note is the application of fuel cells for aviation, which links to what Professor Monks just mentioned, which resulted in the first test flight of a hydrogen fuel cell at Cranfield this year and involved the Aerospace Technology Institute and Innovate UK funding as part of the HyFlyer project.

There have been a number of applications for road transport, particularly buses. Some of you may have heard of companies such as Wrightbus, which is looking at the rollout of hydrogen buses in Northern Ireland.

Globally there have been international advances looking to increase the efficiency of fuel cells that have been improving the performance of current fuel cells. The Toyota Motor Company, for example, demonstrated an improvement from 53% efficiency to 55%, just to give you an idea of the scale involved. These are small improvements where the world is looking to try to drive this technology forward.

There is also the application of stationary fuel cells in Japan for combined heat and power applications in the home. That is another area that we have not really utilised in the UK, but it offers opportunities. Another example globally is that Microsoft powered its data centres for 48 hours last year using hydrogen fuel cells.

There is a breadth of technological advances that are actually quite small, particularly with regard to efficiency gains and catalysis, and there have been demonstrations of that around the world, but there is a huge need to drive this forward even further and to think about how we do that so we can exploit that commercially.

Baroness Walmsley: Apart from Faraday and the EPSRC, are there any other ways in which battery and fuel cell research is being funded in the UK?

Professor Paul Monks: There are private companies doing it. A company based in Loughborough called Intelligent Energy is producing commercial sales of fuel cell technologies, including some of the fuel cell technologies used in the aircraft experiment that we were just talking about. It is about matching public funding with private funding and the growth of that.

To return to an earlier point, a fair challenge in this area is how we are driving scale-up and moving from bespoke fuel cells to fuel cells at scale. That remains an issue and a gap in our armoury here. Just last week we launched a £68 million competition for energy storage that includes electric, thermal and power-to-X, so in some senses we are trying to draw out at scale some of the elements around it.

Q54 **Baroness Sheehan:** I would like to explore in further detail the technologies, or the combination of technologies, that are seen as the most likely options for HGVs, buses and trains. We have talked a bit about the different levels of support that batteries and fuel cell technologies are receiving.

Could we talk about the support for heavier vehicles as opposed to lighter ones? Do you anticipate that research and development in this sector will be driven through demand from operators and users of heavy transport, or through regulation?

Professor Paul Monks: That is a question for my colleague from the DfT.

Dr Bob Moran: It is a great question. Heavy transport—fantastic stuff. I would start by linking it to the previous question. In transport, where we have led innovation competitions or funding for R&D, we have always been very focused on the outcomes, such as cutting CO_2. To tackle this climate crisis, we do not have the luxury of being able to pick and choose zero-emission technologies that might be available to us. So our funds have very rarely—they have by exception, really—focused on a single technology and tried to advance that. We have been interested in the integration of zero-emission technologies with transport applications.

On heavier vehicles, I will start with trucks, which is quite timely because we are launching a new £20 million innovation competition today to cut truck emissions and to put demonstrated pioneering zero-emission truck technology on to UK roads within the next few months. That opens today. We are funding across portfolio technologies, but we see three competitors or alternatives in play at the moment. One is absolutely battery electric single units, which comes from the growth of batteries and the performance of batteries in smaller vehicles, moving progressively through smaller light vans into smaller trucks.

However, for the competition today we are not just focused on battery electrics for the big 44-tonne trucks; we are also looking at a range-extender type of system with overhead catenary wires, very similar to tram lines or train lines, where you can provide electricity direct from the grid into a truck on a motorway or a strategic road via an overhead line to produce, in effect, an extension to the range of that vehicle. So battery electric in isolation and then with catenary wires are seen as two technologies. The third is hydrogen fuel cells, and an infrastructure of hydrogen-refuelling stations will also obviously be needed to support those.

Those three technologies are in development with the global automotive industry and truck manufacturers around the world. A couple of really good examples in the UK are Tether and Arrival, which are producing battery electric commercial vehicles. I believe that Leyland DAF will also start to produce battery electric vehicles off its production line next month.

The key driver of this in future will absolutely be regulation and a phase-out date. The Prime Minister's 10-point plan last November committed to taking the same approach to cars as for other road vehicles, and looks to introducing a phase-out date for the sale of new diesel-engined trucks in future. In fact, we will be bringing out a consultation to see what the right date should be for that. That will lead on to regulation, which will then provide certainty to the market. That will probably be a key driver for technologies and how quickly they progress.

Q55 **Baroness Sheehan:** Professor Monks, could I ask you to address where the driver is going to come from—the industry or regulation?

Professor Paul Monks: As Bob said, if we follow the model for what has happened with cars and the internal combustion engine, much of the drive for this will come from regulation. The right timing for regulation is when you can see a clear technology pathway that allows you to make it feasible for people to move to these sorts of technologies. I think the challenge with hydrogen—for example, hydrogen in heavy trucking—is the infrastructure to do the fuelling. This week saw the announcement of the Teesside hub, which will look at the hydrogen production and storage questions and put in some of the early hydrogen fuelling stations.

There will also be the question of how best to deploy hydrogen within our energy system. In the hydrogen projections, the question is whether transport will be the best place to use that.

Another alternative, which we mentioned earlier and is worth mentioning in passing again, is ammonia, where we have more infrastructure and expertise in handling it. The other part of transport that we have not talked about is ammonia and shipping. This is conjecture: I am not in charge of setting regulation for ammonia and shipping, but I think ammonia is easier, because it has calorific value and is slightly easier to store than hydrogen, so you will be able to put it on long-distance shipping. Shipping is an area that is globally regulated via the International Maritime Organization, so the push on it will be quite interesting.

The short answer to your question, having just riffed on the theme slightly, is absolutely regulation, as Dr Moran said, but regulation sited on a clear pathway of technology to allow companies to be able to respond to that sort of challenge in the same way as we have seen car companies and manufacturers do with respect to the 2030 and 2030-X for hybrids' phase-out of internal combustion engines.

Baroness Sheehan: Professor Monks, you mentioned the automotive transformation fund. Could you say a bit about how much that involves and where it will be directed?

Professor Paul Monks: The automotive transformation fund is £500 million and is for late-stage TRL development in transforming the automotive sector. It very much includes some of the things that we are talking about today. There will be a question about how to prioritise, and guidance from this committee will be quite useful in thinking a little bit about how to do that. I do not know whether Tony or Lucy has any greater insights into some of the things it is trying to do.

Tony Harper: Yes. I would like to provide a clarification here. I sit on the programme delivery board for the ATF. There is some late-stage R&D, but the main focus and the bulk of the money in the automotive transformation fund will go towards capital incentives for large capital investment in industrial infrastructure. Gigafactories and precursor chemical industry investments will be the main focus, so that we can

compete internationally with some of the incentives being offered by our international competition.

Q56 **Lord Sarfraz:** We have all these wonderful things happening—gigafactories, challenges and funds—but do we have the people? Do we have the skilled workers across the supply chains? Where will they come from? Who will deliver the training and how do we compete with other countries?

Professor Paul Monks: Skills are an area which we will all violently agree on, in the sense that we need to recognise them. In the 10-point plan, the Prime Minister talked about the Green Jobs Taskforce and the recognition that we will require 2 million jobs by 2030 when it comes to skilling and reskilling, which is as important in this sort of area.

On the more specific aspects that we are talking about today, in automotive there are the national manufacturing competitiveness levels, and the Government are going to invest £16 million in training schemes for that. Are we making sure that the skills that we are developing for this emerging sector match industry needs? Yes, because we are working with the Automotive Council's skills working group to make sure that, as the automotive industry becomes more EV-based, we have the skills and the people who can service those vehicles and understand them, and the engineers who allow us to build those vehicles.

One area that we often forget is apprenticeship schemes. I visited the JET—the Joint European Torus—scheme at the UKAEA site at Harwell, and one of the most impressive things that I took away from that was the brilliant work going on in training apprentices in the basic engineering and technical skills that absolutely underpin this transition in the green industrial revolution. In my view, it is really important that we keep encouraging the basic apprenticeship schemes to drive that level of skills. I was very happy when I met many people that day working in very differing areas of our manufacturing economy, doing apprenticeships to drive those sorts of skills up.

Also, the DfE is running an emerging skills project on the emergent skills that we will need that are different from the ones I have just described—the technical, mechanical and electrical skills that we will need to support this sort of transition.

Lord Sarfraz: How do we compete with other countries?

Professor Paul Monks: I am thinking about the premise of the question. Why do we have to compete with other countries? Is it about making sure that our workforce is ready for the challenge that we have? On high-end R&D, we have the global talent scheme to recruit the best minds to the UK to support the R&D end. We have to make sure that the skills chain runs all the way up through that to support the R&D transformation, the jobs push from industrialisation and the new industries that will be required, such as gigafactories and the like, at the bottom end. I am not sure I absolutely buy the premise of the question.

Lord Sarfraz: Let me rephrase it. If I am setting up a gigafactory, one of

the things I will take into consideration is whether talent is available. If Germany and other countries are competing with us, should we not be thinking about how we compare to our competitors?

Professor Paul Monks: That is the premise of the Green Jobs Taskforce, which is led by the Energy Minister, Anne-Marie Trevelyan, and Gillian Keegan at the DfE: to drive those specific skills to make sure that we have them available for gigafactories.

Absolutely, I think you are right to push on this and to ask whether we have enough focus on skills and reskilling—the idea that we have to make sure that people can change their skillsets as a market and industry develop.

The Chair: Are we confident that we have what is required to train people in place and the number of people with the appropriate skills?

Tony Harper: I am sure Lucy will talk a little more about the high-end skills, but in the Faraday Institution we have several cohorts of PhDs, 450-odd researchers, who are all upskilling. I do not want to say the job is done at the very high end of skills activity, but there is a lot of activity and investment at the higher end.

In mid-scale technology development, certainly for batteries, one must not underestimate the training and upskilling that happen as a result of participating in that activity. I would relate that to my personal experience; the entire electrification department at Jaguar Land Rover today cut its teeth on collaborative R&D programmes back in the early part of the last decade and grew from there.

We have done quite a bit of assessment. The key thing is that, when people look at the UK as an investment proposition, it is almost a tick list. Do they have a site? Do they have the power? Do they have the incentives and the people? We need to make sure that a tick goes in that box as it does in Germany, maybe. The biggest gap there is in what we might call the mid, more vocational, skills that are required to physically operate the facilities. We have understood and quantified those at a curriculum level and at an amount of skills required level. There is more to do to actually execute that upskilling.

Q57 **Baroness Rock:** I have questions on two areas. The first is on the Government's hydrogen strategy and the extent to which it is linked to fuel cell research and development. Fuel cells were not mentioned in either the Prime Minister's 10-point plan or the energy White Paper, so perhaps we could have some clarification on that.

Secondly, we have just heard about the huge amount of activity in this space involving so many organisations, from the net zero innovation portfolio to the new Office for Investment. Who is responsible for co-ordinating all this? Who is accountable for bringing it all together? Dr Martin, perhaps I could start with you on the hydrogen point.

Dr Lucy Martin: Thank you. I will hand over to Professor Monks, given that it is the government strategy that is yet to be published.

Professor Paul Monks: This is a really important point. Let us talk about the innovation piece first, because, as you said in your question, there are many moving parts.

We have something called the net zero innovation board. It is run across Whitehall and chaired by the chief scientist, Patrick Vallance. Its role to align low-carbon innovation across government. The people who sit on that board are all the budget holders. So, yes, it includes UKRI, BEIS, DfT and the like, and it is exactly to do what we are talking about: to make sure that we understand what the Government's portfolio looks like and that we also understand that we are being strategic in how we innovate towards that goal. That is absolutely in mind. If we go to the political level—one level up—we see a number of net zero delivery boards, CAS and CAI, which are government boards looking at the delivery of net zero legislation across Whitehall.

The second part of your question was whether we are co-ordinated on hydrogen. The Government have put into place the Hydrogen Advisory Council, chaired by the current Energy Minister, Anne-Marie Trevelyan. That brings together industry, academia and government to make sure that we are all facing the same way. It will produce a strategy later this year. In that strategy is an element of looking at innovation and R&D. They are absolutely joined up. The net zero innovation board has tried to do that cross-government innovation, with the Hydrogen Advisory Council pulling together the innovation piece across industry and government to make sure that they are linked up. We are working on a jointly owned innovation road map which brings together across hydrogen some of the questions about production, transport and the end-to-end technology stream that you need for hydrogen. It is about making sure that our innovation portfolio meets all the elements of that.

The Hydrogen Advisory Council, which is co-chaired by an industrial partner, keeps an eye on that development and makes sure that the Government are linked into industry need and ambition alongside academic knowledge. I would say that to a high degree, particularly on the hydrogen front, we have the right structures in place. The question for the next period is whether we can deliver a coherent vision that will allow everybody to see a clear pathway to net zero and hydrogen. At the moment, that is very much a technology-neutral pathway.

I will stop there. I do not know whether Lucy wants to add anything more on a strategic level.

Q58 **Baroness Rock:** How co-ordinated is the battery and the fuel cell R&D? We have heard that battery is getting 10 times more funding, and it seems further advanced. We have heard from previous witnesses that they need to be more closely linked and to collaborate. Professor Monk, perhaps you could touch on that.

Professor Paul Monks: I will hand over to Lucy on this.

Dr Lucy Martin: If we look at batteries and fuel cells separately, we see significant co-ordination in the batteries area, as Tony discussed in some of his previous answers. In fuel cells in particular, there is co-ordination

through the hydrogen and fuel cells Supergen hub, which we support. One of its main roles is to bring together industrial and academic collaboration and community to make sure that they can work together on mutual challenges.

On co-ordination, there is a real need to take a whole-systems approach to the breadth of the challenge of net zero. The areas that we are talking about today are two potential technology solutions, but we recognise that a suite of solutions is needed to meet different requirements.

Part of our role in the UKRI energy programme is to look across the research and innovation portfolio, working closely with the net zero innovation board, as Paul has mentioned. Whole-systems research is an area in its own right which can help to inform policy decisions and help us to understand which solutions need to come into play for different applications. Fuel cells and batteries obviously have a huge role to play, but we need to look at that holistically across the breadth of energy technologies.

Professor Paul Monks: I will comment on the systems approach and I will then bring in Tony. Lucy makes a really important point about a systems approach. We are working very hard, for instance, with the Royal Academy of Engineering, which is taking a net zero systems approach with us. Part of the department's energy transition strategy, as embodied in the energy White Paper, is to make sure that we understand the systems elements of this. That is why, to a certain extent, we are staying technology neutral in the strategy, because it is not absolutely clear what the right technology pathway is at this stage. Where we need to be clear is in understanding the systems relationships in order to be able to deliver the energy transition and net zero, with a role for batteries, hydrogen, fuel cells and the like.

Tony Harper: In answer to the question, there is real opportunity for improvement—I mean that in a positive sense. We could be doing much more than we currently are. We must remember, of course, that, technologically, a fuel cell vehicle is fundamentally an electric vehicle. It has a battery; the battery is there mainly to handle power transients, with the fuel cell handling the energy requirement.

To make the system discussion real, we have to do that system integration when we are physically designing a fuel cell vehicle, so the system question is relevant at the vehicle level but also at the system level. I would say that there is a real opportunity here.

Dr Lucy Martin: There is overlap in the areas of expertise and challenge across the two areas. If we think just about materials, for example, there is the need with batteries and fuel cells to look at how we make material improvements that impact on device performance. There are synergies there that we could exploit as well.

Q59 **Lord Krebs:** This question is probably for Lucy Martin, but others might wish to comment. I notice that the numbers that we are investing—£318 million in batteries—are much smaller than many of our competitor countries are investing. The EU is investing €3.2 billion, so an order of

magnitude bigger. The US is investing $1.2 billion, so roughly two and a half times as much. Is that a cause for concern?

Dr Lucy Martin: I may pass to Tony to comment specifically on the batteries programme, given that it is related to the Faraday battery challenge.

Tony Harper: A short answer from my perspective—although obviously I execute the programme and we have to look to government for the policy answer—is yes. One must bear in mind, though, that some of these figures are over different timescales. I think that the European figure is out to 2030, so that is a 10-year investment, but the take-out is that batteries—and fuel cells for that matter, but certainly batteries—are strategic and not a five-year journey but at least a 10-year journey. They need significant investment throughout the value chain in order to be successful.

The Chair: Professor Monks, where do you think we are going to end up, let us say in five years' time, with batteries and fuel cell technology in this country?

Professor Paul Monks: That is a really good question. I think it will be pervasive in our system. We have not talked as much about the other areas, such as energy storage, where battery technology will come to the fore, but it will be an integral part of that. We have nearly 1 gigawatt at the moment in lithium battery storage, and we will see that grow over a period of time. That also offers an opportunity in the system. We will need that, given our increasing reliance on wind energy and the intermittency that drives in the system. So there is that.

The challenge of battery technology will be quite simple. It will be reduced weight and increased power, because with respect at least to vehicles it will be a key driver of where the future lies.

That is probably the big picture. In five years' time, I would like to see the first gigafactory turning out batteries with UK technology and UK science at the base of it, leading to economic jobs and growth, and at the same time the scientists building and developing the next generation of science that facilitates that. I have a broad and optimistic vision. The committee's discussion this morning about the opportunities offered here are absolutely key, and we welcome those insights.

The Chair: On that positive note and hope, I thank all four of you for coming this morning. It has been a most informative session and we have been well informed in our deliberations. Thank you very much.