

Environmental Audit Committee

Oral evidence: Technological Innovations and Climate Change: Hydrogen, HC 348

Thursday 9 July 2020

Ordered by the House of Commons to be published on 9 July 2020.

[Watch the meeting](#)

Members present: Philip Dunne (Chair); Duncan Baker; Feryal Clark; Barry Gardiner; Mr Robert Goodwill; Ian Levy; Marco Longhi; Caroline Lucas; Jerome Mayhew; John McNally; Dr Matthew Offord; Mr Shailesh Vara; Claudia Webbe; Nadia Whittome.

Questions 1 - 62

Witnesses

I: Professor Nigel Brandon, Engineering Dean, Imperial College London, Amanda Lyne, Chair at UK Hydrogen and Fuel Cell Association, Richard Halsey, Representative of Energy Systems Catapult, and Dr Angie Needle, Director of Strategy and Cadent Gas Limited.

Written evidence from witnesses:

- [Professor Nigel Brandon](#)
- [Energy Systems Catapult](#)
- [Cadent Gas Ltd](#)

Examination of witnesses

Witnesses: Professor Nigel Brandon, Amanda Lyne, Richard Halsey, and Dr Angie Needle.

Q1 **Chair:** Welcome to the Environmental Audit Committee. This is our second hearing into technological innovation and climate change, and in this session we have a couple of hours to consider hydrogen production and distribution and the role that it can play in reaching net zero. We have four distinguished witnesses in a single panel, and I would like them to introduce themselves for the broadcast, starting with Professor Nigel Brandon.

Professor Brandon: Good morning. Professor Nigel Brandon. I am Dean of the Faculty of Engineering, Imperial College London. I am Director of the Sustainable Gas Institute, which is largely an industry-funded group looking at the role of hydrogen in the energy transition. I am also Director of the Hydrogen and Fuel Cells SUPERGEN Hub, which is the major strategic investment from the research councils in this space, and I am the founder of two companies in the field.

Amanda Lyne: Hi. My name is Amanda Lyne. I am here representing the UK Hydrogen and Fuel Cell Association. We are a member-led industry association that represents companies, academics and all parts of the supply chain, from production through to use. Obviously, we particularly have an angle on fuel cell technology, but our members cover all aspects of the hydrogen economy. I personally have been involved in hydrogen and fuel cells for over 20 years, and I currently run a company based in Liverpool—an SME that has a globally innovative way to make hydrogen-enabled commercial vehicles.

Dr Needle: Hi, Angie Needle here from Cadent. I am Strategy Director at Cadent. Cadent is responsible for delivering fossil gas today through the gas distribution network. Just in case you want to know what that entails, you can think of the National Grid as the motorways and Cadent's network as the A roads and B roads that bring natural gas to your homes and businesses. That is the bit that we are responsible for maintaining. Our interest is in ensuring that we use this valuable asset to transport—*(Inaudible)*—in the future to achieve net zero. I have 10 years of experience in energy and 10 years in water.

Richard Halsey: Good morning, everybody. Richard Halsey. I am a Director at the national Energy Systems Catapult. It is a network of leading technology centres helping to transform the UK's capability and drive innovation to promote productivity and economic growth. I lead a wide range of energy innovation programmes at the catapult, looking at whole-system solutions to decarbonisation, and I am involved directly in a wide variety of projects, looking specifically at integrating hydrogen in local energy systems.

Q2 **Chair:** Thank you very much, Richard. I am going to kick off with some



wide-ranging questions, if I may, and I would like each of you to give me your overview to start with. The question is, as Amanda highlighted in her introduction, that we have been around the buoy on the potential for hydrogen for some decades now and it is yet to have kicked off in terms of much activity. Yesterday the EU announced a package of €140 billion for a hydrogen strategy for the EU, and here in the UK the Hydrogen Strategy Now campaign announced that it has £1.5 billion ready to invest in hydrogen in various forms, once the Government produce a strategy.

Could I start with you, Nigel, and ask you to give us your perspective on what significance hydrogen technology has and what the potential is to help the UK meet its net zero commitments if we were to adopt a hydrogen strategy in a full-throated way?

Professor Brandon: Thank you, yes. You are right that hydrogen has been around as a topic, with its potential as a low-carbon energy carrier, for a very long time, and it has had a number of surges of interest over decades. As someone who has been involved in the field for 30 years, I have seen these come and go.

The difference today is that the commitment to net zero is a substantive impact. I think you can avoid mitigating some of the really hard-to-decarbonise sectors if you are not committed to net zero, and hydrogen has really come to the fore in helping us think through how we decarbonise things like industrial heat and long-distance transport, whether that is trucks, trains, ships and so on; the role of hydrogen in helping balance the system—I am sure Angie will talk more about the interplay between gas networks and electrical networks; and simply the challenge of decarbonising heat in general. These challenges in a net zero world really bring hydrogen to the fore, and that is, for me, why you are seeing the upsurge of interest.

The other thing to recognise is that the previous waves of interest in the technology have driven innovation. That innovation has taken time to come through and mature, particularly when there has not been a strong market pull, but we are now seeing technologies that are being applied and being deployed. There is still scope to take them forward at scale and to improve them, but we have a much stronger level of technology maturity that underpins the interest. For me, it is that combination of those two factors that are important.

Q3 **Chair:** Thank you. Amanda, I will ask you the same question.

Amanda Lyne: I totally agree with Nigel there. I have seen the ups and downs. As Nigel has illustrated, some of the ups and downs have been associated with some of the technologies in the innovation space, so fuel cell technology has certainly, from an investor and company perspective, been up and down, mostly targeted at mobility. Fundamentally, the thing that has changed is the need for us to fully and 100% decarbonise, and that requires everybody to change. It is not about justifying it and needing to justify it on efficiency or other aspects. The fact is we need to



stop putting CO₂ and greenhouse gases into the atmosphere in everything that we do.

One of the reasons why hydrogen can help do the hard-to-do bits is it requires potentially less compromise or change for those applications, whether it is industrial heat or, as Nigel said, long-distance transport. We have the opportunity that, by providing a solution in some of those areas, we may be able to do it quicker and sooner, which is what we need to do, than needing to do other innovation to come alongside it.

Q4 Chair: Thank you. Angie, a number of other countries have developed their own hydrogen strategies and seem to be ahead of us, and we will come on to some of those later on. From your perspective as a distributor, are there other countries that are including hydrogen within their gas grids, and how far behind are we or how far away is that as a prospect?

Dr Needle: It is a good question. Hydrogen is being distributed today globally in pipes, so that is not a new thing. Largely that is being done for industrial processes and connecting industry together.

We are in a good situation in the UK, in that the mains replacement programme that has been ongoing to replace metal mains with plastic mains over the last few years—it will continue to do so to improve the current gas distribution network—makes it hydrogen-ready, so that you can distribute gases and distribute hydrogen, and 100% hydrogen if you wanted to.

In terms of blends of hydrogen, we have been doing quite a lot of work with Keele University, where we have been blending hydrogen into a gas main there, demonstrating that up to 20% blending is possible and feasible without consumers having to change their appliances or their behaviour.

In terms of what is going on in other countries, there are largely, so far, limitations on the amount of hydrogen that is in their natural gas mains today. A lot of European countries are looking at blending. I think we are ahead in terms of the technology and understanding of blending, but we have yet to set out our own strategy. Technologically and innovation-wise, the UK is ahead. We have been doing lots and lots of things from a production end, a distribution end—is it feasible, is it safe, is it technically possible?—and the consumer end. A strategy over the top of that would really drive extra support, innovation and funding into those places. I do not think we are behind on what is possible. I think we are behind on the strategy.

Q5 Chair: Thank you. Richard, from your perspective at the energy catapult, the UK Government have made some baby steps this year to put some money behind some projects. Could you give us a sense of where you think those are headed? They are small. Presumably, you are looking for something much more significant. Again, how are we placed compared to



other countries' investment and strategies?

Richard Halsey: One of the things to say, echoing Nigel's point, is that, at the catapult, one of the things we have done this year is look at many possible pathways to net zero. What has come about is that there is a consistent need for very large volumes of hydrogen across the system in delivering net zero outcomes. As Nigel says, the gamechanger has been the net zero position, which could mean using as much as 300 TWh of hydrogen across the system by 2050. That is broadly equivalent to the size of our power sector today, which is a massive change and will require very, very significant investment for us to just keep pace with other economies. That investment is needed in a range of different aspects of hydrogen production, hydrogen distribution and hydrogen use across that entire value chain.

It is fair to say the level of investment, if we are to exploit the opportunities that the UK potentially has, needs to be much greater than it currently is. As Angie highlighted, we are seeing other economies making some fairly significant investment. Certainly, that is something where we feel the UK, if it is going to retain a strong position in a global hydrogen economy, needs to be making those investments itself.

I would also echo what Angie said, in that what those investments need to do is to be aligned to that strategy and to a road map for an end-to-end view of hydrogen in the UK, and that road map and strategy need to then effectively guide those investments to ensure that they are co-ordinated and joined up and we realise the value of them.

Q6 Chair: You have just described an enormous increase in investment in order to achieve the potential that is there. At the moment, 95% of hydrogen produced around the world is derived from fossil fuels. How realistic is the production side in achieving net zero? That would presumably require much less being produced from fossil fuels, and over time none of it being produced from fossil fuels.

Professor Brandon: You are absolutely right that we produce hydrogen today from fossil fuels, mostly natural gas, and of course we produce it for a range of different reasons. We are not producing hydrogen as a low-carbon energy carrier. We are producing hydrogen for the petrochemicals sector in particular, for upgrading chemicals production and for fuels upgrading. We are making it for very different reasons.

Obviously, if we are going to go down the route of hydrogen as a low-carbon carrier, the carbon intensity of that hydrogen, how we make it, becomes extremely important. Indeed, if we do not address that, the only benefits we might see from hydrogen are air quality benefits, as a transport fuel in cities. That is a valuable thing to get, regardless of the source of hydrogen. It is always worth remembering that. From a carbon perspective, clearly, we need to address it now.



HOUSE OF COMMONS

If we are going to continue to make it from fossil fuels, and we may choose to do so, we have to integrate it with carbon capture schemes, and we have to integrate it with very high levels of carbon capture as well. We are approaching the 100% carbon capture levels if we are going to do that.

If we are going to do it with fossil from natural gas primarily—and there are some reasons we might want to do that, and we can discuss them, by all means, because of scale and particular types of applications and the type of hydrogen you produce in terms of its cleanliness and in terms of the level of other things that are in it—then we need very high CO₂ capture rates, and we need to address all the issues associated with methane emissions in the supply of that hydrogen. As we seek to decarbonise the economy completely, those residual emissions from CO₂ capture or those residual emissions from the methane production and distribution chain become much more significant.

Alternatively, or in addition, I suspect, we can produce what people refer to as green hydrogen. This is hydrogen made entirely from low-carbon sources—primarily from renewables. You could also conceive of it from nuclear, but I think renewables are the mostly likely source. Then you are looking at electrolysis, so now we are going into electrolyser, taking the renewable electricity and breaking down water and producing hydrogen and oxygen and/or other oxidants. There are quite a lot of innovation opportunities around making things other than oxygen for integration into chemical processes and so on, but none the less from a hydrogen perspective.

Then we have the issue of scale, how we get that electrolyser. It is worth reinforcing at this point comments others have made, that the UK has some world-class technology companies in this space. They are quite small. They are 300 or 400-person businesses. They have been working really hard for the last couple of decades to get to that point. You are seeing investment into those companies from major overseas players and those technologies being deployed. That is a really important thing to note. We make stuff in this country that is used in this sector, and it is globally leading. There is a great opportunity for us to build on that innovation and grow that sector, and I am sure we will want to talk a little bit more about that. Those are the technologies you have, and the UK has strengths in all of those areas.

Q7 Chair: Thank you. Richard, do you see renewable hydrogen accounting for all of the hydrogen production in due course, or is that not feasible?

Richard Halsey: A bit like Nigel says, we see a possible number of different futures that could play out. Blue hydrogen in a net zero world, as Nigel said, is going to need innovation to achieve really high carbon capture and storage rates if it is going to play a major role in a net zero end state.



There is an argument that it plays a valuable enabling role in transitioning to a hydrogen economy and as a stepping stone, but it is important to recognise that, without low and ultimately zero-carbon hydrogen, blue hydrogen will not be able to play a significant role.

Green hydrogen production is certainly a proven and mature technology. It is being deployed. However, it is certainly more expensive than blue hydrogen production, and there is the question of the volumes of renewable—as Nigel suggested—electricity being used to convert into hydrogen to then ultimately be converted into another end use, which is a consideration.

Certainly, there is a need for industrial-scale demonstration of green hydrogen, but that needs to also be done as part of integrated energy systems rather than just an isolated technology demonstration. How does hydrogen fit into a wider, more sophisticated energy system?

The other area, certainly, in terms of production, which has potential value in terms of the end state that needs innovation and R&D, is biomass gasification with carbon capture and storage, because of its potential to produce negative emissions as well. Certainly, in the mid to near term, it is less available and deployable than blue and green hydrogen production.

Q8 Chair: Amanda, your trade association must include a number of these innovation companies that Nigel was talking about. Do you see benefits from having a technology-neutral strategy in terms of stimulating innovation?

Amanda Lyne: Yes, certainly, Philip. The important point here is that electrolysis of hydrogen itself has been around and done for many years, and outside of the UK, in some places, electrolysis and the underpinning science and technology has been known for many, many years—much longer than we have been doing a lot of the other processes we have talked about.

The issue with green hydrogen is about doing it at scale and, as Richard says, making sure it is connected in with renewable electricity or ways of making it renewably. We do not know what price it will be when we do it at scale, so today's assumptions of costs are best guesses and theoretical assumptions. We only need to look at what we have managed to achieve in the UK on some of the other renewable technologies like offshore wind to say that we don't know where it could get down to, because we have not tried yet.

Our association argues that in terms of the here and now, between now and 2030, which is the other thing that we think needs to happen, you might have 300 TWh of hydrogen energy in the system by 2050, but, as has been pointed out, we do not have any as an energy vector today, effectively. We need a target by 2030. Because electrolysis and/or green hydrogen production is quite modular, it can be scaled. The road map to



HOUSE OF COMMONS

ensuring that we can do grid-scale electrolysis means we can do chunks of smaller investment now that are independent of a lot of the other infrastructure challenges that would come from what is called blue hydrogen and Angie's type of investment requirement. Therefore, we would argue, trying to find as many no-brainer and doable scenarios where we could develop green hydrogen, and as Nigel says produce and manufacture the technology here in the UK, will do the other part we need to do, which is to get jobs going.

Q9 Chair: Cost is a really interesting issue. I know Australia has set as part of its hydrogen strategy—I forget the catchy expression it used, but it was something like "A2 for H₂"—hydrogen for \$2 a measure, if it is kilowatt hours or whatever the measurement is. It is currently at 6. Angie, can you give us a perspective and context for the cost of production today and how you think it will develop over time, building on what Amanda was saying?

Dr Needle: Yes, I can. The gas distribution networks—I think it is worth saying, especially Cadent—are hydrogen colour agnostic, if you like, because we want the distribution network to be able to transport hydrogen. How it is produced is important, and making sure it is produced with as little impact on the environment as possible is very important.

In terms of blue hydrogen, which is the methane reformation, and green hydrogen, which is from renewables, we have recently done some work projecting out to 2050 what the costs might come down to on the basis that you have this technology learning hurdle rate, similar to what you get in the wind sector. You have seen the power prices come down in offshore wind. You have this learning rate.

You also have to take account of the input fuel. For blue hydrogen, that is less expensive today because the input fuel is natural gas, which is inexpensive. The expectation is that if you increase the carbon tax on methane, as is expected, to quantify the damage that it is doing to the environment in terms of carbon emissions, the price of natural gas goes up. Therefore, the cost of blue hydrogen will increase. Then green hydrogen becomes more important, so you have this big opportunity to invest in blue to begin with to get the production going on hydrogen, because we need scale so that we can do some of the big pilots and projects to demonstrate its value. We need scaled hydrogen production early on so that we can test it in power generation, in reciprocating engines, for heating homes. There are loads of pilot opportunities. We need hydrogen now.

I know you want to ask me about costs. Today, blue hydrogen, we think, is about £40 to £60 a megawatt hour. There are lots of different units used for hydrogen. We think green hydrogen is significantly higher, around £140. By maybe between 2035 and 2040, they will both be in line with what natural gas is today, including that carbon price.



When you look at it as a system, it is a sensible option. It is not beyond the realms of affordability. It is not too expensive for it to be impossible. Do not forget that hydrogen is needed to balance the system. We are going to need it because the UK has a massive seasonal demand for energy, which is very difficult to source in other ways. There are lots of benefits of having it.

Amanda Lyne: The point about the cost today, the cost for electrolysis, as Angie has pointed out, is largely the input price from the electricity that you put into it and the capital cost for the system. (*Inaudible*)—both the capital cost, and it is a long-term capital investment, it depends on what electricity price you can feed into the electrolysis. If we do not do the work to run green hydrogen now, that cost curve will not come down, and other countries will have green hydrogen technology that does come with the cost down. Therefore, they will be able to take greater advantage of the economic benefits. We certainly would not argue that you wait on doing green hydrogen. There are plenty of places where scale is a matter of conversation, so, clearly, grid-scale would seem to be terawatt hours and gigawatt hours, but we need megawatt hours even now. With hydrogen on green scale, you can do megawatt hours of it now, whereas some of the other technology solutions do not work at that level.

Chair: Thank you very much. We are going to move on now to other questions.

Q10 **John McNally:** My question is principally to Amanda, and it is on the Orkney Islands producing more clean energy than the inhabitants can use. You would have to agree that their foresight has been absolutely admirable in looking at a hydrogen-based economy, looking at the world's first hydrogen-based, seagoing car-and-passenger ferry. Our Committee would be very grateful and extremely interested if you were able to provide us with an update on Orcadians' plans, their ambitions, their progress and maybe what lessons we could learn from them. Thank you.

Amanda Lyne: The Orkney Islands and any of the other islands around the UK actually represent great opportunities for us to develop the technology in clusters as an energy solution. That is what has been driven. It has been driven by a need, because the Orkney Islands are not well enough connected to the rest of the grid. Certainly, all of the applications have been explored. You mentioned the ferry.

What is really important about what we need to do now, and what is happening at Orkney, is making sure all the other issues associated with creating the hydrogen economy are addressed now.

Our company has been hydrogen-enabling the Shapinsay ferry. A proportion of the energy of the Shapinsay ferry is hydrogen-enabled. The biggest thing we have been working through there is to make sure that we can have the standards and the shipping requirements so that the



HOUSE OF COMMONS

technology is regarded as safe and the ferry can carry passengers, and all of that will put us in great stead going forward to be able to prove that this is not just something on paper and theoretical but is really happening. All the energy projects in Orkney are great places for demonstrating that.

We are hoping to have the ferry available towards the end of the year. I think Covid has put some delay on us being able to finish that off. Obviously, the guys are manufacturing megawatt scales' worth of hydrogen already, and that illustrates the example that I previously made.

Richard Halsey: Just building on what Amanda is saying, what they are doing up in Orkney is very much also thinking about this concept of a smarter, more integrated local energy system and about the role that hydrogen has to play as part of that wider system, and about how they can use advances and innovations in other aspects of digital technology and of control as part of an integrated solution. I think that is potentially a really powerful example of how you might be able to take this more integrated approach and not just view hydrogen as an isolated carrier but look at how it fits in with other innovations and with other demonstrations of deployment activity needed to deliver net zero.

Chair: Thank you, John. Did you have a follow-up? You are muted, John. I think that was a good example of applications from the very northern tip of Scotland, which I know John was keen to get across, which he has. That takes us nicely into Robert's question.

Q11 Mr Robert Goodwill: Following on from what we have just been talking about, if we can have production at volume of sustainable blue hydrogen, or quantities of green hydrogen from sustainable sources or nuclear, could I ask Richard to start with, , which particular application of hydrogen should we be looking at as a priority if our priority is achieving our net zero targets? I know there is research across a whole range of different applications, but where should we be targeting our efforts?

Richard Halsey: Robert, that is a really, really good and important question. As you say, there are multiple possible end uses for hydrogen, and certainly we see at this stage that its most valuable end state and end use in a net zero system in 2050 is not certain. It is fair to say at this time that we see the opportunities in the hard-to-decarbonise sectors—such as industrial processes and transport, including heavy goods vehicles, aviation and shipping—as high priorities. Potentially, it can also provide a very valuable resource for managing peak electricity demand, particularly in a system where you have very high renewable energy generation capacity.

With regard to hydrogen for heating, that certainly needs to be maintained and developed as an option at this time, particularly, as Angie highlighted, given the challenges that we have with our quite high winter peak heating demands and the relatively inefficient housing stock we



HOUSE OF COMMONS

have. That cannot be seen as a silver bullet solution, particularly given, as was highlighted, the current costs of hydrogen production and also the technological and commercial maturity of other options.

Q12 Mr Robert Goodwill: If we are making electricity anyway for electrolysis, you might as well just wire the electric into the house and turn it into hydrogen and pipe it in.

Richard Halsey: Exactly. There are conversion efficiency questions here. However, we have to recognise that with the deployment of some of those more mature technologies and commercially mature technologies, such as electric heat pumps and other solutions, we have not seen the market traction. There are some consumer barriers to achieving uptake that we need to consider. That then comes back to ensuring that we develop system solutions that look at appropriately deploying the right technologies.

It is important that we do not see hydrogen and electrification for heating as a binary decision. Potentially, they can very much be complementary approaches. One of the things we feel is that to be able to develop these more sophisticated, integrated solutions you need a much more sophisticated way of planning for local energy systems and ensuring that there is a way of understanding what those options might be, and developing solutions and designs that can engage people, citizens and communities to understand them. Then you can unlock credible plans that align to delivering net zero.

Q13 Mr Robert Goodwill: Yes. I saw Angie indicating. I suspect you are going to say that we cannot store electricity but we can store hydrogen and use it off-peak. Is that right?

Dr Needle: Yes, exactly. Richard is right. I agree in terms of the applications of hydrogen in the short term. We have a great opportunity to decarbonise industry. We have an opportunity to blend into the current gas network if we have surplus, because we know we can take some hydrogen and it will not have an impact.

The question on heating in homes, for me, is quite an important one to resolve because it is not electricity versus gas. It is what is right for that particular property in that particular location, given its needs. That could be a whole range of different things. You are going to need a massive roll-out of insulation, a massive roll-out of heat pumps, and some hydrogen potentially as back-up in some properties that might need it because they cannot have any other solution.

From a feasibility point of view, though, we are working quite heavily on the things that we would need to do with the distribution network to make it hydrogen-ready. There is a big piece of work that BEIS has done called Hy4Heat, looking at 100% hydrogen in the home and the impact that that has from a safety and feasibility point of view.

Q14 Mr Robert Goodwill: Thank you. Perhaps we could turn specifically to



HOUSE OF COMMONS

transportation. I might bring Nigel in here, from Britain's premier engineering university. My son is one of your graduates. Could I ask about where we should be prioritising the transportation network? For example, we already have electric trains that are pretty efficient, running directly on electricity. In other applications, hydrogen takes about eight times as much storage. I have a 44-tonne truck; I could conceivably carry hydrogen on the back of that, but maybe less so in aviation.

Could I ask Nigel, if we are going to target transportation, particularly for larger vehicles or vehicles that cannot access the grid, where would you say we should be looking at putting our emphasis and research?

Professor Brandon: Thank you for your recognition of Imperial as one of the UK's leading engineering institutions—let us be generous to my colleagues. I hope your son had a good time with us.

Mr Robert Goodwill: He is earning more than me now, so thank you very much.

Professor Brandon: One of our claims to fame is we do produce the highest paid graduates in the UK, so—

Chair: Enough of the advert. Thank you so much. *[Laughter.]*

Professor Brandon: To answer your specific question, at the end of the day, we are talking here in many cases about putting that hydrogen into a fuel cell, so we are talking about a hydrogen fuel cell electric vehicle. You are really comparing the benefits or merits of a battery electric fuel cell vehicle with a hydrogen fuel cell electric vehicle. The trade-off comes down to the amount of energy you need on the vehicle. There has been fantastic progress in batteries, and they clearly have a very important role to play in light-duty transport. Great progress has been made, and there is more progress to come.

As you want to put more and more energy on to that vehicle, eventually the batteries get to a sufficient size and weight that it becomes untenable for the vehicle, so when we start to—

Q15 **Mr Robert Goodwill:** What is the energy density of a battery at the cutting edge now in terms of hydrogen? How many kilos of battery are needed equivalent to a kilo of hydrogen?

Professor Brandon: Off the top of my head, I would not want to give you the answer, but I can certainly send you the answer. It is probably unwise for me to just speculate off the top of my head.

What I can tell you is that once you come into looking at something like, at the extreme end of this, an aircraft, or certainly aircraft as they are currently configured, you need more than the payload of the plane for it to be able to take off, if you are looking at it on batteries. There is a trade-off between the two technologies and an overlap between the two, of course, as well.



We are fortunate to have a Toyota Mirai at the university, and that is a hydrogen fuel cell car. Toyota produces a number of them in the UK. As a car to drive, it is great. The challenge with it is that there are only three places we can refuel it in the London area. We also have to come back to the infrastructure at some point.

If we are just comparing the powertrain technologies, as you start to go up in energy requirements, as you would if you want to drive a long way or if you have a larger vehicle like a truck and so on, or an off-road vehicle, it gets hard to electrify that with batteries. That is when the option of effectively carrying a fuel on the vehicle and converting that fuel into electric power becomes attractive. That is the trade-off. It is in that space. A large car probably is the overlap point between those two technologies.

It is going to be coupled to infrastructure—we might come back to that, and I am sure we will—in terms of the availability of refuelling infrastructure for mass roll-out of vehicles for consumers. Once you come into buses, for example, a really important, probably early adopter in the transport space would be bus fleets. There is a social benefit to bus use. They are often—not all—in urban contexts, where air quality is a factor, and obviously electric vehicles have a great air quality benefit, whether it is a battery or a hydrogen fuel cell electric vehicle. They run on a fixed set of routes, with a fixed refuelling point, so they overcome some of the infrastructure challenges. If you are looking at early adopters in the transport sector, there is that public transport or other public vehicle use—it could be council vehicles, road sweepers or things like that, where you are operating out of a depot, and you do not have some of the infrastructure problems.

With trains, you are right, of course, that we have electric trains. They have commercially been around for a long, long time. Where people are looking at hydrogen fuel cell electric trains, it is when you are looking at branch lines with, currently, diesel trains, that electrifying that line would be a very expensive proposition. It does not carry the volume of passengers to justify that capital spend. When you see these programmes being implemented in the train sector—particularly in Germany, for example—it is those sorts of applications, where they do not have the volume of traffic to justify the capital investment of electrification, where they are interested in, effectively, electrifying the train and then refuelling it.

Q16 Mr Robert Goodwill: I think there is some work going on already on allowing the train to continue, once it reaches the end of the electrification section, using batteries. Would hydrogen be an alternative there?

Professor Brandon: Yes. It is certainly an option. At the end of the day, if it is an electric vehicle, whether it is a hydrogen fuel cell electric vehicle making its electricity from the fuel directly, or it is a battery electric vehicle storing it in the battery, from the vehicle perspective, there are



some technical differences around some of the interface between the motor and the energy store or the fuel cell, but broadly speaking the rest of the vehicle is the same. You still have the motors and control architectures. You benefit a lot from the cost down and innovation that we are seeing in electrification and powertrain generally. There are some differences in terms of how we are generating that DC power. Beyond that, it is largely common, once you have got the DC voltage right. It does not matter beyond that. The vehicle is rather agnostic. There are a lot of parallels between those two.

Air travel is, of course, one of the tougher ones to do, clearly. We note the Prime Minister's commitment in a recent speech to thinking about hydrogen for air transport, and that is a great ambition. You would bootstrap it off buses, refuse trucks and perhaps the slightly less glamorous end of the transport sector because that is a great place to start and where there is a very strong case already.

Q17 Mr Robert Goodwill: It would be short-haul anyway, initially, for aircraft, possibly?

Professor Brandon: Yes, I think so, because you are absolutely right that the energy density of a hydrogen tank is going to be better than a battery pack but still well below that of a conventional liquid fuel. Of course, we can always think about—and there are people looking at it—effectively using green hydrogen as a way of producing synthetic fuels, which have a much lower carbon footprint and then using those synthetic fuels in those really long-distance, hard-to-decarbonise sectors.

The general philosophy should be, if we have electricity, we should use it. If we cannot use it cost-effectively at the point at which we have the electricity, we should convert it into something we can move, and that is where hydrogen comes in. If we cannot use the hydrogen effectively, then we might choose to convert the hydrogen into something else that is easier to move, like ammonia or a liquid synthetic hydrocarbon. Each step in that chain loses us useful work and costs money, so we have a hierarchy.

The challenge is that you cannot always get the electricity cost-effectively and practically to where you need it, so that is why we are looking at other carriers like hydrogen.

Q18 Mr Robert Goodwill: Thanks. Just turning to industrial use, I know there was mention of using hydrogen as a heat source, but obviously in the metallurgical industries or in cement production we need a large amount of energy, and hydrogen is a reducing agent. I do not know who will be best qualified to answer that. Where could we see applications in steel production or cement production using hydrogen as an alternative to carbon-rich fuels?

Richard Halsey: Certainly, I think all those applications are potentially very high value and important applications for hydrogen use. In the



HOUSE OF COMMONS

German investment, one key area that it is looking at in particular is zero-carbon steel production and the potential role that hydrogen could play in that. Certainly, in terms of the system perspective, those areas are quite often some of the trickiest to think about your alternative options to decarbonising and potentially are very high value. Again, it seems like it could have a really good potential application in that context.

Q19 Mr Robert Goodwill: Would that be dependent on having high levels of carbon tax to incentivise that or just banning the use of certain fuels to enable that to be facilitated?

Richard Halsey: Yes. You would need a range of sticks and carrots to incentivise that fuel-switching, but also the challenge there is ensuring the competitiveness of things like steel production and how you ensure that zero-carbon steel has a value within the global market. There are a number of things that need to be thought about. That is coming back to that point about a strategy and road map. Those pieces are things that need to be thought about within that as to how you create the right incentives and the right market conditions to incentivise production of zero-carbon industrial outputs, but also in terms of applications for industrial processes.

Q20 Mr Robert Goodwill: Thank you. I think Angie wants to make a last point there, and then I had better hand back because I am conscious of time.

Dr Needle: Thank you. It was just to make the point that quite a lot of effort is going into developing industrial clusters from a decarbonisation point of view at the moment. There is HyNet in the north-west. There is the Humber cluster in the north-east. There is obviously the Scotland Acorn cluster as well. The whole purpose of those is to look at it as an entity in terms of how you can decarbonise a whole range of heavy industrial processes, including chemicals and steel. The HyNet one that Cadent is associated with is glass manufacture as well as chemical processing, and it includes hydrogen production, carbon capture and storage, and CO₂ capture of some of the industrial processes already.

I know it is part of Government commitment already to support the investment in those clusters, but they all need to happen. I think it is important that we consider what those clusters need to get off the ground, which would be the business models that support both production of hydrogen and carbon capture and storage, relatively quickly.

Mr Robert Goodwill: Thank you very much.

Q21 Chair: I know Amanda was just trying to get in on the transport issue. Without wanting to go back to competitive universities, I am aware that last month one of the other leading engineering universities got an aircraft to fly powered by a hydrogen fuel cell. I think it was arranged by ZeroAvia. There is a small company that started life in my constituency



HOUSE OF COMMONS

called Riversimple, which is making small commuter cars, and I think they are due to be on the roads by September.

Amanda, did you want to mention something on transport?

Amanda Lyne: Yes, there were a couple of things. You were talking about the energy density. Hydrogen is effectively 25 times more energy-dense than battery technology today. What that really means, and the reason why it is important when we think about HGVs and long distance, is that if you had 18 tonnes' worth of battery, you will get 45 kilometres in a truck, as opposed to 450 kilometres if you were including that with onboard-stored hydrogen energy. That is one of the reasons and the limitations.

We have to consider the wider environmental implications of battery technology as a ubiquitous energy store. If you use a proportion of the energy from hydrogen, then you are broadening the numbers of vehicles and technologies that can be decarbonised, as opposed to running out of scarce resources that are related to electrification and battery technology.

I would also make the point that the discussion for transport has only mentioned fuel cell electric vehicles. The heating scenarios are working on hydrogen combustion technologies. My own company is working on hydrogen combustion technologies here and now—cost-effective, cheap, accessible ways of us providing the equivalent of what consumers and users have with these vehicles today. There is no doubt that, in the future, as we need to be more efficient with using hydrogen that is going to be expensive to make, there are potential opportunities for other technologies that can use hydrogen more efficiently.

I would also point out that, in the heat sector, what is missing in some of the understanding of heat is that if you do combined heat and power in a smaller, micro scale—and fuel cell technology is superb for that—then we can improve the overall energy efficiency of buildings. That limitation on the fuel cells in heat is about making sure the hydrogen is available at the home.

Chair: Thank you, Amanda. We are just coming on to heat, so I will, if I may, let Duncan ask his questions, which you can elaborate on there.

Q22 **Duncan Baker:** This is a fascinating topic this morning, and it is very apt to start thinking about homes in terms of the Chancellor's statement yesterday. It is a topic that I am quite keen on, particularly when I think that 15% of all our greenhouse gas emissions come from our homes. If we are frank, we probably have not done enough about dealing with that situation so far.

It is quite flippant to say that one thing we need to do is start retrofitting our homes—our boilers—in potentially moving to hydrogen, without conceptualising in our heads just what an enormous task that is across the whole country. This is for Angela and Amanda. First of all, can you just explain to us what work would be needed to make the grid and



people's homes ready to use hydrogen, in conceptualising that this is not an easy task? I still think that the actual technology to be able to do it is very much in its infancy.

Dr Needle: Thanks for the question. The gas distribution companies working with BEIS and Ofgem through our innovation programmes have been looking quite closely on what aspects of the current gas distribution networks would need to be changed or updated in order to be able to take 100% hydrogen. The plastic mains that we have today—and there is a mains replacement programme going on as part of our obligation anyway to replace our metal mains with plastic mains—effectively make them ready to carry hydrogen. We are already doing that mains replacement programme, and consumers are already paying for that in their gas bills.

By 2032, that mains replacement programme will be complete, but there are a few stretches of main that are seen as less risky, so the mains replacement programme is based on safety at the moment. There is an opportunity for us to repurpose the mains replacement programme to make sure there is 100% hydrogen readiness in the distribution network.

There are other bits of work that are going on at the moment to make sure that other assets that are part of the distribution network are compatible with hydrogen. We have things like governors, which control pressures, valves and things like that that we are testing at the moment.

I think the current gas network can be repurposed for hydrogen. We are confident that, technically, that can be achieved. In comparison to the amount of infrastructure investment in electrification, it is seen as a sensible way of carrying energy, and it is something that consumers have already paid for. You are going to have to have investment in electrification because the electricity mains are going to have to be upgraded, and we are going to have to do some extra things to repurpose the current gas distribution network. If you are moving all the energy that we current provide in gas to electricity, that would cost a lot more to upgrade.

Then when you come into the home—let's say we can get hydrogen into the home—what needs upgrading in the home? Through the BEIS work already on the Hy4Heat programme, they have been working with boiler manufacturers. This is innovation in action. There is a piece of work going out that says, "What aspects of hydrogen in the home do we need to think about?" Worcester Bosch and Baxi have already gone, "We can make a hydrogen-ready boiler." The expectation at the moment is that if we know that hydrogen is feasible in people's homes and we know we can make sufficient hydrogen, there will be a transition over time. In terms of the natural recycle rate of condensing boilers, or the exchange rate, we currently upgrade at—1.6 million boilers a year are sold—if you imagine you can have a hydrogen-ready boiler that can work on methane today, up to a 20% blend of hydrogen and on 100% hydrogen when the



HOUSE OF COMMONS

conversion happens, that customer who is just buying a new boiler is going to buy a new boiler anyway.

Then, in the home, we have the other things that we still need to think about in terms of metering and making sure that a customer buys the energy that they need.

In terms of our analysis on converting homes to hydrogen versus electrification, this is not something I really like talking about, because it is not going to be “that versus that”, and there are going to be options. If you look at it that way, the whole infrastructure investment of full electrification versus maintaining some hydrogen in a balanced scenario is £13 billion a year difference, and that includes the investment in the property and the investment in the network. That is work that the ENA has done on behalf of the gas distribution companies.

Q23 Duncan Baker: That is very helpful. I am glad you are much more positive than I am, which is great. What you have just said is the key: if the technology is there so that you can replace infrastructure, but it can flip to hydrogen when necessary, that is the absolute key, isn't it? That is really good. You have touched on what was going to be my second question, which was particularly what the differential was in cost in terms of electrifying heat. With the Chair's permission, I will go on to the next question, because what you are saying there is that it is far, far cheaper to be bringing in hydrogen than electricity. That is really positive.

Dr Needle: Can I add to that? I think it is important because it is situational. If you have a property that has a G-rating in energy efficiency, or is a listed building or something, the improvement that you would need to make to make that available for a heat pump would be significant, whereas there are some properties that you could build now that do not need hydrogen, that should be electrification only. You have this spectrum in between.

What we are saying today is that there is not sufficient information across how decarbonisation of heat will happen for you to hedge your bets and just pick a winner. You are going to need both. You are probably going to need a hydrogen network because of the peaky energy demands. As the CCC reported last week—I was listening to a presentation where they were talking about wind drought—you need the resilience in the network so you always have a source of energy. That is quite important.

Q24 Duncan Baker: Yes. If I can bring Amanda in, have we started to make any kind of estimate of what the consumer preferences are in terms of hydrogen heating, and when will we start to think about having full-scale consumer trials on this? Is preference an option or is it just as simple as, “If you've got gas, you'll have to move down into hydrogen”? Will there be that consumer preference in the mix?

Amanda Lyne: The work that Angie referred to has started to look at consumers. The reality is that, right now, consumers are so far away



from understanding the experience that their homes will have to go through in the net zero, decarbonised world, that a lot of the data today, when you ask consumers, has to be predicated with, "If we can provide you this that is used for what you are doing, would you be okay with it?" The answer is yes, of course they would.

One of the important points on that is safety as well. Generally, people think that there will be a challenge to understanding hydrogen safety. In reality, all the BEIS and other sector work has effectively said that people will expect us to manage the technology safely. We need to have the standards and the regulations in place. What they want is their boiler to heat their home, and they do not want to have to dig up or redo all their plastering and take out the wet pipes and those kinds of areas. It is quite difficult, when we have done the work, for consumers to relate to that. Energy efficiency is a classic example. It can make sense that you should all have an energy-efficient home, but the disruption and the investment required needs us to have quite significant incentives for households to make the change. Ultimately, that is what we are learning.

The nearer you can make this particular phase to not requiring consumer change, the easier it will be for us to have people adopt these technologies. It is hard enough if we are trying to ask them to eat less meat or change their mode to walking and cycling. Let us give them an opportunity to see that we can solve some of this energy "easily".

Duncan Baker: Yes, you are right. Your comment about how we are so far away from people understanding those changes that are needed underpins a point I made at the beginning, which is that we probably have not done enough in our homes to contribute to starting to make these changes. It is a progression I would like to see come very quickly. Thank you very much.

Q25 Jerome Mayhew: I am interested in exploring further the technological developments that are necessary to harness hydrogen and their reliance on other technologies beyond the production process.

First of all to Mr Halsey, we know that 95% or so of current hydrogen use is from fossil fuels. We have talked a little bit about the potential of green hydrogen, but with blue hydrogen, we are reliant on the development of carbon capture and storage to make it a reality. We have had a hit-and-miss approach to carbon capture and storage. The development of it over the last decade or so has not lived up to Government expectations. How realistic do you think it really is that carbon capture and storage is going to develop at a sufficient pace and scale to make blue hydrogen a reality?

Richard Halsey: Thanks, Jerome. That is a good question. You are right in terms of the progress that has been made on carbon capture and storage. It certainly has not been at either the scale or the pace that many had either hoped or expected.



HOUSE OF COMMONS

It is important to recognise that there is stuff happening. Angie alluded earlier to things that are happening on the HyNet project and other projects, looking at demonstrating carbon capture and storage solutions. There is inherent uncertainty and risk there, which means that we cannot bet the farm on it. But given the challenges we face with net zero and the cost of producing hydrogen by alternative means, we need to develop it. We need to invest in R&D. We need to continue to support it and to retain it as an option. If we do not do that at this stage, we are closing down too early, and we have the imperative to continue to invest in that. We need significant investment. We need demonstration at scale, which we are starting to see happen, but it needs support and it needs momentum.

I mentioned earlier that one of the key things with carbon capture and storage in blue hydrogen production is that we need innovation to achieve those high carbon capture rates. If we do not achieve near enough 100% carbon capture rates, then, in terms of the contribution to a net zero energy system, it is difficult to see the role for blue hydrogen, other than transitioning and enabling. We need that R&D and that innovation in ensuring that carbon capture and storage solutions deliver that high level of capture as well. It might be something that Nigel has a comment on as well.

Q26 Jerome Mayhew: That is a good segue. Nigel, do you have a comment on that?

Professor Brandon: Thanks, Richard. Yes, there have been some interesting advances in the reforming technology. That is the technology that takes natural gas into hydrogen-rich gas. One of the leading technologies that is demonstrating approaching the sorts of capture rates that Richard is referring to is a UK-based technology. That is with a fairly major company. It is not in a small company. That is very exciting.

We know most of the things we need to do for CCS—at least, the principles, the underpinnings. It is an area where there has been innovation, particularly on new types of reforming technology. It is a question of getting on and doing some of that and demonstrating. As with any large-scale engineering programme, the devil is in the interfaces between different processes. It would be important to explore that.

Also, largely not linked into this issue but important is the issue of methane emissions in the supply chain. That is a little bit unnoticed. The sector is aware of it. There are a lot of initiatives to try to mitigate, measure and then manage. Angie may wish to comment because some of these emissions are in the distribution system that her company would manage. But this is something we also have to get to grips with this, so we should be looking at the whole supply chain for methane and natural gas.

Q27 Jerome Mayhew: With methane, given its relatively short half-life, how significant in the big scheme of things is a degree of methane leakage?



Professor Brandon: It can be significant. It has a high global warming potential, so its relative impact on climate change is impactful. There are some difficulties in telling you exactly what that is, in the sense that the short-term impact of methane is much greater than the long-term impact of methane because it does have a short half-life in the environment.

The current climate measures take a relatively long-term time horizon for methane, which gives it a 20-times forcing factor, but in the mid-term it can be much higher than that—80 or so. But you can say that it is higher. The rule of thumb is that if you have a 1% leakage of methane from its production to its end use, you are at a point where it is not having an environmental benefit.

The sector as a whole wants to get those emission rates right down, but we must not ignore that fact, which is associated with the additional burden of methane. We have to manage the CO₂ capture rates vigorously, and we have to manage the methane supply chain vigorously.

Q28 Jerome Mayhew: Quite a lot of the evidence that we have heard about the potential use for hydrogen has been about creating hydrogen clusters, where we bring a number of industries together to take advantage of local hydrogen production. What kind of industries do you have in mind that can be supported by co-location in hydrogen clusters? Is this something we can leave to the private sector to naturally sort itself out, or do you think there is a role for the Government here? Richard Halsey, perhaps you could have a go at that.

Richard Halsey: There is a wide range of industries, and there are a number of examples in the industrial clusters. Angie alluded to some of them and to the variety of different production and industrial processes.

On the important point there around whether industry will configure itself and figure itself out, that is highly unlikely, in my view. The industrial cluster strategy work is helping to bring together organisations and focus some of our efforts.

The important thing with the development of that activity around those industrial clusters is also thinking about how that fits in with wider local areas and how the initiatives around production, distribution and use connect with the wider infrastructure needs and wider distribution needs of hydrogen. Placing those activities within that context could provide an effective way of co-ordinating and planning the UK-wide infrastructure that is going to be needed for us to achieve a hydrogen economy. If we fail to do that, we will run the risk of a variety of investments not realising their potential or, equally, investing in the wrong things in the wrong places.

It is easy to say, "Let us have a co-ordinated, joined-up strategy, and let us ensure these roadmaps sit within a plan and within a strategy." Now, and certainly over the next five years, is the window of opportunity to really do that and help to identify and demonstrate those areas where



HOUSE OF COMMONS

hydrogen has the greatest value and those businesses that are seeing the most potential and can realise the opportunities both within the UK and globally.

- Q29 **Jerome Mayhew:** Thank you very much. Professor Brandon, I was interested to hear you describe the hierarchy of energies for transport starting with electricity and then moving down through hydrogen and derivatives from hydrogen as delivery became more difficult. We have also heard about the potential of hydrogen as energy storage and balancing on the grid. Can you expand a little bit on those two topics?

Professor Brandon: Yes. To be clear, that hierarchy applies to all applications. It is a generic comment. Also, in the context of using hydrogen in the industrial sector, again, if you need hydrogen as a feed stock into your process, particularly as we come to a world in which we are not deriving chemicals from fossil fuels, we are going to need stronger reducing agents to process biobased feed stocks. We are going to need a lot of hydrogen to do that. Regardless of its role as an energy carrier, we would want to use a low-carbon hydrogen if we are trying to make a low-carbon chemical from a bio feed stock. There are broader implications of that as well. I have forgotten your question now.

- Q30 **Jerome Mayhew:** It was about the potential use of hydrogen for energy storage and balancing the grid.

Professor Brandon: On energy storage and system balancing, I am sure Angie will want to comment as well, and Richard can also comment on this. If you look at future energy systems, they are characterised by the greater need for flexibility. The energy system we have today moves very large amounts of energy as natural gas and in fact has the largest flows through the UK energy system to date by far as natural gas. That has this strong seasonality aspect that Angie has mentioned, with massive demands in the winter months and much lower demands in the summer months. The flow of energy as electricity through the UK system today is relatively modest. It is the smallest in energy terms. Then, in the middle, is energy flows through the system as gasoline and diesel.

So if we choose to transition to a low-carbon system that is built around renewables with its intermittency and to some extent its seasonality and certainly diurnal cycles on solar and the risk of winter lows in energy from wind, we are going to think about how we balance supply and demand and we have to think about how we balance it across multiple timeframes from fractions of a second through to, potentially, weeks. There are a range of technologies and things we might think about. Batteries and battery-related technologies will have a role to play.

But if we want to store energy for several weeks to back up the UK system if we have a reliance on offshore wind and we get frequent lows in wind energy in February when the winds stop blowing, at the very time when we have our maximum energy demand in the UK because it is the winter season, we will have to have some strategic reserves of energy for



that. Do we do that with natural gas, which is what we would do today? Would we back that up with a fairly low-efficiency open-cycle fast-response gas plant? That is how we would do it today. But that does not address the carbon issue.

Can we also do it with large storage of hydrogen? The storage of hydrogen in underground caverns sounds like science fiction, but we do it today. It is a mature technology. We do it for a different reason: to provide strategic reserves of hydrogen for petrochemical facilities. The British Geological Survey has done quite a lot of work looking at the potential for underground hydrogen storage in the UK. It is significant. It is at the level at which you could deliver those long-term strategic energy stores. That is one type of role for hydrogen.

The other important opportunity is this segue between energy carried down pipes as gas and energy carried down cables as electricity. The ability to time-shift between those two forms of energy could give us huge amounts of flexibility in the system, which we could use to manage energy flows on this second-by-second, hour-by-hour basis. There is a huge value in that as we look out to the future. Perhaps Angie or Richard might want to comment, because these are very much system questions.

Q31 Jerome Mayhew: Dr Needle, over to you for your views.

Dr Needle: Thank you. Nigel has said it all. He is quite right on all fronts. I will add some numbers to that, which might help. Peak energy demand in this country today is only 50 GW. Peak gas at the moment is about 350, and it swings all the way up to that in the winter. We have this maximum flexibility and a system that is built for storage. The gas system and the gas pipes we have are designed for the one in 20 winters, the Beast from the East types of scenarios, where we really have to think about having a flexible system to make that happen.

We are in agreement that we need storage of hydrogen. We are working through the HyNet project, which is the North West Hydrogen Consortium, on where we might store hydrogen for that particular project. There are salt caverns where we can store hydrogen.

There is not much more to add. This is the way that we are thinking as a distribution company and how we do this. We were talking about innovation and technology innovation, but much more than technology innovation is needed. This system is going to be a new market. How is that going to work? How are the flows of energy going to work? How is it going to be regulated? What kinds of goals and outcomes are we going to be driving for? That is another place for innovation that is needed to start to think about the long-term system. At the moment, we are focused on the short term. Is it feasible? Is it safe? The next step is how the economics of that system work.

Q32 Jerome Mayhew: The technology that we have not really mentioned until now is nuclear. That has a potential role for balancing and for



stepping in when renewables are fluctuating. Do you see a role for small modular reactors in the balancing of the grid and also, in fact, in hydrogen production itself? If so, what support is necessary for this technology? I know Rolls-Royce has a scheme that they think is ready to go. I am opening this up to all of you. What do you think is the role of small modular reactors?

Richard Halsey: I am happy to start on that, Jerome. From our perspective, looking at the system role, nuclear does have potential value within the system in terms of addressing our—*(Inaudible)*—needs. Small modular reactors have potential in a number of areas, potentially feeding things like strategic district heating networks in the future. Not just in electricity production but also in hydrogen production there is the potential to have a role. It needs R&D and it needs investment to understand that, to develop that and to understand the credibility of the deployment of those solutions in the context of the net zero target and then how those things fit within the system. I would not see it as a silver bullet or a panacea solution to all our problems, but it certainly needs to be investigated, developed, demonstrated and considered as one of the options.

Q33 **Caroline Lucas:** I want to rewind a bit because I am still not quite clear about one issue, and that is the extent to which we face a strategic decision right now between blue hydrogen and green hydrogen. I am not clear whether blue hydrogen is a bridge or whether it risks being a distraction and giving out mixed messages to investors around not investing in green hydrogen. I would like to get that fundamental bit clearer in my mind before we go any further.

Dr Needle: If you do not mind, I would quite like to help with this. We have done quite a lot of work on blue and green hydrogen. From my perspective, to get to 2050, based on what we understand today is the amount of hydrogen that is needed, we need both blue and green. That is partly because green hydrogen schemes today are quite small-scale and latent technology. We really need to start putting the investment, the infrastructure and the support mechanisms in place to get that going.

In the meantime, though, and because we need carbon capture and storage anyway for industrial process and negative carbon schemes, we have an opportunity for industrial decarbonisation from blue hydrogen in the shorter term. That may end up being just for industry, and green hydrogen takes over, but my view is that we need both—we need a mechanism to support hydrogen production and we need the supporting CCUS business model as well.

Richard Halsey: To echo that, Caroline, I have a similar view. I do not see it as a binary decision. At this point in time, we need to retain and pursue both options. Coming back to that point about blue hydrogen production having to achieve those high carbon capture rates for it to be zero-carbon and ultimately to support a net zero energy system, we have to innovate and we have to consider that as an option, but we cannot



assume that. At this stage, we would not want to take it off the table, given the challenges we have in delivering a holistic net zero solution.

Amanda Lyne: I am not entirely clear which is competing for resources in the sense that, if we looked at the most consumer-demanded area in transport, we effectively are comparing renewable electricity for the future. The voice is largely that it is a bit of a compromise to look at blue hydrogen instead of green hydrogen because you are already potentially offering a lower efficiency solution.

However, price becomes a factor. A third of our CO₂ emissions are now in the transport sector. We have a solution at the moment that is for shorter-range and electric. There is lots of development work going on. If we focused resources to capture the low-hanging fruit between now and 2030 and tried to prevent CO₂ emissions in that period, it is much more accessible for us to do that with green hydrogen focused into an area that will provide that benefit.

In the meantime, the gas distribution network and the bigger-picture stories we have been talking about, and the industrial clusters, can clearly be making progress on engineering feed studies. How do we do it? They are complex. They require massive individual investment. But in the here and now, if we want to visibly see some progress in the hydrogen area, we really need to try hard.

Q34 **Caroline Lucas:** That was helpful. That timescale really matters. What we do in the next 10 years is important when talking about getting emissions down.

Professor Brandon: I have a quick addition. You can look at a world in which you have large amounts of offshore wind coming into parts of the country where it is probably quite difficult to accommodate all that with electricity directly. You might choose to integrate that with electrolysis to make green hydrogen, whether that is in the north, up in Scotland, or whether it is off the south-east corner. That green hydrogen could be distributed or could be used for transport purposes because electrolysed hydrogen is very high in purity. It is ideal for putting into a fuel cell and making a fuel cell bus or something move.

We could also see a world in which we have natural gas coming into some of our big industrial clusters on the coast next to CO₂ storage sites where we make perhaps a slightly less clean hydrogen through reforming and carbon capture. That does not matter if you are going to put it into a gas turbine or a hydrogen turbine or you are going to raise heat with it or put it in as feed stock into a petrochemical plant or a cement works.

This reinforces the point that others have made. There is value in both of those things. You have to be careful. As other people have said, we have to make certain that we have green hydrogen technology that is investable, that is at scale, that can be manufactured with a global supply chain, which are missing in some areas at the moment, and that has the



HOUSE OF COMMONS

right lifetime and the right characteristics so that it is a genuine option on the table.

We have to invest in that ahead of time so that it is ready. We are well-placed in the UK with some very exciting technologies and companies to invest in. We have to do the work on the blue hydrogen and we have to make certain that there is attention paid to the CO₂ capture rates, the methane emissions and all these good things we have talked about so that it is a relevant option in a zero-carbon world.

- Q35 Mr Shailesh Vara:** Could I turn your attention again to distribution and storage? Some of the issues have already been covered, but I want to narrow the focus. This is perhaps one for Dr Needle. Do you feel that there are any significant challenges in terms of storage and distribution that need to be addressed earnestly?

Dr Needle: The work we have done so far has been looking at whether our assets are hydrogen-compatible so that we can think carefully about, if we want to put 100% hydrogen through the network, whether all the assets will work as they do today.

We do not have hydrogen being produced at scale. We have done demonstration projects and pilots, and the next step, which we plan to deliver over the next few years, is to put 100% hydrogen into some pilot distribution networks so we can test what happens. The view based on the work we have done is that most of our assets are hydrogen-ready. From a technology point of view, there are not going to be significant issues with transporting hydrogen through the existing infrastructure.

There are some things we need consider, like the pressure that hydrogen needs to run at, how to step down the pressures as you go through the distribution network and how to ensure that consumers are metered for the energy they consume. From both a safety and quality perspective, we have not uncovered any showstoppers yet, although please bear in mind we have not finished the research programme. There is more to do. We are positive about the option for using the network should the Government decide that that is the right thing.

- Q36 Mr Shailesh Vara:** You mentioned hydrogen boilers. Are there any other advantages or advances in technology that the UK could be making use of that it is not at the moment? In terms of storage and distribution, is there any other way that we can be doing this that we are not at the moment? Professor Brandon mentioned underground and other sources, but is there anything we need to be looking at that at the moment that we are simply not?

Dr Needle: In terms of appliances in homes, the research programme Hy4Heat that has been running for some time has not just looked at boilers. It has looked at cookers and fires. It has looked at commercial boilers. There are also CHP engines. You can buy a hydrogen CHP engine today if you want to. From a technology point of view, on the things that



use natural gas today, the research is going on into whether they can be effectively converted into hydrogen. For some of them it is quite simple to change the burner and things like that.

We have done the work on whether the odorant is the same. You may not know that we put an odorant into the system so you can smell the natural gas. It is something we have to put into the network. That still works with hydrogen. We also know what colour flame it burns with and whether you can see it. We often get asked questions about what it looks like. People say that hydrogen burns with a clear flame and that is a safety issue. Hydrogen burns with an orange flame, and you can reconfigure your appliances so that you can see the flame. There is a lot of work going on.

It is key for me that this work has happened because the Government has asked for innovation in this space. If you put in place the strategy on hydrogen and you set some goals of what we want to achieve, there would be significantly faster paced innovation in this space. That is a bit about other uses of hydrogen.

In terms of distribution innovation, we have a full programme across the gas distribution side of things. There are not many gaps in that that we are not addressing. There are some extra things we are looking at in addition to that. One of those is whether we could use the distribution network to transport hydrogen for fuel cells. As soon as you put hydrogen at one end of the distribution network, it does not come out the other end quite as pure as it needs to be for use in a fuel cell—I will pass over to Nigel in a moment—because we put odorant and things in there.

I would like innovation in technology to clean hydrogen from a distribution network so that we can therefore send it to wherever it needs to go in the country using the existing infrastructure rather than inventing another way of transporting hydrogen.

Q37 Mr Shailesh Vara: Nigel, do you want to follow up, and then Richard as well?

Professor Brandon: On the specifics on innovation, to be transparent, one of the companies I helped set up some years ago developed a technology in this space. That is a fuel cell integrated combined heat and power system.

Like any technology, when we are comparing burning a fuel to putting it through a fuel cell, we get a higher-efficiency product at the back end. For a fuel cell CHP system fed on hydrogen, for example, the purity point is important. It depends on the type of fuel cell technology. There are technologies you can put in that are agonistic to those contaminants. You generate electricity in the home as well, so you are then independent of power cuts and you are capturing the heat from generating that electricity. That gives you a high-efficiency home heat and power system.



The technology I am referring to, which is a UK technology, has just gone into the first product. It is available in Japan. If you look at where the world is leading on this technology's implementation, you would look to Asia and to Japan in particular. Something like 350,000 Japanese consumers have now purchased with their own money—subsidised to some extent by Government grants, but they have still spent their own money—this technology to heat and power their homes. That does not run on hydrogen. It runs on LPG because we do not have a hydrogen distribution system yet, but it would run even better on hydrogen if it had to. That is an innovative technology. Today it is still an expensive choice for a consumer to make, so you have to have a commitment to it. But the technology costs will come down if we build the new supply chain. That is a UK technology that is currently world-leading in that space.

Richard Halsey: I want to make one other point, particularly around the issue of heating at home. There is the opportunity from our net zero ambition and our decarbonisation goals not just to maintain the experiences and the standards people have today but to deliver better heating and comfort experiences for people at home.

There are lots of great UK-based companies that are doing innovative things around digital control, flexibility solutions and advances in thermal storage technologies in homes and on a larger scale. Those innovations potentially have the ability to better manage supply and demand of heating at home and influence then the volumes of electricity or hydrogen that you might need. There is a huge raft of great companies such as Sunamp looking at phase change materials; Octopus and OVO looking at different control solutions and dynamic pricing arrangements; and Passive Systems looking at more advanced hybrid control systems. Those innovations are potentially as important and as critical to delivering particularly decarbonisation of heat.

Q38 **Mr Shailesh Vara:** Thank you. Finally—and this is for anyone here—what is the relevance of the accurate measurement of hydrogen flow for all its uses? How can this most effectively be achieved?

Dr Needle: I have a couple of things on this. It is a very specific question.

On metering, if you are blending hydrogen into networks—we have done this at Keele University—you would meter the hydrogen at the point of entry. There are devices today that can measure gases, so we can measure hydrogen and we can measure the quantity of it in a gas. We would encourage blending into a network up to 20% because we know that is possible and you could decarbonise your heat use today by doing that. It is important that the consumer pays for only the energy they use, but at the point of entry of hydrogen into that network you can take measurements of the blend of hydrogen and natural gas. You can apply a conversion factor to the meter in the property, which is a volume meter. It is a calculation of the calorific value of the energy that is going in. We think that is feasible, and we are doing a piece of work on metering and



HOUSE OF COMMONS

blends of gases. Also, we blend biomethane today into the current gas network, which is produced from anaerobic digestion plants, so we are used to dealing with more than one type of gas coming into different properties.

Then, in terms of metering of 100% hydrogen at the point of a person's home, which I think you are referring to, the current gas meters would need to be replaced with ones that work for hydrogen. The BEIS project on Hy4Heat currently has a tender out to do further work and research on that.

Q39 Chair: On that, this is a rather specific point, but as part of a Government hydrogen strategy, does work need to be done to invest in metering technology? Is that something the Government should be investing in?

Dr Needle: Yes. They are already. It is important that we have the right kinds and flexibility of metering and that we have a way of deploying that in a cost-effective way. Both of those things are going to need investigating.

Q40 Barry Gardiner: On that last question, I was speaking earlier in the week to somebody who is doing the flows and metering exercise and currently doing one of the projects for BEIS. There is a bid in for a project, but we are far from having that proper calculation of flow, which is going to be so vital. This is about price. This is about cost. Unless you have within the 0.5% that we are looking at with our petrol pumps, then there is a lot of money at stake here eventually. It is important as part of the overall strategy.

Welcome to the panel and thank you for a fascinating session so far. My questions are going focus on Government support or, depending on what you say, perhaps the lack of it. If I could start with Dr Needle, Cadent leads on the HyNet project that the Government have invested £7.5 million in. How effective is the overall investment, not just with HyNet but other projects like Gigastack and HyDeploy, which I think you also lead? How are they managing to move the sector forward to being a key part of the low-carbon economy we want to see?

Dr Needle: To be clear, HyNet is a consortium project and our role in it is about the potential building of the country's first hydrogen pipeline that will bring hydrogen from the production to nearby industrial users and an option to blend into the distribution network for Liverpool and Manchester. It is quite an important programme. The consortium consists of large organisations that want to decarbonise industry and the CCUS Liverpool Bay gas field, as well as Progressive Energy, which is the consortium lead for pulling us all together and doing the engineering design work. It is an important project.

In terms of its progress, though, we have had Government grant funding and match funding to do the feed studies and the first phases of each piece of work. There is the design of the methane reformation plant.



There is the design of the CO₂ pipeline and carbon capture and storage. There is the design of the hydrogen pipeline. There is the fuel switching that each of the industrial players will need to do. Quite a lot of effort has been done to date.

My ask of the Government, if I am honest, is that we cannot continue doing projects of this scale on grant funding. You get to a point when you need a business model that underpins the investment that we need to make. When we get to the feed study and final investment decision, which is not that far away in terms of years, we need a business model that investors can invest in. At the moment, they are not going to invest in a grant-funded feasibility study. It needs a business model that underpins it for carbon capture and storage, hydrogen production and a RAB-based model for the hydrogen pipeline. If that was in place, these things would move significantly quicker.

Q41 Barry Gardiner: You are going ahead of me. Thank you. You are making my life easier—perhaps more jumbled, but much easier, because you are giving voluntarily the things I thought I might have to pull out of you.

If I could press Dr Needle, how effective has the investment in these projects been? You have set out the forward vision, but looking at the effectiveness not just of HyNet, and HyDeploy as well, but the other projects—Gigastack and the others—how effective has that investment been, in your opinion?

Dr Needle: If you consider the amount of CO₂ that is at stake with these projects, which drives me personally, these projects are incredibly effective in terms of the amount of money we are investing to make that carbon abatement. If you can get all the industrial clusters running, you have a massive amount of CO₂ being sucked out of our carbon budget. In terms of investment versus carbon abatement opportunity, it has been incredibly effective.

We are still not doing it yet, which is the point I keep making, but these projects have to happen. If they do not happen now, they will probably happen later, but it will make it much harder.

Amanda Lyne: I want to contrast with transport. I know the Committee is looking at production and distribution, but the fact is we need an end use. In transport, the investment in hydrogen solutions probably does not even appear on the scale. Mostly it has been short competitive schemes and a miniscule proportion of what we need to do to help the transport sector change.

It has had an element of passenger car support. There has been almost nothing looking at what we could do with HGVs. We have a couple of small projects being done on the rail opportunity. There is nothing in marine yet that has been specifically targeted.

We need the upfront, proper, collaborative projects that Dr Needle has described that we have done in some of the heat areas for transport and



across transport, but we also need the business model. The renewable transport fuel obligation was changed about 18 months ago to allow for some hydrogen support, but because it does not reflect the long-term investment in hydrogen, it needs changing to really provide a useful tool. The quantum that it is doing possibly would be effective, and the reality is that we have investors and companies ready to go, but they need the business model that Dr Needle has described in transport as well.

There is a whole stream of anomalies in different Treasury parameters. Really, if we have an overarching view that we want to make hydrogen work in transport, the consumer or user needs to be able to understand that and we want the investment. You would review the whole lot and make sure that it was aligned to supporting and allowing people to use hydrogen fuel in vehicles, ships or whatever.

Q42 Barry Gardiner: Great. From the two of you, I gather that the project investment that has taken place so far is being used effectively, but perhaps there are not enough projects with enough diversity in them and it needs to be carried forward in an overall strategy.

If I could turn to Richard Halsey next, you said to the Chair earlier in the session that we need huge volumes of hydrogen, but all our projects are at this trial phase, aren't they? How quickly can we move beyond the trial phase? Can you give us an estimate of how much investment you think might be required and where best it might be focused? On a scale of one to 10, tell us where you think the UK currently lies on the journey towards hydrogen playing its full role in the net zero economy that you were discussing with the Chair earlier.

Richard Halsey: Echoing the points that were made earlier, it is fair to say that the scale feels insufficient at this stage. We all seem to be collectively agreeing that. It is important how we recognise our investment in the context of a global hydrogen economy and that we certainly do not invest in areas when we are able to get learning from other places or are not able to get an advantage or unlock the economic benefits for ourselves. We have to position ourselves in that wider global context.

As Nigel alluded to earlier, some of these technologies are there, particularly around green hydrogen production, but they do need demonstration at scale. Some of the barriers to that are fundamentally the business model and the scale of investment you need. Some of that does need public stimulus and public support, but there is a willingness from industry to come forward and participate, a bit like Angie said, in some of the projects that Cadent and others are involved with—to participate in those consortia. It is important, though, that those investments create that runway to a business model and to a market and that that is seen from the outset.

With the volumes of investment, it is difficult to put a number on it. Others might have a view. In Germany, a £9 billion figure was suggested.



HOUSE OF COMMONS

In terms of the volume and scale, we certainly need to be talking billions, not tens or hundreds of millions, if we are going to take a significant leading role and in the context of the net zero challenge.

The real point for me is what you alluded to about how those investments need to form part of a clear end-to-end vision and roadmap so that we can understand how the investments we are making now fit together, what the gaps are, where the investments we are making for the future can be prioritised, and the areas that we are better letting other economies and other areas lead and drive forward. There are areas of opportunity that we really want to exploit and go after in the near term.

Around timelines, we need to get going on some of this stuff pretty quickly. The 2050 goal scares the hell out of me. It is fantastic and brilliant that we as a country have made that commitment and that ambition. I see local authorities making even more ambitious commitments in terms of timescales and declaring climate emergencies. How we are going to get there scares the hell out of me. It feels like we are behind in the race already. It is in the near term that we need to start making some of these investments.

Q43 **Barry Gardiner:** Richard, we are politicians. We like long-term targets. They allow us to have elections without having to meet them.

Richard Halsey: I understand that.

Q44 **Barry Gardiner:** Amanda wanted to come in, but please continue a moment, and then I will bring Amanda back in.

Richard Halsey: Nigel spoke a bit earlier about how the net zero commitment has changed the game in terms of the areas that you have room to manoeuvre on emissions. With things like blue hydrogen and carbon capture rates, you could probably get away with lower levels of capture rates in areas of innovation, but now you really do need to go hell for leather on quite a lot of things.

Q45 **Barry Gardiner:** On that scale from one to 10 of progression towards the full-blown comprehensive engagement that we want to have by 2050 for hydrogen, 10 being the ultimate goal and starting off at one, where are we?

Richard Halsey: I would say we are at four and a half.

Q46 **Barry Gardiner:** Thank you. Amanda, you wanted to come in?

Amanda Lyne: Yes. I wanted to illustrate that we have quantified what sort of investment we think would be doable in transport. It is £500 million over the next 10 years. We could make substantial inroads into the CO₂ emissions from the sector and help build the infrastructure. That would all be match funded. The reality is that our sector is comfortable with match funding in that process.

Q47 **Barry Gardiner:** Yes, the private finance really is there to come in



HOUSE OF COMMONS

behind you. Excellent. Thank you.

Professor Brandon, your Hydrogen Fuel Cell Association has told us that the Government's approach is "fragmented and short-term". That does not sound like a world-beater. How can we make sure that the UK becomes one of the leaders, not one of the laggards, in this hydrogen technology? Where should we focus our money and our energies? You mentioned that interesting heat and power project in Japan. Where do we need to be pushing to get a global lead here that would enable us to be exporting technologies around the world and be a real global leader?

Professor Brandon: The first thing to say—and it is nice to say this—is that we do have some globally leading players in the UK delivering products, components and services into this sector. That is a great place, and we cannot always say that. Those companies and organisations have been working hard for quite a long time, in many cases when hydrogen as a topic has not been particularly fashionable. They have worked hard through quite difficult times.

Now we are seeing for some of those companies—many of which are SMEs, but not all; some of them are larger organisations—international that investment is coming in. Large organisations with deep balance sheets not in the UK are now taking significant shares in those businesses. That is great. It is bringing value into the UK. But you can see the direction of travel there. If we do not have a home market and a place where these companies can develop themselves here in the UK, they will eventually go offshore and will disappear from us.

We are in a great place. We have done innovation and we will continue to innovate. Of course innovation will continuously be needed, but it is not that we need that innovation to make a start. Just to get that point, we have some excellent technologies and some excellent companies. We are in a great place.

If we were to do demonstration programmes of the scale that all my colleagues have advocated and that I would support as well, we do have UK participants who could play an important role in those demonstration programmes. That is great.

I am an academic. I work at a university. Of course I would say it, but there is a need for continued innovation going forward. We have had the gas turbine for a long time, but that does not mean we cannot innovate it. We continue to need innovation in all these technologies. That matters because if we are looking at electrolyzers, as an example, for green hydrogen, the cost of the hydrogen that that electrolyser will produce will be dependent of course on the cost of the electricity, which is going to come through innovations in offshore wind and scale. It is also going to be dependent on the efficiency of the electrolyser, which we can continue to improve through research on materials, designs and so on. That is an important route to note.



Universities have a role to play, but are not the only part of this, in skills and people. When I talk to companies in the space—you have folk here who can comment from their perspective—at a university level we are not training that many specialists in this sector, because academic funding in this area has rather declined. While it is great to see that investment in the industrial space has grown, the academic space has been going the other way. Part of our remit is to provide those skills. Of course, other academic sectors—higher education and so on—have a very important role to play in providing skills at all levels, not just at the university level but at the technical skills level as well. Provision of people into this sector, if we are going to see the rate of growth that we hope and feel we need, is vital, too.

Q48 Barry Gardiner: Thank you. If we were talking about where to focus investment, you would be talking about, one, pure research and, two, skills development. At a central level within the industry, where would you suggest?

Professor Brandon: Sure. I lead the hydrogen and fuel cell Supergen hub, which is the Research Council investment in this area. We have been running for a number of years now. As a community, we have been advocating that we should try to have a national hydrogen research institute. In the same way that we have talked about the integrated nature of this energy carrier in terms of its applications, we also need an integrated research programme, and that integration needs to cut across the different topic areas, whether it is how hydrogen diffuses inside steel, which influences its long-term stability for a high-pressure pipeline, or some of the new process modelling simulation tools that we might need for industry.

It also needs to integrate along the innovation chain. Part of that innovation chain is university research. We need the university research integrated and feeding into these demonstration programmes, and the outcomes of these demonstration programmes feeding back into the research questions.

Ultimately, of course, we need a partnership with industry. We need a strategy that brings together the university work and the national labs. The National Physical Lab, for example, is doing a lot of good work in this space. The Health and Safety Lab, again, does important work in this space. The big facilities at Harwell are doing important work in this space. It is a combination of all those national capabilities being focused together.

I draw a parallel, to some extent, with what is happening with Covid-19 at the moment. I hate to say it, but when you look at what has happened around funding for research on Covid-19, it is fantastic in the sense that it has been deployed at speed, at scale and in partnership. We could do with that momentum in some of the other areas we are trying to address, including this one.



HOUSE OF COMMONS

- Q49 **Barry Gardiner:** Finally, Amanda Lyne, earlier Dr Needle told us that we might have to wait until 2040 to get green hydrogen at the sort of price that gas is coming in at today. You rightly went on to say that we need to be getting on with producing green hydrogen now to bring the cost curve down.

You have touched on this in the response to my colleague Caroline Lucas, but do you see any signs that the Government understands the need to do this to drive the cost curve down and to get that green hydrogen flow going? As Professor Brandon was saying, we still do not have a full-blown hydrogen strategy. What are the signs from the Government that the green hydrogen agenda is underway and is going to get that cost curve down?

Amanda Lyne: That is a good question. From our experience, it is fragmented, again.

- Q50 **Barry Gardiner:** But not in the short term this time, like Nigel said? Fragmented in the long haul or just fragmented?

Amanda Lyne: The belief that green hydrogen is more expensive than blue hydrogen is a fairly ingrained assumption. It has certainly existed—also the challenge of doing green hydrogen at scale to enable it is fairly ingrained—and that will disable it and will make it hard.

There is a light brewing. Because of international studies, the Hydrogen Council, European hydrogen groupings and other countries are standing by and verbalising the expectation of electricity-generated hydrogen being competitive much sooner than you have described. If we could listen to those, with the chestnut of some sort of interest that believes that, maybe, that could be possible, then we should build on that. That is one of the reasons we firmly believe there should be a specific target for the amount of green hydrogen that we have supported into the system by 2030. For the green hydrogen part of the story, we have production, capability, and globally recognised areas. We have the world's largest gigawatt factory for electrolysis. We believe that there has so far been insufficient belief that we could get there, and other countries are making that progress faster.

- Q51 **Barry Gardiner:** Amanda, if I may paraphrase, just so that I am clear on what you are saying, you think we should be more optimistic, more ambitious, and set a target for green hydrogen for 2030, in order to encourage the co-investment that will inevitably come into this area from the private sector if we, as Government, are ambitious in setting out our goals? Is that a clear paraphrase?

Amanda Lyne: Yes. A lot of the noise in investment most recently, which has been really pleasing, is to recognise that we can do hydrogen at scale, full stop, and that hydrogen should be part of the system into 2030, as we started with. The reality is to do good hydrogen and really make that happen.



Chair: Thank you, Amanda. Thank you, Barry. I am afraid we have hit 11.30 am and we still have two more sets of questions. So, let us move along quickly now to Nadia Whittome. If we can have quite pithy answers, I would appreciate it.

Q52 **Nadia Whittome:** The Committee on Climate Change noted that there was no hydrogen or industry strategy in the Government's June 2020 progress report to Parliament. In light of that, how co-ordinated do you think the Government's approach to policy and regulatory development of hydrogen is?

Amanda Lyne: We have been campaigning for a whole-spectrum energy approach across Government to understand the role that hydrogen has as an energy vector, and all the other benefits, for many years. We feel the most recent verbalisation of our request for hydrogen strategy now is it is well overdue. In fact, we are too late, almost, because the EU have already done theirs, and other countries have done theirs. I think it has not existed and is desperately overdue.

Dr Needle: May I add to that as well, please? You can see from this conversation that when you look at things in isolation, you miss some opportunities to make them more efficient—if you look at hydrogen just for transport, if you look at it just for heat, if you look at it just for power or just for industry. There is an opportunity to bring these things together. Government has done well to move its perspective from, "We do not need it," to, "Actually, we really do need it." The next step now is, how do we join these things up in an efficient way? There is definitely more to do, and I know there is progress being made, but joining up the themes from the different sectors that can use hydrogen would be really important, from an efficiency perspective.

Q53 **Nadia Whittome:** Nigel and Richard, did you have anything to add?

Richard Halsey: Yes, I was going to say, building on that, that it is really important that we see hydrogen in the context of that whole-energy system. Government needs to think about the challenges that we are facing around mobility, around heating, and around power. They are the challenges that need to be thought about, and then the solutions that fit within that context and how it fits together is really important, but it cannot be seen as individual componentry. Like Angie said, there have been signs of progress in thinking in that way and in wanting to be able to think that way. It is very easy to say, "Let us have a joined-up strategy and let us work effectively," but it is obviously much more challenging to implement it and do it on the ground. There are those positive signals, but there is a real, pressing need to make more progress on that and to inform where we go with a number of these different things.

Professor Brandon: Very briefly from me, it has been stated that BEIS have made great strides in building their hydrogen capacity within the team, and that is to be acknowledged and recognised, but hydrogen,



because of its nature, falls between a range of different Government Departments and that cross-departmental focus is very important. Technologically, I cite the example of investment in batteries that has been made through the Faraday Institution and that cross-industry, cross-academic investment would be great to see in this space as well.

Q54 Nadia Whittome: Thanks all. A question for Angie and Amanda. You have already touched on this. We have had many, many calls for the Government to develop a hydrogen strategy from Energy UK, from the Hydrogen Strategy Now campaign, which is supported by 40 businesses and trade groups, and then from stakeholders from Bosch to UNISON. What, in your view, would this need to include to develop the industry at the pace that is required?

Amanda Lyne: That is a very good question. I think we have illustrated already a number of things. There needs to be a very clear verbalisation of where we will get to in the vision; a short-term target breakdown; programme-related investment that covers everything from the R&D innovation that is required to the business models that will be developed; a strategic approach to ensuring that we have all the detailed issues about regulations; standards being co-ordinated so that when we are ready to go we can go; and leadership. What is very important in this is a leadership role that makes sure that that can cross all of the departmental challenges. In that way, we will make sure that we make the investment go into the right places, make the investment as valuable as we want it to be, make sure that we do the skills elements that we need, and make sure the air quality and the aspects of all parts of what we are talking about are provided as a solution in terms of all the different users that are going to use hydrogen.

Dr Needle: If I could add to that, there are other people's hydrogen strategies now. It is not like we have a blank sheet of paper. There are lots of things that you will have seen, with people writing to you on the things that we want to see in that strategy. As you have quite rightly said, Amanda, we need a goal. We need something to be aiming for. Personally, I would like us to have some kind of consumer advocacy in this. We need to frame this as what this means for normal people, people who have to pay their energy bills, drive their cars, and buy products that have to be decarbonised. Making this both a sector-specific, innovative, and investor-worthy programme, as well as translating that into something that near-term makes a difference to the carbon economy and the hydrogen economy, is really important as well. That means jobs and skills as well.

Chair: Thank you, Nadia. I think you are calling for a people's plan for hydrogen. Caroline Lucas.

Q55 Caroline Lucas: Thank you very much. You were just beginning to touch on my next question. I might just roll the two questions together, because I am mindful of time. The first question was, what can we learn from other countries' hydrogen strategies? Are there any good examples



HOUSE OF COMMONS

you would want to point to—best practice in other countries that we could learn from? Secondly, what could the sector achieve if there was a sector deal for hydrogen, along the lines, for example, of the one that has been successful with offshore wind? Who would like to kick off on either or both of those?

Amanda Lyne: To answer the second question, we have made it clear that we will invest alongside the industry—the whole variety, whether that is the renewable-sector or investors. There is a latent wish to invest alongside it all. That is the biggest thing. Obviously if we put some decent targets into it and some decent focus, we can start to deliver some CO₂ emission reductions in the shorter term, not just in the longer term as well. Those two things are the latter part of what we want to do with it.

In terms of other countries, it was only yesterday that the EU announced their hydrogen strategy. I have not had a chance to fully review it and decide whether I think it was a great one or not, but it does exist. China has, in their inimitable fashion, had commitments to hydrogen investments and programmes in a whole variety of ways for a long time. Japan have had an absolute understanding of the role that they want for hydrogen for a long time. If you look at California, you will see how California views the role of hydrogen in its process, and they have been doing it for a long time as well. Germany announced their hydrogen strategy a week ago, so that they had it before the EU's hydrogen strategy. There is plenty out there that, in our inimitable fashion, we can shape to be specific to what we need in the UK. I do believe the BEIS Hydrogen Economy team also have quite a good grip on what they would like to see, and they just need to make sure that that is prioritised politically alongside it, I guess.

Dr Needle: Thanks, Caroline. I would just add one extra thing. Amanda is right on all fronts when it comes to what is happening globally. I would just say that in this ecosystem there are monopolies like Cadent. We have rules that we have to obey at this point in time when it comes to what we can and cannot do. It is really important because of that that we look at the system and the way it is regulated alongside this strategy. What do we want to achieve, how is it going to work, and how do we as companies work with regulators like Ofgem to get the best outcome? There are lots of different ways of going about doing this and making this happen.

Richard Halsey: Building on that point, I think there is a real need to think quite holistically about how these things fit together and how the regulated, monopoly infrastructure investments relate to the downstream investments that are made by us all in our homes and buildings. That really needs support to enable that more effective planning and co-ordination to happen, and see hydrogen in the context that we all alluded to earlier, with the challenges of different places wanting to run and deliver net zero ambitions. Underneath that, there really is an absence of credible steps and a plan for how we are going to get there. It is really



important that that comes together and that a wider hydrogen strategy for the entire economy is able to connect to that, inform that, and be part of that, and also that any strategy is in that context of achieving net zero and our ambition for doing that.

The German strategy is a good example. Like Amanda, I have not had a chance yet to read the EU one, but I am sure it has some really helpful pointers and things that we can start to think about. For me, the important thing is making sure that we do not see this in isolation, that it is part of a net zero strategy, that it is one of the important building blocks and pillars, and also that we recognise the importance of connecting with places. Angie made a really good point that people have to come with and want a net zero future. I recognise the challenges of cost, and the challenges we face in a number of things in our lives, but I also personally would like to think that a net zero future is a brilliant future for us—is better, is more desirable, and gives us better mobility and better utility. Our strategies should have that in mind, rather than compromises at this point in time, because that option is there to be realised.

Q56 Caroline Lucas: Music to my ears. Thank you very much. Nigel, did you want to add anything?

Professor Brandon: No. I think my colleagues have made very good points. I agree with all of them. Just to bring in the point I made earlier, the UK is well blessed with a strong academic base and some fantastic companies. I would like to make certain that we are working together and ensuring that that is looked at holistically. There is a little bit of a temptation to keep universities over there with their Research Council strategy and industry over here with its BEIS strategy. We need an integrated piece that builds right across that.

Chair: Thank you, Caroline. Now the last set of questions. We have been very positive in looking for the upside. There are some potential risks associated, and Ian Levy is going to touch of some of those.

Q57 Ian Levy: Thank you, Chair. I am very conscious of time restraints, so I am going to join my two questions together, if you do not mind. Whatever fuel we use, there are obviously relevant risks involved. As Dr Needle said earlier on, hydrogen runs at pressure, you have an orange flame, and there is an odorant smell that is added to hydrogen so people realise it is there. First, I would like to ask what assessment there is of the risks associated with hydrogen technology. Also, we have to make sure that people feel safe to use hydrogen in their cars, in their homes and when they are at work. What additional work is there to be carried out to make sure that people feel safe to use hydrogen? I will open that to the panel, so whoever wants to can go first.

Dr Needle: I will go first, if that is okay. Gas distribution companies are safety organisations, because we already transport a combustible gas through the network. It is not only our engineers; the way we do our



work today is very much with safety in mind for both our consumers and ourselves. A good example is the piece of work that we have just done at Keele University on blending hydrogen into that gas distribution network. In order to do that specific piece of work, we had to get an exemption from the Gas (Safety and Management) Regulations, which currently say you cannot put any hydrogen in the gas network. We are working very, very closely with the HSE, who basically say whether we can or cannot do this. Ultimately, they have the power. We are doing a lot of work on the safety aspects of hydrogen, because it is absolutely paramount.

There is a difference, I think, between what is safe and what we all feel is safe, versus people's perception of it. One is about education and involvement from consumers, and trials, pilots and demonstrations, and one is about the actual rigour of the science of safety. There is lots of work going on with the safety aspects of hydrogen, and the BEIS programme that I have referred to a few times, the Hy4Heat programme, has looked in quite a lot of detail at the aspects of hydrogen from a safety perspective. If you knock a nail into your gas pipe and hydrogen leaks, how does that accumulate in the home, how does it disperse, how does it ignite, and what kind of safety devices might you have? One of the benefits is that there are no carbon monoxide emissions, so there is an upside of having hydrogen. The other positive is that it is a light gas, so it disperses much quicker than methane does. It may be, when we have finished our safety assessments, which are still ongoing, that hydrogen might be seen as a safer combustible gas than methane.

Q58 Ian Levy: Yes. Amanda, do you want to come in?

Amanda Lyne: Yes. I would echo that. We have real-world experience. We have vehicles being driven, filled up by bin men, or doing deliveries, and going around the street, and the actual drivers of the vehicles are comfortable with it as a process. They are comfortable with that. I heard a great anecdote about hydrogen hobs: you would be able to put your hand much closer to a hydrogen hob than you would any other hob, because there is no conducted heat. In our case, in transport, we designed the system to benefit from the fact that hydrogen is a very light gas and disperses quickly, which means you do not have accumulation of the gas in a low level if it is leaking. There are all sorts of other benefits that you can get because it has a different risk. It is very important to understand that hydrogen has a different risk profile than combustible fuels that we are used to or the energy systems we are using now. In our experience, to get people to use hydrogen in vehicles there is an assumption, a belief, and a confidence that the systems are safe.

Q59 Ian Levy: Thank you. Professor Brandon, did you want to come in on that?

Professor Brandon: Yes. Just to add that underpinning all of this is the understanding of the science and the engineering, and its impacts on the codes and standards. There is quite a lot of work going on globally, and particularly in the EU, which the UK participates actively in, in developing



HOUSE OF COMMONS

the tools, codes and standards that you need to be able to design and operate safely. It is being led by the transport side, because of course carrying relatively high-pressure hydrogen in a vehicle brings forward the need to look at this very carefully, understanding what happens if hydrogen is emitted in a tunnel, and all of these things. These are very active programmes. I want to reinforce that there is a good science base on that, and also the health and safety labs are very active. It is an area where we do have very good collaboration between the university sector, health and safety, and industry. We all recognise the need. To reinforce Amanda's point, all fuels have hazard. You need to work on the specifics of that hazard and mitigate that risk.

Ian Levy: You are absolutely right. All fuels do carry that hazard with them. As Dr Needle said, a lot of this is about education as well, and once people feel more comfortable using hydrogen, they will feel that it is a fuel they can use. Thank you. Back to you, Chair. Thank you very much.

Q60 **Chair:** Thank you, Ian. Just on that last point, in terms of awakening public interest in this, is there anything that you can say in relation to the combustibility of hydrogen compared with kerosene or diesel?

Amanda Lyne: In what sense?

Q61 **Chair:** In the sense that it might be used in practical lives. If we are refuelling vehicles from a pump on a garage forecourt, everybody knows the risk associated with diesel in liquid form. If we are refuelling vehicles from a forecourt with a hydrogen pump, is that more or less risky?

Amanda Lyne: Echoing the previous question, there is a hydrogen station off the M40 already integrated alongside other fuels. The HSE process, the risk management process, is designed for the fact that we know a consumer will be there and to mitigate what risks we see in that process behind it. In my case again, doing the ferry over in Orkney has involved detailed work with all the safety folk involved to make sure that the system is designed in the first place understanding that consumers will be likely to be involved or interacting around the system. I do not think hydrogen has any specific differences that need a change from our existing process, if you like.

Q62 **Chair:** Thank you. Nigel wanted to come in.

Professor Brandon: Yes. As others have pointed out, hydrogen disperses very readily, because it is lighter than air. Its transportation characteristics, away from a leak, are very different. Outside, it probably has less hazard than petrol. Petrol forms a pool on the floor and the vapour builds up over that, and then it is the vapour that will ignite. In a hydrogen case, hydrogen is characterised by having a wide explosive range, so it will explode over quite a wide range of concentrations but because it is lighter than air, outside it disperses very readily. The difference to that hazard is if you are indoors. Because it is lighter than air it pools in roof voids, and then you need to ensure you have a



HOUSE OF COMMONS

ventilated roof void, for example. We understand the risks, and you have to manage them differently.

Chair: Thank you very much indeed. This has been, as others have said, an utterly fascinating session. We have all learned a lot, and I think we will be making recommendations to the Government to get this hydrogen strategy out of the backwaters and on to the front page as soon as possible. Thank you to each of our witnesses, Nigel Brandon, Amanda Lyne, Richard Halsey and Angie Needle. Thank you to the Committee members for an excellent session, and to our Clerks, in particular Medha Bhasin, who prepared the brief for this session.