Science and Technology Committee

Oral evidence: The role of Hydrogen in achieving net zero

Wednesday 24 March 2021

Ordered by the House of Commons to be published on 24 March 2021.

Watch the meeting

Members present: Greg Clark (Chair); Aaron Bell; Dawn Butler; Chris Clarkson; Mark Logan; Rebecca Long Bailey; Carol Monaghan; Graham Stringer.

Philip Dunne, Chair, Environmental Audit Committee, attended the Committee.

Alan Brown and Paul Howell, Business, Energy and Industrial Strategy Select Committee, attended the Committee.

Questions 73 - 136

Witnesses

I: Professor Marcus Newborough, Development Director, ITM Power; and Tim Dumenil, Acorn Hydrogen Project Manager, Pale Blue Dot Energy.

II: Dr Martin Pei, Executive Vice-President and Chief Technical Officer, SSAB; Dr Richard Leese, Director for Industrial Policy, Energy and Climate Change, Mineral Products Association; and Paul Booth, Chair, Tees Valley Local Enterprise Partnership.

Examination of witnesses

Witnesses: Professor Newborough and Tim Dumenil.

Q73 **Chair:** The Committee is continuing its inquiry into the role of hydrogen in achieving net zero. I am pleased to welcome to the Committee for this inquiry the Chair of the Environmental Audit Committee, Philip Dunne MP, and two members of the Business, Energy and Industrial Strategy Committee, Alan Brown MP and Paul Howell MP.

I am pleased to welcome our first panel of witnesses. Professor Newborough is the development director of ITM Power, which produces electrolyser equipment for hydrogen production from electricity and water. It operates hydrogen refuelling stations for cars and buses and, among other things, is developing a new 100 MW electrolyser as part of the Gigastack project in the Humber area.

In his academic career Professor Newborough has been professor of energy systems at Cranfield and Heriot-Watt Universities. He is very welcome to join us.

Tim Duminel is the project manager for Acorn Hydrogen, a blue hydrogen production plant being built at St Fergus, Scotland. It aims to be operating with a 200 MW production capacity by 2025 linked to the Acorn carbon capture and storage project in the same location. Welcome to you both.

Perhaps I may start with an introductory question. A key thing that we have heard about is the different ways of obtaining hydrogen. Grey hydrogen generates unmitigated greenhouse gas emissions. Blue hydrogen uses fossil fuels, but the greenhouse gas emissions are captured and stored. Green hydrogen is generated using renewable energy.

I ask our witnesses to comment on the potential for the type of hydrogen that their work is associated with, starting with Professor Newborough.

Professor Newborough: Our focus is green hydrogen, and therefore we relate directly to the amount of renewable resource that a country has. The UK is particularly well endowed compared with most of its European counterparts because we have vast offshore wind resource potential. I think that Imperial College estimated it is something like 1300 GW of potential offshore wind, while we only have a 50 GW peak demand for electricity in the country. That begs the question: how much of that resource should you try to capture in the form of hydrogen as opposed to electricity?

The conversion of electricity to hydrogen is a straightforward splitting of water into the constituent hydrogen and oxygen gases. Therefore, green hydrogen has great scope for accessing large renewable resource without any CO_2 emission or disposal problem, and without any methane upstream emissions. It also lends itself to rapid deployment, because it can start to become embedded in the power grid as it gets increasingly greener, as well as potentially made offshore in the North sea.

There are two major avenues of production that we can exploit.

Q74 **Chair:** The same question to Mr Dumenil. Your project is in the blue hydrogen area. Perhaps you would summarise what it is about and why you think it can make a contribution.

Tim Dumenil: I should say that Pale Blue Dot Energy is a Storegga Group company. We are involved in the development of both blue and green hydrogen production facilities and of the necessary new and repurposed infrastructure to first create and then rapidly scale up a range of hydrogen routes to market.

You mentioned grey hydrogen. Today, the total global production of grey hydrogen is already 230 GW. There are 2000 TWh of hydrogen production globally, which equates roughly to the total UK energy demand today, so it is a well-proven, established technology.

The difference with blue hydrogen is that we capture, transport and sequester the CO_2 that arises from those same hydrogen production facilities. The Acorn Hydrogen project is based at St Fergus because a third of the UK's gas currently comes onshore at St Fergus. The 200 MW reformer would represent just a 2% blend of hydrogen by volume into that natural gas that is flowing through St Fergus. It is a small start that can be rapidly scaled up. We could see up to 10 GW of blue hydrogen production installed at St Fergus, with the associated full chain transport and sequestration facilities attached to that.

We are also looking to flag St Fergus as a SuperPlace—as a landing point for green hydrogen. Blue hydrogen creates and establishes the route to market for the hydrogen deployment through into Scotland and the rest of the UK, and potentially beyond. The ScotWind project offshore of north-east Scotland could then see significant green hydrogen deployment, taking advantage of the route to market that has been established.

Chair: Let us go into a bit more detail.

Q75 **Rebecca Long Bailey:** Thank you both for coming to the Committee today. Evidence to the Committee so far has contained contrasting views on the prospective feasibility, maximum efficiency and use of blue and green hydrogen in the UK's energy system.

On the maximum feasible level of deployment, for example, issues were raised around the unsuitability of the existing transmission grid and the technical changes needed to home boilers, not to mention the increasing availability of electricity-led home heating systems.

On the question of efficiency, the Energy Technology Institute's chief engineer wrote in 2018 that: "A strategy to enforce comprehensive adoption of hydrogen across the economy looks grossly inefficient based on current understanding of the relevant technologies."

Very generally, what role do you think blue and green hydrogen will play in the UK's future energy system? What, in your view, is the maximum level of deployment for each?

Professor Newborough: Ultimately, you can envisage a very large amount of green hydrogen being produced because, simply, we need a lot of molecules; we use a lot of energy in the form of molecular energy, or fuel, as opposed to electricity.

Often, the debate has focused on electricity, but now it is shifting to a worry about having very green fuel. Green hydrogen is the greenest version of that. It has no impact on oxygen depletion in the atmosphere. It does not consume more water than it liberates when it is used. It does not emit CO_2 and it does not have upstream methane emissions. Everyone is focusing on this phrase "hydrogen economy", but we are still on day one of that journey. There is very little blue and green hydrogen produced today. We are talking about a far-future solution. We need to concentrate on the individual steps to advance hydrogen production and use. It is very much about production and use. We need to build the demand for it as well as the supply for it.

Breaking it down into sectors is a really key way forward. We need to look at the transport sector and have a coherent approach to that in early deployment and growth. We need to look at, for example, the oil refineries or the ammonia producers, which already use a lot grey hydrogen, and look to displace some of that use with green hydrogen. Again, that is an early opportunity because those uses already exist.

Then you have the heat and gas grid challenge, which is one of either blends at low concentrations, to try to achieve some decarbonisation with green hydrogen, or, in the longer term, switching to a full hydrogen grid, similar to the one we have today. Obviously, that route opens up all opportunities because many different industries and buildings are connected to the gas grid.

This is a medium to long-term solution. I think we are in danger of envisaging that too much, and not focusing on the short term and the early steps we can take. Green hydrogen is very good for making early steps— for example, for refuelling buses in bus depots—or as a way of generating hydrogen locally in 100 towns and cities in the UK. That sort of early strategy can be adopted. Even though, when you look at the national statistics, they may show it is a very small percentage of the total problem, it is still an early step that we can take.

Tim Dumenil: I think the key message to take away is that the UK needs to develop a wide range of energy sources to be able to get to net zero. Low-carbon or clean hydrogen is an essential part of that energy mix. To decarbonise our economy, we need all the technologies to play their roles.

Over 10 years ago, David MacKay, the chief technologist for DECC, wrote "Sustainable Energy - Without the Hot Air". The key takeaway is that there is no single silver bullet. We require a range of technologies and primary energies to deploy the scale of ambition for the energy transition to achieve that net zero outcome.

To help to put that into context, 30 years ago most of the UK's power generation was from coal. Coal-fired power has now been almost fully removed from the mix, with most switching to gas. According to the UK Government's own figures from 2019, 75% of the UK's primary energy today remains fossil fuel. This is about the scale of fossil fuel that we still have against the climate emergency and the stated ambitions of net zero by 2050.

Both blue and green hydrogen are clean hydrogen sources. For instance, blue hydrogen captures 95% of the CO_2 produced. Deploying clean hydrogen should be the priority, hence why our strategy tries to develop both blue and green hydrogen in a complementary way. We want to see both forms of hydrogen succeed, and for that transition from blue to green to be made as quickly as possible.

We need to use the initial scale and low price of blue hydrogen to create and then grow that initial hydrogen market. We need to continue to leverage the learning curve for both green and blue hydrogen, to further demonstrate value for money for the UK Government ahead of this transition ultimately to green hydrogen.

Rebecca Long Bailey: Thank you, that is really helpful.

Q76 **Chair:** Professor Newborough, you mentioned surplus energy that we might have from wind—times when the wind is blowing but we are not using that energy. One of the witnesses to the Committee, Michael Liebreich, said that it would be entirely uneconomic to run an electrolyser to produce green hydrogen on the curtailed power of renewable—in other words, when we do not need the power that it can produce—since the intermittent output this would produce would struggle to pay back the capital investment required, making this opportunity a mirage.

You are involved in a commercial venture. I assume that you have persuaded your investors that this is not a mirage. What is your answer to this charge that the surplus energy is not going to be sufficient to be able to make this work?

Professor Newborough: The consequence of deploying more renewables into a power grid is that you suppress wholesale prices. We are already seeing that at the level of renewables that we have today. Occasionally, you go into negative territory, negative prices. That is curtailment, and that is what the press tends to talk about. It is far more interesting to study the price of electricity away from the peak demand periods. You find that it is down at quite a low level—£20 or £30 per megawatt-hour. In other words, it is very cheap. Why? Because renewables are generating, demand is low, and you have to use electricity when it is generated. You cannot store it. If it is available, you find that its price starts to drop and become suppressed.

If you model that into the 2030s, you see a continuum of decreasing electricity price, which therefore makes green hydrogen cheaper. You also see a greater availability per annum of low price and, indeed, negative price, or curtailed energy, which again helps the economics of green hydrogen production.

In most of the studies done, you see this continuum—convergence, if you will—of falling power price plus falling electrolyser price, which helps you to achieve a much more economic green hydrogen outcome.

To comment that there is not enough is simply not to understand this trend in the power system as a result of the greater expansion of renewables. Indeed, the Government's commitment to achieve 40 GW of offshore wind by 2040 transforms our grid into a much more variable and high-res grid that needs electrolysis to help it to manage that variability and avoid wasting that renewable energy and curtailing it. It is an intrinsic synergistic solution that we are advocating.

Q77 **Chair:** There are moves to make the grid smarter and to be able to integrate more intermittent power. Is it not the case that the more successful that is, the smarter the grid, the smaller the opportunity for technologies such as green hydrogen that make use of surplus electricity?

Professor Newborough: It is certainly a competitive market to make use of that electricity, but the opportunity is less about how you fit in the electricity system box and more about how you exploit the renewable power source that you can potentially generate. That is far greater than what you need in the electricity system and, therefore, the transference of that energy into molecules as green hydrogen is a major way forward in the future.

Q78 **Alan Brown:** Mr Dumenil, you suggested that blue hydrogen is effective as a transition in creating the demand for hydrogen as technology develops and moves towards green hydrogen. What would be the operational lifespan of the carbon capture plant in order for there to be a return? Is there any risk that the Government need to limit the sunk costs in the development of blue hydrogen, as even you yourself have said you want to switch to green hydrogen?

Tim Dumenil: Those are both excellent questions. The lifetime that we are working on within the economics modelling that we are completing is a 25-year lifetime for a reformer. With the first hydrogen through that Acorn Hydrogen 200 MW reformer going live at the end of 2025, you would see that reformer running through to the end of 2050. By the time we get to 2050, we would envisage those earnings—the cost efficiencies that we would see through from green hydrogen. You would get to that point in time and have a pretty hard look at whether you reinvested into a new blue hydrogen unit, or, as we envisage, re-deployed that capacity as green hydrogen to take that on, and hence that transition as we move through from blue to green.

That would be the first point. Will you remind me of the second part of the question, please?

Q79 **Alan Brown:** Given the aim to progress green hydrogen, do the

Government need to look at limiting sunk costs in the development of blue hydrogen as that technology gets overtaken, effectively?

Tim Dumenil: I guess there are two parts to that sunk cost question. The first is the clear difference in unit price between blue hydrogen and green hydrogen today. It is the value for money that you have in the short to medium term through investing into blue hydrogen and green hydrogen together. That is a point very clearly made. We see them very much as complementary and necessary for them to grow together.

In terms of investment into the carbon capture and storage assets, we still have key industries such as steel and cement that will continue to emit CO_2 emissions. They will need to have a route to sequestration. Those assets can be deployed and will be deployed for that, and for technologies such as bioenergy, carbon capture and storage and direct air capture as well.

Perhaps I could build on one of the Chair's previous questions. One of the key roles and a real strength of green hydrogen is around intermittency and how that gets managed. The UK's wind profile—availability and strength—pretty much mirrors that of the UK's heat demand profile. We have a very seasonal profile for heat demand, primarily from commercial and domestic end users. Lots of space heating is needed in the winter. The wind strength and availability is much stronger in the winter. The ability to have dispatchable green hydrogen that flows into the grid to manage our peaks can significantly reduce the sunk costs that we would need to put into significant geological hydrogen storage to provide that grid resilience in security of supply. Today, the gas distribution networks are regulated to supply a 99.46% availability of natural gas. Our consumers would expect to have that same availability and security of supply from hydrogen going forward.

Q80 **Alan Brown:** Are there any restrictions in using blue hydrogen due to impurities? If so, how will that be managed?

Finally, does the North sea transition deal that was announced last night mean that blue hydrogen production will be up and running at St Fergus by 2025, or is further funding still outstanding?

Tim Dumenil: On the purity side, the interesting thing is that we started our basis of design for the reformer at St Fergus working on the very high-purity spec of hydrogen for fuel cell applications. Fuel cell applications are primarily focused into transport. The overall primary energy demand for transport is a small component of the UK's primary energy mix. The majority of gas usage today is for commercial, domestic and industrial heat. Those end users basically burn that gas. At the moment it is burned with carbon emissions at the point of use. The beauty of hydrogen is that you burn it at the point of use and do not release any CO_2 emissions. Instead, we are able to deliver that either through the green hydrogen route or through blue hydrogen, and we capture and sequester that hydrogen at the landing points for natural gas—the likes of St Fergus.

In the engagement work that we have done with National Grid Gas and Scotia Gas Networks we have discussed the hydrogen purity specification. They said that even if you put in fuel cell grade, very high-purity hydrogen into our network, our existing networks have been carrying gas for years, so by the time the hydrogen comes out at the far end you are going to have to do some clean-up work at the point of use for some of these very sensitive fuel cell applications.

This is, again, a real strength that Professor Newborough mentioned earlier. Green hydrogen has a prominent role in things like transport hubs and refuelling stations for hydrogen fuel cell vehicles. That is where you would look to deploy green hydrogen to provide that high-purity requirement. You do not need to penalise all UK taxpayers with very high-purity hydrogen when the majority of them are going to just burn it.

That was the first point. Will you remind me of the second point?

Q81 **Alan Brown:** Does the North sea concession deal mean that you will be up and running, or is further funding still required?

Tim Dumenil: The key is to look at the forecasts that are published. Every year, the National Grid publishes a future energy forecast, which shows that the UK will continue to use and import natural gas right through to 2050 and beyond.

Natural gas is forecast to decline. If we look specifically at St Fergus versus the current baseline today, by the time we get to 2050 we expect the natural gas flowing through St Fergus to halve.

As I mentioned earlier, the initial 200 MW reformer that we invested in at the end of 2025 comprises only a 2% blend by volume into the network. That equates to about 0.6% of the energy that flows through.

Again, we are not concerned about that project and its investability. It is more about the build-out plan, and how that will address all the remaining natural gas that is still forecast to flow through St Fergus by 2045. I say 2045 in terms of the net zero target for Scotland as well as 2050 for the UK. We need to ensure that any gas that continues to flow, not just through St Fergus but through the other import points, can be negated of carbon, either at that landing point or elsewhere within the UK, through post-combustion carbon capture and storage.

Q82 **Philip Dunne:** Thank you very much, Chair, for inviting me to guest with you from the Environmental Audit Committee for this session.

I have a couple of questions for Professor Newborough in relation to the debate that is raging through this Committee on the relative merits of blue and green hydrogen. We have had quite a lot of evidence that they should be developed in parallel and that blue hydrogen should be able to come on stream ahead of green hydrogen. Given your company's involvement in green solutions, will you give us your view on how quickly green hydrogen production can be scaled up in the UK?

Professor Newborough: The first thing to say is that green and blue are very different and it is important to distinguish between the two. Green can be deployed quickly. Electrolysers are being purchased this year and installed next year. It is that kind of speed. There is no need for extensive feasibility studies prior to major investment in blue hydrogen production CCS. You can start to do things at bus depots, truck depots, trains for hydrogen refuelling. You can do injection into the gas distribution networks at low concentrations. You can start to decarbonise refineries by deploying electrolysers. Indeed, the Germans have set a target of 2 GW for electrolysers for refineries for 2030. All of this is quite doable in the immediate term.

The other thing to bear in mind is that green hydrogen is net zero. It does not have CO_2 emissions to handle or dispose of. It does not impact the environment; therefore, it is a benign solution. You are making a step change.

Where you can go to fuel cell technology rather than engine technology—for example, in the transport sector—you really get a step change in efficiency. You need to buy less than half the energy to travel the same distance. You can fill up your vehicle as quickly as your conventional diesel vehicle. You can travel long range. There are value propositions around green hydrogen in its immediacy and to the customer that suggest you can pull it through quite quickly.

It is decentralised, so you can pop it down anywhere where the electricity grid is. You can start to envision a national spread of green hydrogen production without having to centralise it at certain key points and then use the gas grid to distribute it. You can get on and do things quickly is the message.

Q83 **Philip Dunne:** You have recently invested in Sheffield and in a production facility in the Humber—in Sheffield in an electrolyser manufacturing site and in the Humber in a green hydrogen facility. You also invested significantly in a project in Germany for a gigawatt-scale plant. Can you give us a sense of when you expect these facilities to be up and running?

Professor Newborough: The facility at the Cologne refinery will be up and running this year. We have just sold a 24 MW unit to Germany that, again, will be running at the end of this year, or soon thereafter. There is not a long lead time in deploying this. This is about how individual countries feel about this green/blue balance. As you know, probably, about a dozen countries have come out prioritising green. These clearly are the early markets.

The irony for the UK right now is that we are waiting for the hydrogen strategy. It is an acid test to see how it talks about green. As I said earlier, we have very large renewable resource in this country, and therefore it would seem that we have a strong position in green.

How things develop is a function of other countries' Governments, and other markets internationally. We certainly are very active in Europe and elsewhere, in Japan, in Australia. We are seeing movement in some sectors and by some Governments. That will really stimulate the market and fully utilise the manufacturing capacity that we have. We are very confident about that.

Q84 **Philip Dunne:** We are going to come on to the hydrogen strategy in a few moments I think, but before we do, may I ask another quick question? Is a gigawatt-scale capacity in UK impossible without a hydrogen strategy? Is there any commercial viability to scaling production, or does it require Government support at this stage?

Professor Newborough: We require some Government support in the early years to get over the initial hurdle. As I said earlier, there is a convergence of falling power price due to renewables and falling electrolyser price due to upscaling manufacture. By the end of the 2020s you arrive at a very good place, but we are still very much early days in how we commercially exploit the technology, and therefore a regulatory framework, a policy framework, is needed in each of these countries to move things forward. I think that the country that moves quickest will pull through the benefits soonest.

Q85 **Graham Stringer:** May I follow up on that point? Can you be explicit about when you expect there to be no Government subsidy and for green hydrogen to be commercially viable?

Professor Newborough: If you wanted an estimate, I would say 2030, but I would qualify that by asking: what is the renewables penetration in the power grid in the future? It very much pivots on that. It depends how quickly you achieve your renewables target in the power grid. We are very well advanced in the UK, especially in Scotland, for example, and therefore you can make green molecules very easily via the power grid.

As I said earlier, in the medium term, perhaps the late 2020s or early 2030s, offshore green hydrogen production will augment that which you can produce inside the grid. That avenue could become a very large avenue in the medium to long term.

Q86 **Graham Stringer:** Taking your estimate of nine years, what would you estimate the quantum of Government subsidy to be over that period? Would it depend on a high carbon price?

Professor Newborough: I think it would depend to some extent on a high carbon price. I do not have the figure to give you today in terms of what the Government commitment would need to be, but I can certainly write to you and let you know that.

Q87 **Graham Stringer:** That would be helpful. My constituents and everybody else's constituents, I guess, would be interested in what the impact of a large subsidy and high carbon price would be on the final cost of hydrogen to them, whether it was into transport or into heat. Have you any estimates of that?

Professor Newborough: I think we have, but I do not have them with me, I am afraid.

Q88 **Graham Stringer:** Do you think you could send them to the Committee?

Professor Newborough: Yes, certainly.

Q89 **Graham Stringer:** That would be helpful.

Mr Dumenil, you mentioned in answer to a previous question that, at some stage, to make the use of offshore wind viable you would require large storage facilities for hydrogen. Can you give us a quantification of that?

Tim Dumenil: It was actually the opposite to that. I was stating that the use of large offshore wind generation converted into green hydrogen to match the peak of the heating season can reduce the amount of investment that would need to be put into large-scale hydrogen storage.

Graham Stringer: I misunderstood. I apologise. Thank you.

Q90 **Chair:** Mr Dumenil, one of the witnesses at our last hearing, Professor Cebon, described the inefficiency of hydrogen production as an Achilles heel, and said that hydrogen should be used only in places where you absolutely cannot electrify. You described a route that is broadly based—you introduce hydrogen across a broad range of different uses. That seems, on the face of it, quite appealing. I think that everyone would recognise that that incremental approach gets people used to what might be possible.

The downside is that it can put off, and perhaps prevent, decisive choices, and if heating, for example, needs to be electrified, then you should get on and do that, rather than introduce marginal increases of hydrogen into the gas supply. What do you make of that argument—that it defers an important strategic decision?

Tim Dumenil: I guess I will recycle back to one of my previous pieces and say that it is the scale of transition that is needed. Some 75% of the UK's primary energy store remains fossil fuel. We need a mix of technologies and solutions, and routes and vectors of energy, to solve that.

Perhaps I can use a particular analogy. For several years now we have been working extensively with the Scottish distilling sector on its journey and ambitions. A medium-sized commercial distillery would have a 6 MW boiler installed on its site, taking natural gas and converting that to steam. That boiler would deliver and produce about 90% of its primary energy needs for its industrial process, with the remaining 10% coming from grid electricity. If we were to electrify that site, which has a gas supply pipeline and a small electrical incomer sized at about 250 KW, we would have to install a 6 MW electric boiler. That requires a significant investment into the incomer and subsequent upstream reinforcement of the grid. It is not just for that one distillery. If all the other 50 distilleries in the region are going to do the same, that exacerbates the problem.

In addition, the distillers currently pay about six to seven times more for their electricity on a pence per kilowatt-hour than they do for their gas. If they have a £500,000 annual energy bill today, they would have to pay £3 million in future, if they went down an all-electric route.

I hope that I am explaining some of the complexity of that issue for that one particular case. The same issue will roll out when we look at commercial, domestic and industrial end users.

The approach that the distilling sector is taking, which is written within its net zero road map report published last year by the Scotch Whisky Association, is this combination of solutions. It is looking to integrate electrically driven high-temperature heat pumps to recover waste heat from within its processes, significantly to reduce the primary energy that it needs in the first place. It is looking to fulfil the residual primary energy through hydrogen. It has a preference for green hydrogen, but it recognises that the cost of green hydrogen today is significantly more than that of blue hydrogen. We will be looking, as I have mentioned a few times, at the scale and cost efficiency of blue hydrogen, which creates the hydrogen for those markets. We are specifically engaged in working with the distilling sector on both blue and green hydrogen projects in order to achieve that outcome.

Q91 **Aaron Bell:** In a similar vein, may I turn to Professor Newborough? We have heard that electrification should be the preferred option for renewables, but you have spoken about the times when we are producing more electricity than we can use. Why is hydrogen a better bet for Government investment and development than battery technology or gravitational storage?

Professor Newborough: In terms of investment from Government, I think that energy efficiency should come first, electrification second, and green hydrogen third. The problems are that you cannot get to net zero through energy efficiency alone and you cannot get to net zero through electrification alone. You can try to load some of the heat on to the electricity system, but you will end up ripping up the roads and replacing all the cables from the transformers to the buildings, because the power load will go up substantially.

It is a case of how you cover that gap. How large is that big gap of heat? Conceptually, a hydrogen grid is a route to covering that gap. The question is whether you want to do that with green hydrogen or blue hydrogen.

Green hydrogen, as I have said already, is available today. You could start injecting low-concentration-out mixtures today. The TEN-E regulations that the Commission published before Christmas talk about 100 MW plus electrolysers feeding three major hydrogen transmission backbones across Europe. We could connect into that and produce a lot of green hydrogen, or import hydrogen from it, as we wish, into the medium to long term.

It gives you the ability to store energy. You can put that hydrogen into a salt cavern. Conceptually, you can make it in summer, store it until you need it in winter, and use it then. You cannot do that with batteries, or with electricity. Batteries are good for short duration load matching, supply and demand matching. Hydrogen is about the only solution where you can store renewable energy at terawatt-hour scale for meeting large variations in power and heat demand.

One of the major questions before us is whether we should be using our geological storage for CO_2 and the accumulation of it as a waste, or using it as a lung, effectively, for storing green hydrogen.

Tim Dumenil: It is really important to recognise the role that the UK energy grids play today, and the nature of energy demand across those two grids. Without going into detail, the electricity grid has very little flexibility within it. Across the year, across the seasons, it has about a 1 to 2 flex, whereas the gas grid is a phenomenal asset in both its low-impact storage capability and its connected large-scale storage facilities. That gas grid is able to manage the inter-seasonal and inter-day peaks and swings. Everybody switches their heaters and boilers and gas hobs on in the morning and evening. The gas grid today manages a 1 to 15 swing. That is a phenomenal asset of flexibility for the UK.

If we do nothing else in our usage, and end users and consumers do not change their usage habits, that 1 to 15 swing will then fall on to the electricity grid, if we go down an all-electric route. To Professor Newborough's point, how expensive will that be for the UK in upgrade costs all the way through that?

We believe that it is far better to be able to use both: upweight the amount of electrification that takes place, and re-look at our existing gas network assets to repurpose them for hydrogen, and, where necessary, build in new hydrogen pipeline networks to supplement and support that as well.

Q92 **Aaron Bell:** Many years ago I worked very briefly in the gas industry. You are right that the flexibility in storage is much greater in that portion of our energy needs than in the electricity sector.

Both of your organisations put in your submissions the need for the Government to set out clear business models for hydrogen production. Which business models would work best, and should they be separate for green and blue hydrogen?

Tim Dumenil: The ongoing conversation with BEIS and the business model team is happening today in parallel. There is a meeting just now. We are continuing to work through a range of business models. They are yet to be finalised, but we hope to be able to progress that a little further later this year. The early indications are that a contract for difference approach, similar to that which has been adopted and has worked very successfully for the electricity sector, is looking like a preferred route at this point in time, but it is still subject to the ongoing work.

Q93 **Aaron Bell:** At what point would you envisage true price discovery becoming part of that business model? We heard from Michael Liebreich that, until you bring price discovery in, you can go down some poor dead ends in policy development.

Tim Dumenil: That is already taking place at the moment. There is a shortlist of six business models that we have been working on over the past 12 months. For each of those business models an economic model has been developed. They have been helping to inform the bilateral conversations that are ongoing between the BEIS business model team and the project.

Q94 **Aaron Bell:** Professor Newborough, on business models, what would your firm advocate?

Professor Newborough: The main interface for us is with the electricity sector. It is the tariff the electrolysers operate on. It is the ability to provide grid services, and the income they can earn from providing that.

There is a need to look at it sector by sector. We have things like the RTFO in the transport sector, which is helpful but needs modification. That is a way of initiating an early market in the transport sector. We probably need a combination of stick and carrot in the refinery and ammonia industrial process sector. We need something like a feed-in tariff for the gas grid, if we are going to inject hydrogen into the gas distribution networks, a bit like we inject biomethane today. It is probably going to be that sort of approach.

We think the CFD is a good approach. It is still early days, but we think it should be tied in some way to the offshore wind CFD, because our energy source is electricity, and therefore the complementarity is with the expansion of renewables. There is a synergy there to be found that is mutually advantageous.

Q95 **Aaron Bell:** Finally, you mentioned the RTFO. Will you briefly expand on how you would like to see it reformed to take better account of the role that hydrogen might play?

Professor Newborough: At present the RTFO insists on a direct coupling between the electrolyser and the wind farm, or the solar farm. That is a huge geographic restriction on where we can put electrolysers for refuelling stations.

For the transport sector, you need a geographic spread, and therefore we seek freedom within the grid to locate electrolysers where it makes sense, in towns and cities, for refuelling vehicles, bus depots and so on.

Secondly, it follows the additionality principle of the European Commission, which basically says that you must connect to a new wind farm or new solar farm. We think that we need some flexibility there; otherwise we are waiting each time for a new renewable deployment before we can actually initiate the hydrogen route forward. For a period, we need that flexibility.

The point to bear in mind is that the expansion of renewables is occurring anyway. The amount that will actually be used for hydrogen production is a small fraction of that ongoing expansion. If it is handled correctly around the interface with the power industry, the whole green hydrogen approach is an enabler for further and continued expansion of renewables, while minimising curtailment, and avoiding this suppression of prices on the wholesale market in low-demand periods. There is a lot to be won around that interface.

Q96 **Graham Stringer:** I will try to make up for the mistake that I made on the question about hydrogen storage.

You mentioned hydrogen storage, Professor Newborough. Have you done any market testing of the public's response to hydrogen being stored close to them? I know that when people have talked about carbon capture and storage there is a terrific resistance to people being anywhere near carbon dioxide storage. Carbon dioxide is not flammable. It does not explode. It is a relatively passive gas. The problem with carbon dioxide is that you cannot breathe it. Have you done any market research in that area?

Professor Newborough: We are certainly aware that salt caverns have been used for at least 50 years for storing hydrogen. There is no leakage issue. There has been no safety issue. North-west Europe is full of caverns. We have quite a lot, both under land and under sea. Germany has a very large amount. The envisioned future is that they buffer the whole hydrogen grid across Europe. It is a proven way of storing gas in a completely safe and tight manner. Natural gas is stored in a similar way. There are many decades of experience of that. I do not think underground storage of hydrogen is a particular issue, no.

Q97 **Graham Stringer:** Is it stored in this country underground?

Professor Newborough: Yes.

Q98 **Graham Stringer:** Can you tell us whereabouts?

Professor Newborough: I am not an expert, but I think it is in Cheshire. There is a salt cavern in Cheshire.

Graham Stringer: In the old salt mines in Cheshire.

Q99 **Chris Clarkson:** My colleague Philip Dunne has already alluded to the hydrogen strategy. I wanted to get the thoughts of both our witnesses on what you want to see from the Government in the hydrogen strategy.

Professor Newborough: We want to see coherency for green hydrogen. We can accept that the Government wish to describe it as a twin track. We need to see coherency for the track involved with green hydrogen. We think that it is achievable in the short term. We think that it is scalable to large scale as well.

We would like to see specific policy changes, such as the waiving of grid fees for the connection of electrolysers into the power grid, the waiving of VAT on the sale of hydrogen fuel to vehicles, some form of feed-in tariff to inject hydrogen into the gas grid analogous to biomethane injection, and a placing of the UK on the world map in green hydrogen general production.

As a manufacturer we feel that other countries have pushed out there, ranging from Germany and France, all the way across to Chile and Australia, with very forthright green hydrogen ambition. They have clearly stated it is a priority. When you state something as a priority, everybody understands what that means.

We think that green hydrogen should be the priority. We think there is a danger of a conflicted message potentially in a strategy that tries to advocate both blue and green. We are hoping for greater clarity and prioritisation of green.

Tim Dumenil: I would counter Professor Newborough's position. We do not think it is particularly helpful to create a division between blue and green. They are complementary, they are both needed, and each has different advantages and benefits to bring. We would rather see the strategy focused on clean hydrogen, and advocating the role of clean hydrogen.

If you consider your end consumers and there is a debate between them about what hydrogen is and different colours of hydrogen, I do not think it is particularly helpful. Hydrogen is hydrogen. It is the most common element that we have. It is important to focus on it as an energy vector of importance for the UK.

What would be very useful within that strategy is, again, to have the clarity around the business models and the funding mechanisms that will then come through behind that. What would be particularly useful is the use of hydrogen, and how hydrogen will then be deployed across the different areas of transport, but in heat in particular. As I mentioned earlier, heat accounts for 55% of the UK's primary energy use today, and that is the role where clean hydrogen will come out on top, and provide a strong advantage and leverage.

It is understanding the Government's position with regard to the decarbonisation of heat within that strategy, and the role that hydrogen will play, and, in particular, the approval of the blending of this 2% through to 20% hydrogen ahead of the eventual road map to pure hydrogen uses. To be clear, it is really important in the advancement in tandem of both blue and green hydrogen, and, yes, such that green hydrogen can eventually take over as the primary energy vector.

Q100 **Chris Clarkson:** Picking up on that, do you think that the Government's low-carbon hydrogen projection targets risk demand outstripping supply?

Tim Dumenil: The problem is it is the other way round at the moment. It is very difficult for first-mover projects like Acorn Hydrogen to be able to get to that final investment decision that we seek for the significant investment that needs to come into these projects.

I say that because at the moment there is no hydrogen market in the UK. The Gas Safety (Management) Regulations currently limit the inclusion of hydrogen in our gas networks to 0.1%. If we are looking to deploy hydrogen at scale where it is needed, which is for heat, the GSMR need to be deregulated and the new gas standards set up and established at pace. That is a significant piece of work that has been under way for a few years now. It has been put in place by BEIS and led by IGEM.

Q101 **Chris Clarkson:** Would it be fair to say that the problems are more regulatory than logistical at this stage?

Tim Dumenil: Absolutely. This is very much about policy. Policy comes back to the strategy and why having that really clear policy is very important. Then it is the subsequent regulatory part of it.

The regulatory part focuses on the pipelines. It is the ability to get hydrogen from A to B. The interesting piece is when we look at it from an end user perspective. If we look back, it was only in the 1960s that we had town gas, which comprised 50% hydrogen. We have already worked in a regime where we have had a 50% hydrogen blend being supplied to commercial, domestic and industrial end users. It is eminently doable for us to replicate that.

The appliance code for end users at the moment, interestingly, still has a bit of a legacy, in that appliances—gas boilers, cookers, etc.—from an engineering standard have been signed off to have up to a 23% blend of hydrogen within them.

The key is how we initially create and then stimulate the demand for hydrogen through these early blending projects. What we are trying to do in St Fergus is this initial 2% blend into the national transmission system with National Grid, but we are also working with Scotia Gas Networks—SGN—to install a new pure hydrogen pipeline that will run from St Fergus into Aberdeen. It will connect to the three pressure reduction stations that feed Aberdeen and supply an initial 20% blend into the Aberdeen network. The end users, whether they are commercial, domestic or industrial, will see no change. There should be no difference or impact to their end use. That will create a significant initial step change in creating and stimulating the hydrogen market.

Professor Newborough: I think it is quite straightforward to achieve a target of 5 GW of hydrogen production and demand by 2030. I think you can divide that into injection into the gas grid, into large processes, and into the transport sector. You could do it all with green hydrogen if you wished to.

Q102 **Philip Dunne:** The Committee might like to write to the Ministry of Defence, which has responsibility for a large part of the salt caverns in Cheshire. When I was last there, they were involved in storing the remnants of some second world war military fuel, and I am sure that the Ministry of Defence would be very interested in offloading that responsibility on to somebody else.

I have a couple of very quick questions, probably initially to Professor Newborough. We have heard of the challenges in persuading decision makers within the Treasury about why they should look at other technologies than electrification for transport and home heating. What do you think are the convincing arguments that should be put to the Treasury and other decision makers about why they should support alternatives?

Professor Newborough: Simply, if you operate at this latitude you have a large seasonal variation in energy demand and you need to be able to store energy. If you advance renewables to a large extent, that creates a supply/demand mismatch. In the middle of that mismatch you must be able to store energy. Your cheapest way of doing that is to store hydrogen in bulk underground. That is the basic physics of the situation. You can put your foot on the pedal with electrification, but you will not get all the way there. You are going to have a gap.

It is the same with electric vehicles. You can advocate battery electric vehicles, but you will still find that in some applications, especially with heavy vehicles, or people who simply want to fill up quickly and move on, they will desire the hydrogen solution. You have to recognise that. If you try to put those loads on to a power grid, you will need to invest an extremely large amount of money to replace a lot of cables and a lot of transformers. It is a decision of how far you want to go with that, and do hydrogen. That is a difficult one—how much of each you need to do—but you cannot do it all with electricity.

Q103 **Philip Dunne:** Do you agree with that, Mr Dumenil?

Tim Dumenil: I agree and I would recycle one of my points from earlier. A pure electrification future would suggest significant grid reinforcement to accommodate transport and heat requirements. There is the example I gave of the distillery.

I also agree with an analysis by Transport Scotland, which has suggested that electrification makes sense for domestic vehicles, particularly on busy commercial routes and inter-city connections, but not beyond that, in terms of heavy goods vehicles, particularly trains, and in the more remote locations. All the rail network north of Dundee is currently diesel. It would be very difficult to electrify that and hydrogen would be a key solution for that application.

Q104 **Philip Dunne:** Picking up on one of the earlier questions about international competitive strength, the UK has some academic and scientific strength in hydrogen. Do we have a competitive advantage internationally at present? Is that at risk of disappearing if we do not get hydrogen strategy clarity soon?

Professor Newborough: Yes, exactly. You are dead right. We have invested in the Gigafactory in Sheffield and we are importing technology into Europe and elsewhere. That is about wealth creation and about engineering and manufacturing. We could easily lose out to other countries that invest in those things quicker, or better, or to a greater scale. At the moment we have a head start and it is very important that we exploit that head start.

Tim Dumenil: At the top of the call I spoke about the 230 GW of hydrogen reformer capacity installed globally. The five largest single sites combined form 4 GW of installed capacity. In different plants of slightly smaller size, there are about 2 GW of blue hydrogen installed capacity, so a full chain reformer with carbon capture, and the use of that CO_2.

Q105 **Philip Dunne:** Which countries dominate?

Tim Dumenil: It is the USA, Canada and Japan, where I am aware that those three projects are installed.

The opportunity is for the UK to do the same. Most of these installations are within the oil and gas sector, which brings considerable experience in hydrogen production and carbon capture and storage. The UK has a wealth of CO_2 storage resource off its north-east coast. We need the support from a wide range of stakeholders to get to net zero. Low-carbon hydrogen is an essential part of this energy mix. In engaging the oil and gas sector, it is not about prolonging oil and gas production. It is about the fastest and most cost-effective way in which to reduce emissions.

Several global players are actively investing in both blue and green hydrogen, including the involvement in the ScotWind leasing rounds. The fact that oil and gas companies are now engaging in hydrogen is a huge positive, in my view. With their skills, knowledge, technology and innovation capability, their infrastructure and offshore expertise, this can support the acceleration of hydrogen deployment, scale up and cost reduction, while supporting the just transition of a highly skilled industry, leading to long-term job security, economic stability, and ultimately growth—and a competitive position for the UK.

Q106 **Philip Dunne:** I think Professor Newborough wanted to come back.

Professor Newborough: I just want to state a fundamental. Please bear in mind that green hydrogen is produced with, if you will, British energy. It is wind and sun that is striking our territory, and it is inexhaustible. If the technology is manufactured here that makes it as well, that is another benefit. You can use it locally and export it.

If you contrast that with blue hydrogen, you have to import the natural gas from Norway or Russia. The energy source is not local. You then have to store the CO_2 locally here, so your subsidy is for CO_2 disposal primarily. There is a great distinction between blue and green in the Britishness of the solution. I think it is worth reflecting on that.

Q107 **Chair:** Mr Dumenil, as Philip Dunne has just said, and as the Professor just said, if we are to go down the blue hydrogen route, we need to rely on carbon capture and storage. What estimates have you made of the steady-state cost of that?

Tim Dumenil: That work is ongoing. We completed the Acorn carbon capture and storage site. It is a European Commission project of common interest. It is the first site to secure a UK licence and lease.

As part of that, we have done considerable study work over the past few years, and that has involved evaluating the CO_2 transport and storage price associated with it. It is not something that I can submit to the Committee just now, but I could come back to the Committee with a written statement.

Q108 **Chair:** Thank you. Do you agree with Professor Newborough's assessment that there is more that is known and dependable about green hydrogen, and that in its reliance on CCS blue hydrogen is a hypothesis on a hypothesis?

Tim Dumenil: No, I disagree, on two counts. One would be that I mentioned earlier the future energy scenario and its projections. Within that there is a 10-year natural gas statement. In the UK, the significant majority of the natural gas that flows through St Fergus is British gas. It originates from within the UK continental shelf and it will continue to originate from within the UK continental shelf, on that piece.

I have alluded to the scale of deployment that has already happened. The largest reformer units are up at about 1800 MW. There is a proven installed reformer unit of 1800 MW. The largest proven demonstrator of green hydrogen is 20 MW in Bécancour, Canada. That comprises a series of 2.5 MW stacks. The largest installed electrolyser today, a single-stack electrolyser, is a 10-megawatt unit in Fukushima, Japan.

The scale difference is stark. To be able to expedite hydrogen at a significant scale, as I mentioned earlier, it is not useful to be trying to differentiate hydrogen as blue or green. Hydrogen is hydrogen. They are complementary. They need to work together. They need to accelerate together and eventually enable this transition from blue through to green as the UK natural gas resources decline.

Chair: There is one final question from Dawn Butler, who has a topical question to ask.

Q109 **Dawn Butler:** Thank you both for giving evidence today. It has been extremely informative. Professor Newborough, would you suggest that one of the areas the Government's new Advanced Research and Invention Agency should be investigating is hydrogen?

Professor Newborough: Absolutely. I think that hydrogen is a central component of our future net zero solution, for the reasons that I think I have already stated. The issues of renewable power, renewable hydrogen, its storage, its utilisation are a central vein. It is perhaps as significant as renewable electricity on its own today. We need to encourage thinking and development around that central vein of our long-term solution, because it is intrinsically net zero. There are no residual emissions to deal with. There are no consequences of it. It gives us that environmentally benign solution for 2050. It is a very good channel, if you will, to go down to put thinking and development effort into for the next 29 years.

Q110 **Dawn Butler:** I figured the answer would be yes. A quick question to Tim: I think we all agree that ARIA is not going to be able to do a lot. I know that you say that blue and green hydrogen are interlinked, but if ARIA had to choose one of these streams to focus on, would you still be supporting a focus on blue hydrogen as opposed to green?

Tim Dumenil: That is a really tough question. I do not think that there is a simple yes or no answer. I think I have answered this several times already. The answer would be yes for blue hydrogen in the short term, but yes for green hydrogen in the long term.

Chair: Thank you very much indeed. I am very grateful to both witnesses. I think we have covered pretty extensively the question of whether it is green or blue, or green and blue, or whether indeed it is hydrogen at all. For your expertise on this, we are very grateful. There are one or two points that witnesses have agreed to follow up on, and we would be grateful for that.

Examination of witnesses

Witnesses: Dr Pei, Dr Leese and Paul Booth.

Chair: I welcome our next panel, of three witnesses: Dr Martin Pei, the executive vice-president and chief technical officer of SSAB, the Scandinavian and North American steel maker; Dr Richard Leese, the director for industrial policy, energy and climate change at the Mineral Products Association, which covers among its areas the cement industry; and Paul Booth, chair of the Tees Valley Local Enterprise Partnership, and former chair of the UK branch of the global petrochemicals company, Sabic.

As is evident from the introductions, we are going to look at particular industries that are associated with high emissions of greenhouse gases, of CO_2, to look at the potential role of hydrogen.

Q111 **Carol Monaghan:** What role do you see hydrogen playing in decarbonising your respective industries?

Dr Pei: First, I thank the Committee for the invitation to be a witness today.

SSAB has production facilities in Sweden and Finland, where we use blast furnace technology. In the United States we have two steel mills using electric arc furnace technology. In the steel industry, making steel from iron ore, the current most dominant technology is blast furnace technology. That is based on using coal and coke, melting iron ore and producing steel for industry.

SSAB is today the steel company with the most efficient blast furnace production processes in the world, even though we still emit the largest emissions in Sweden and Finland.

We started an initiative called HYBRIT—hydrogen breakthrough ironmaking technology—at the beginning of 2016. I have been working on it for five years. We have launched a programme of research activities involving the most important universities and research institutes in Sweden. We decided to build a pilot facility at the beginning of 2018. Right now we have a pilot plant in operation in one of our steel sites in northern Sweden, at Luleå.

We are close to carrying out the first exciting trials using hydrogen completely for iron ore reduction. Our plan is to scale that technology up after the trials in the pilot plant to a commercial-scale demonstration plant in 2026. We are now on the way to developing a breakthrough technology to replace the blast furnace technology that is widely used in the world, using green hydrogen only in our process.

We want to replace coal and coke for iron ore reduction by using green hydrogen. We want to do that all the way from iron ore mining to the steel production step, and, finally, deliver what we call fossil-free steel to our customers. That is what we are doing and we are the company that is leading these developments, together with our partners, LKAB and Vattenfall in Sweden.

Q112 **Carol Monaghan:** Thank you, Dr Pei. Mr Booth, do you have a few comments on this?

Paul Booth: I would encourage systems thinking around hydrogen. There are a number of examples that I could give. If we have green hydrogen, we can make green ammonia, which makes green fertiliser. If we have green hydrogen and CO_2, we have a route to greener aviation fuel.

I mentioned previously green hydrogen within the chemical industry. The process is called hydrogenisation, or depolymerisation of polymer. Hydrogen offers the facility, the wherewithal, completely to chemically recycle polymer—to go around and around, because mechanical recycling has its limitations. There are lots more examples that I could give in that area, but I will move on to something else.

Some of the larger facilities are moving from naphtha cracking to ethane cracking. One of the major biproducts of ethane cracking is hydrogen. As was mentioned before, Tees Valley has six hydrogen cavities. They have been there for over 50 years. We have been storing that in a salt strata that comes out underneath the east coast and re-emerges on the west coast. With that facility, we can store hydrogen at scale, which means that that plant making excess hydrogen can continue to run in an efficient way.

Those are some examples of how hydrogen can make a contribution to greening the industry.

We are also in the process of converting furnaces to run on hydrogen. They are already running on something called hythane, which is a hybrid hydrogen/methane mix. Industry, probably better than domestic, can get to significantly higher values, maybe 20%, 30%, ultimately 100% hydrogen, which significantly reduces CO_2 production from those plants.

Q113 **Carol Monaghan:** May I ask the same question of Dr Leese?

Dr Leese: I thank the Committee for inviting the Mineral Products Association to the session today.

MPA members have a range of activities that represent aggregates, asphalts, cement, concrete, silica sand, lime, water and a whole range of activities, some of which are energy intensive at the combustion side, and some less so.

To focus on the more energy-intensive side of the business, which is lime production and cement production, the role for hydrogen is quite different. Lime production is a predominantly natural gas-consuming activity. Hydrogen consumption in that process brings considerable value in the fact that it is decarbonised, but it also fits the purity requirements for lime production, because lime is used in water treatment and needs to be a pure material. There are advantages there, and I can see quite a considerable role for hydrogen in lime production.

Cement production is quite different. It is predominantly solid fuel based, but liquid and gaseous fuels are burned to a very small extent. The overall fuel demand for cement production in the UK is the equivalent of about 1.3 million tonnes of coal. About half of that—44%—is sourced from waste-derived fuels. Cement production in the UK is probably the most diverse of any sector in switching from fossil fuels, because probably nine or 10 different waste-derived fuel categories are used in cement production. Hydrogen can be used in two ways in cement production. It can be used for the energy value into the process or as a combustion enhancer to help to burn some of those other fuels.

In summary, hydrogen has a role to play, but it depends on the process and on the subsector.

Q114 **Carol Monaghan:** Dr Pei, you said that you were concentrating on green hydrogen. May I ask Paul Booth and Dr Leese to give an indication of what percentage of green versus blue hydrogen you expect to use?

Paul Booth: Off the top of my head, I cannot. All I would say is that, if you want to make green ammonia, you would be using green hydrogen, not blue. I will take note of the question and write back to you in respect of the Tees Valley.

Where it is being burnt, where it is being used in furnaces, it obviously would be blue, but there are applications as I have described going forward where it should be green. I will write to you and try to give you a split on that.

Dr Leese: In terms of the green versus blue aspect, our production is, as I said, a combustion process, and therefore we would want to burn the fuel directly. To provide hydrogen into that combustion process, you need massive volumes. We are running a trial at the moment in both lime and cement production to look at what level of replacement we can go to in the fuel mix with hydrogen. That is sourced from the UK's current hydrogen production. Alongside the trial that MPA is running, we have seen one of our members, CEMEX, install what we think is a hydrogen electrolyser to provide green hydrogen to their process—predominantly, I assume, as a combustion enhancer—because their plant in Rugby is being run on 100% green energy.

We have the opportunity for both, but the real question comes down to scale, and how quickly we can scale up production in the UK. I see blue hydrogen predominantly as a stepping-stone, and probably the first move.

Q115 **Carol Monaghan:** Thank you very much.

May I ask a final question of Mr Booth? Teesside is already producing large amounts of hydrogen. Is this going to play a major role in decarbonising businesses? How has it been received by customers?

Paul Booth: Very well. There is something called the Teesside Collective. Pretty much all the major CO_2 emitters have signed up to the proposition that they will at some point in the future tip their CO_2 emissions into a collective system that is part of the Net Zero Teesside project. Hopefully, you will be aware of that. It is the BP consortium to build a 3 GW power station with carbon capture and storage. That allows all the major customers to tip their CO_2 into that system. BP has also recently announced an expansion into blue hydrogen and hydrogen infrastructure.

Going back to the previous conversation, it is horses for courses. There is room for green hydrogen and blue hydrogen. We need both. That is an important point that we should not lose.

My experience of forecasting is that it is either far better than you thought, or far worse than you thought; it is never actually what you thought. I tend to keep an open mind.

Carol Monaghan: Thank you very much. We will watch the Teesside area with great interest.

Q116 **Chair:** I am sure that the Chancellor would agree with that assessment of forecasts.

Dr Pei, do you have a view on to what extent the industry will be able to be decarbonised? Will you be able to get to 100%, or are there limits that practically constrain that?

Dr Pei: Our aim in our HYBRIT initiative in Sweden is to replace completely the fossil fuel that is used today in the steel value chain. The blast furnace step is where the most CO_2 emissions occur in the production chain. That is where we are focusing the first step.

We are also looking into further steps in the steel process, in the steel plant itself. Our aim is to electrify every step that is technically possible.

If there are specific steps that we cannot in the near term electrify, we are looking at the possibilities of a combined solution, using partly where it is necessary biomass or biofuel in our processes. Our aim is to get to a complete fossil-free value chain—and we are on the way to doing that.

Q117 **Chair:** When is the ambition to get to that complete decarbonisation by?

Dr Pei: Right now we are running pilot plant trials in Sweden. We are very close to making it from the purchase scale to the pilot scale—a 1 tonne per hour production pace—in a couple of months. Our plan is to make the first demonstration plant facility in 2026. In five years' time, our plan is to put fossil-free steel on the market at commercial scale.

Q118 **Chair:** That is 2026 for a demonstration plant. Assuming that goes according to plan, how long would it take for the Swedish operation to be converted to be entirely carbon neutral?

Dr Pei: Our plan is that after the demonstration stack we will continue to convert all our current blast furnace-based production sites before 2045. As I say, we aim to become a completely fossil-free company.

Q119 **Aaron Bell:** Thank you, gentlemen, for coming in. What are the major challenges that your industry is facing with hydrogen adoption? I assume that they are mostly cost and supply, but I am open to hearing others. Which of those is more significant? What support could Government or Government agencies offer to help you to overcome those challenges? May I start with Dr Pei on the steel side?

Dr Pei: For the steel industry itself, as I mentioned, we are in the middle of the most exciting technology development stack. We believe it will take a few years.

In the future transformation when the technology is available, the most important aspect is the availability of fossil-free electricity. Here, we have a good starting point in Sweden and in Finland. There are good opportunities to enable that transformation.

For us, timing is most urgent. We are getting a lot of interest from our customers. The market is asking for fossil-free products.

On the challenges that we have in Sweden, timing for getting permits is one of the critical questions that we are working with, and support from the Government to create a market for fossil-free steel products. That is one of the areas where we are in conversation with the Government.

On top of that, of course, creating a market depends quite a lot on the cost of CO_2 emissions from our current production facilities. Lately, we are seeing that the emission cost has increased. That will even out the cost of the advantage of the new technology to start with. Those are the areas we see we will need support to get this transformation started.

Q120 **Aaron Bell:** Dr Leese, for your members is it cost or supply that is the biggest issue, or are there other issues?

Dr Leese: Without a supply, we cannot determine the cost. The amount of supply will determine the cost. We certainly do not have a supply network for hydrogen at scale for combustion purposes at the moment. We at MPA are running trials with our members. If we had a full-scale hydrogen combustor cement plant, we would be looking at 1 million trailers of hydrogen being delivered to site each year. That is the scale of hydrogen delivery that is needed. Clearly, that is impractical.

It depends on the method of production in how you look at the cost. If you go down the electrolysis route, we can expect that to produce a massive demand on the electricity system. We have seen electricity prices in the UK rise by 205% in the last 20 years anyway. The UK has some of the most expensive electricity in Europe.

If we are expecting our members to install electrolysers, relief would be needed for the additional power, if that power were available. The Committee on Climate Change—I think Baroness Brown mentioned this in the previous session—has forecast that the electricity system in the UK needs to be two times the size it currently is. In some of its scenarios, it is probably nearer three times. We need a massive amount of power in the system if we are going down the electrolysis route.

Q121 **Aaron Bell:** Dr Pei mentioned the demand side for low-carbon steel. Is there significant demand out there for low-carbon cement? Is that what your members are hearing? Is there a demand?

Dr Leese: You can get low-carbon cement today. I am running a project in MPA whereby some of the new products that we are making are 60% to 66% lower carbon than the current market leader. We are going through a standardisation process for those cements. Some of our members are providing offsetted products that are essentially carbon neutral.

The products are out there. I would say that the demand is not as strong as we would like. We have quite a huge task in educating the specifier and contractor community, and particularly the client community, about using some of these new products that might steer away from traditional convention. Obviously, construction is quite a conservative sector to supply, for obvious reasons.

Q122 **Aaron Bell:** You said that the demand is not as strong as you would like. Is there not much commercial imperative? Is it mostly public sector bodies that are ordering low-carbon cement in your experience, because of their obligations, or is there a commercial imperative for low-carbon cement from private sector organisations, too?

Dr Leese: Certainly in some of the big projects. We saw this with the Olympic Park. That is where it mostly started. We are working with HS2, for example, on some very low-carbon demonstrations. There are bits out there. It is moving very quickly, to be fair.

Q123 **Aaron Bell:** Mr Booth, may I come to you, and go back to the initial question about what the main challenges your industry, and indeed the

Tees Valley area, have found in adopting hydrogen, and low-carbon hydrogen, in particular?

Paul Booth: I think that, if the existing industries were all here together, they would say that one thing we need is certainty. These are big investment decisions that we are asking companies to make. Certainly, carbon price and structure are very important. It would be very helpful if we delivered certainty around that regulatory framework that went beyond the life of the project. In the past we have seen big project decisions being made based on a price, which then changes one or two years later. That is very unhelpful.

That also applies to whatever regulatory framework is put in place to incentivise the positive side. One thing I would say is that it is not necessarily asking the Government for money. It is asking for certainty in policy, and within those frameworks an understanding of the huge capital investments that companies have to make to ensure a certain payback. The risk, of course, is that the investments are not made because that certainty does not exist. That is probably one point that I would make, which is a general point.

The other point is to do with technology. We have touched on this. I mentioned depolymerisation earlier. I am aware that there are new catalyst developments in Japan to mobilise polymers at far lower temperatures. We are at the beginning of this journey, and we probably do not have enough time to go through all the examples now, but if the UK wants to be leading in some of these technologies, we have to think about how we engage collectively with academia, with certain industries, and with Government bodies, with UKRI and others, to figure out which of these areas of R&D and innovation we wish to pursue. That will be what value and what impact we think it will have on the economy, and on the environment. There are two or three or four—and I have mentioned one—that I think are very important for us to work on collectively that will make this far better for industry going forward.

Currently, rare earth elements—you might ask what this has to do with hydrogen, and there is an answer—are becoming increasingly short in supply. There are some 64 million tonnes of electronic goods lying around the globe not being processed. Recovering rare earth elements is going to become a critical part of what we do. The point about that is that, if you think about laptops or mobiles, or whatever, 60% to 70% of those are polymer. I come back to my point that properly, professionally and carefully recycling that with the use of hydrogen as a holistic systems approach becomes far more economic, and a far smarter thing to do. It is those areas where we need to be seeking help and collaboration.

Q124 **Aaron Bell:** As chair of the LEP, you are partly responsible for regenerating the Tees Valley. You mentioned the overall role for the UK. How can industrial decarbonisation be driven without harming the international competitivity of domestic companies such as the ones in the Tees Valley? Do we need carbon border adjustment mechanisms, for example?

Paul Booth: We would argue for a level playing field, so, yes. The only other way would be that we come up with things that are so smart and so competitive it becomes irrelevant. I think that at this stage I am not sure that we are there. I am not into protectionism per se, but I think it is about being the incubator for some of these new technologies, recognising that they will become world beaters, and they will stand on their own, whether or not other countries subsidise their own.

Q125 **Aaron Bell:** You will have seen yesterday that we had the Second Reading of the ARIA Bill in the Commons. Do you see a role for ARIA in some of the things you are talking about?

Paul Booth: Yes, but not exclusively so.

Q126 **Aaron Bell:** I will go to Dr Pei on that last point about international competitivity. You have an international perspective from your company. What mechanisms are needed to have that level playing field that Mr Booth just spoke about?

Dr Pei: For the steel industry it is important because Europe is now leading the development and we are likely to be the first companies to move ahead with big investment decisions. Initial support—policy support—will be necessary to have a level playing field. Currently, the European Union is discussing its common border adjustment mechanism. We believe that, initially, that will be necessary.

We see also a need for policy support in supporting the de-risking of the first large industrial deployment projects, because the first facilities will have higher costs than fully commercial developed projects in the future. Initial support will be necessary, and in the transition period common border adjustment mechanisms might be a tool that we see as necessary.

Q127 **Aaron Bell:** Were the UK or the EU emissions trading schemes the driving force behind what your company did to use low-carbon hydrogen?

Dr Pei: We saw the need for reducing emissions overall in the industry. The market was also asking for possibilities to decarbonise. Those are of course the underlying reasons why we invested a huge amount of our own resources and drove this technology development. In the future, we believe that fossil-free steel products will be a premium product and customers will be ready to pay a premium, but initially, before the market is there, we believe that policy support is necessary.

Q128 **Rebecca Long Bailey:** Thank you, everybody, for coming today. It has been so interesting so far.

I want to focus on the Government’s hydrogen strategy. Recently, the Institution of Mechanical Engineers highlighted the fact that a number of policies are quite disadvantageous for hydrogen compared with fossil fuels—for example, a higher VAT rate on hydrogen than red diesel, and double taxation on hydrogen as an industrial fuel.

The Mineral Products Association has also set out examples of de-incentivisation, such as in lime manufacturing, where electricity generation is preferentially subsidised. That means that there is no commercial incentive to investigate the prospect of biogas.

Very generally, what are the disadvantages of the Government's current hydrogen strategy, in your view, and what changes would you like to see immediately?

Dr Leese: We have an energy White Paper and an industrial strategy, but we do not have a hydrogen strategy just yet. Joining these things up is very important. I would add into the mix the Treasury's review of meeting net zero, in which the Treasury has outlined that carbon leakage will increase as emissions reduce. The cost of transition is uncertain and depends on these key policy decisions.

We need the hydrogen strategy to deal with production and consumption. If we draw some parallels to how renewables have been deployed in the UK, obviously, that has added considerable policy cost to the energy price. Some of that policy cost is partially exempted or relieved for some energy-intensive activities.

That is not all. What we will need if we are going to make the switch to greater gas consumption, particularly hydrogen, is those reliefs, compensations or exemptions for energy-intensive users, otherwise we will just export the problem somewhere else. Yesterday, the Just Transition Commission picked up on the point that we made in our evidence to that session, that you cannot just export the environmental responsibility to other countries.

We need that cost to be equalised. Whether it is for allocation within a UK emissions trading system, or a carbon border adjustment mechanism, and/or relief against the higher energy prices, we need to be able to operate on a level playing field compared with our competitors overseas.

To give you an example of what that means for the cement industry in the UK, we are currently importing 23% of the cement demand into the UK, despite the fact that we have enough limestone in the UK to make all the cement we need. Every year for about the last 10 years imports have increased by about a percentage point per year. If we do not get this right with the transition to net zero, we will continue to lose energy-intensive production from the UK.

Q129 **Rebecca Long Bailey:** Mr Booth, I put the same question to you. You also mentioned earlier a need for certainty in the regulatory framework. Will you elaborate a little on that?

Paul Booth: I do not want to appear critical. If you go back historically and look at how carbon has been priced, and how it has varied over the last 15 to 20 years, if you get significant changes, for whatever reason, you usually find, from my experience, that those changes occurred in the middle of where you have built something on the expectation of a certain carbon price. It has gone up, which meant the payback did not occur because the carbon price went up. Again, I can write to you and give you examples of where projects were not penalised, but did not have the payback that was expected because carbon prices changed through the life of the project. I can give you some examples of those. That is what I meant by certainty.

CFDs are also interesting. If you look at the very early days of wind, contracts for difference were only for very short periods, perhaps two or three years, and now they are five years or thereabouts. In investment terms, if you are going to take out a 20-year lease to develop a new factory and you have a five-year CFD, that is not very certain. I am not saying you do not do it, but it adds uncertainty into the mix about whether the investment comes here, or whether you can get better certainty somewhere else. That is the point. That is another example.

On the point of taxation, I could not talk about where red diesel is because I do not understand that at all. What I would say in terms of mass balance is that any Government should be doing that with their eyes open. Yes, hydrogen might be more expensive, but if you go back into the roll-through of carbon taxation, you need to look at the overall mass balance effect. If we are trying to encourage the UK essentially to go green, there needs to be sufficient incentive in the overall mass balance equation to make us go that way. If it is even close, my suggestion is that the companies will not bother. It is about understanding and doing that maths, so that we can absolutely pick the sweet spot that encourages investment. It is not just those numbers; it is all the other numbers as well.

Q130 **Rebecca Long Bailey:** Thank you, that is really helpful. Dr Pei, you mentioned the EU emissions trading scheme being incredibly helpful, but how has the Swedish Government specifically supported your work?

Dr Pei: I would clarify that the current EU emissions trading system does not support breakthrough technologies. That is an aspect I have been working on.

Coming to Swedish Government support, the most important aspect for us before we started the HYBRIT initiative is that Sweden was among the first countries in Europe to adopt a climate law. The country has decided to become completely fossil free, or carbon neutral, before 2045. That is of course a very clear signal for the whole industry and the whole of society that we will move in that direction. When we started the HYBRIT initiative, we got support to do the research and development work so far. That has been extremely appreciated.

The next most important support that we look forward to is support for us to bring the technology up to scale. Right now we are working on that and, as I mentioned earlier, the availability of fossil-free electricity will be key for us.

There is also the development of infrastructure. The steel industry in Sweden and Finland will need to produce green hydrogen on our production sites—the grid connection where we have a very long permit time in a focused area for us to work with the Government.

Last but not least, we need support to de-risk the first industrial deployment.

In all these areas, we are currently in very good conversations with the Swedish Government. We hope that we will be successful in making the decisions that we need for the coming years.

Q131 **Rebecca Long Bailey:** Focusing specifically on industry, I have heard many people say there is somewhat of a hydrogen paradox, exemplified by the fact that the potential volumes are in industry, but the potential profit margins are largely in transport and home use. However, as Dr Leese will know, the Mineral Products Association has argued that the few alternative options for decarbonisation mean that industrial applications should be prioritised for hydrogen supply. Do you all think that it makes more sense to grow demand in sectors such as heavy industry where there is no decarbonisation alternative? How will the industrial use of hydrogen be affected if the focus is on deployment in other sectors rather than specifically focusing on heavy industry at this stage?

Paul Booth: We need to find a way to do both. The need to decarbonise the major CO_2 emitting areas, like Teesside at 10 million tonnes, is an emergency, and needs to be addressed, and it is being addressed.

Hydrogen use in the rail system is relatively—everything is relative—easy to do. I think there are other areas, in terms of a Pareto and measuring where the impact is and what good it will do. If that prevents us, for instance, from electrifying the whole system, that must save the UK trillions. It is looking at the use of that molecule and what the impact of it is. If we go through that process, it will give us a road map for how this rolls out. Where domestic fits into that, I could not say, but at least we would all have a common understanding of the economic priorities and the environmental impact. That is something the public would understand. Sorry, I did not quite answer your question.

Q132 **Rebecca Long Bailey:** That was really helpful. Thank you, Mr Booth. Dr Leese, the same question to you.

Dr Leese: It is a really interesting question. The decarbonisation path that we know we need to be on requires all of it to be done. The Committee on Climate Change has done the modelling and maximised all the potential, and it all has to happen at the same time for us to get to net zero.

In terms of whether you go with the distributed demand in transport and domestic, or the concentrated demand in industry, if I draw a parallel with the way the electricity system works at the moment, it is the industrial consumers that pay the lion's share of the network costs. The distribution and transmission system costs fall within the large-volume users. Whichever way we go, whether the Government go down the distributed consumption promotion or the concentrated consumption promotion, we have to ensure that the costs are fairly attributed. That is all I would say on industry versus domestic.

On the alternatives to decarbonisation, you are right: lime production decarbonisation opportunities are slightly lower than cement in fuel switching and carbon capture. In cement, we have a road map to be on net zero by 2050. Within that, there are seven levers, three of which are the principal decarbonisation levers. Fuel switching is one, low-carbon products is another and carbon capture is another.

If as the UK we put our shoulder behind carbon capture, it has benefits for industry, and it has benefits for fuel production—in particular, hydrogen. Carbon capture is a considerable enabler to decarbonisation. Really, if we are to focus anywhere where we need action now, carbon capture infrastructure and capability is one of the key areas, not just in the clusters where the Government are currently focusing their attention.

Q133 **Rebecca Long Bailey:** Thank you, Dr Leese. Dr Pei, what are your thoughts?

Dr Pei: In a Swedish context, the steel industry is one of the areas that we need to prioritise. Hydrogen has the possibility to play a major role because iron ore reduction in coal is where we get the most benefit from using hydrogen. Swedish society is already very much electrified everywhere that it is possible to use electricity. In Sweden, there are of course ongoing discussions in many sectors, including the decarbonised transportation sectors and so on, but heavy industry, especially the steel industry, is working very hard to get started with decarbonisation, and hydrogen is the key enabler for us.

Q134 **Rebecca Long Bailey:** Moving on, the glass industry has proposed the establishment of a national industrial hydrogen combustion centre to research common challenges across foundation industries. This is in response to criticisms from across industry that there is not enough support for R&D and hydrogen research. Would you agree with the proposal by the glass industry for a national industrial hydrogen combustion centre? Do you think there is enough overlap between industries for such an initiative?

Dr Leese: We work very closely with glass, chemicals, steel and other sectors. There are many commonalties to our request. I think we have a general request that we need more research in our industries, and we need more development, but, particularly, we need more demonstration. The project that I am running demonstrating gaseous hydrogen consumption in cement and lime production is going to be absolutely invaluable in providing the information we need to see whether we can still make quality products, that we do not destroy kiln systems in the process, and that we can modify our processes.

There are definite commonalties. Provided that such a research centre covers all the energy-intensive processes, I would see that as a welcome initiative.

Paul Booth: First, I think the answer to that is yes. At Teesside University I am now part of building something called the Net Zero Innovation Hub, which is primarily focusing on research into hydrogen systems, be it combustion or chemistry, as I was describing earlier. I would say that having a national centre that focuses on combustion only is too narrow, because the route to decarbonisation, as I have tried to explain, is not just about energy and fuel. It is a far more broad-ranging topic than that. I would encourage that. We are building this centre in Teesside, and I am not suggesting that is it, but I would argue that it needs to be a more holistic approach.

At the risk of being criticised by my learned colleague, clearly clusters lend themselves to carbon capture and storage and hydrogen production, but there are factories around the UK that are not in clusters that emit CO_2. For instance, the Sabatier process, which is reacting hydrogen with CO_2 from your factory, gives you methane. People will argue that is not very economical. What do we have to do to be able to work a process where you can get green hydrogen to a point where you are using it to essentially reduce or remove the emissions from factories that are not in clusters? I give that as an example of where R&D and innovation are required. It is not necessarily hydrogen combustion, but where hydrogen is used in those situations to decarbonise industries that are not in clusters. There are all the chemistry examples I gave earlier as well.

Q135 **Rebecca Long Bailey:** Would you say that a strategy based on industrial clusters is really the best option, because you have just identified the vulnerabilities of that system for factories and businesses outside the cluster?

Paul Booth: The fact is we have the clusters whether we want them or not. They are a fact of life. There is a transition. What life will look like in 50 years' time, people do not know. Right now we have these clusters, and, therefore, the opportunity to collect the emissions and to manage the hydrogen economy in those areas is clear and obvious.

How that goes forward is a question. My point is that it does not need to be like that. It could become far more distributed going forwards, if we have developed technologies that allow a distributed system out of manufacturing, if you see what I mean.

You would not necessarily be building a cluster in 10 or 15 years' time if the economics suggested we could do it in a different way. One reason clusters exist in the first place is what I call industrial symbiosis, where industries sitting next to each other are energy-efficient or product efficient, or whatever. That is why they are there. That is always going to be the case, whether there is a hydrogen economy or not.

Q136 **Rebecca Long Bailey:** Finally, Dr Pei, is there anything you would like to add either on industrial clusters, the creation of a hydrogen combustion centre, or any other general points you have picked up?

Dr Pei: From the Swedish perspective again, because I am not very familiar with the UK situation, hydrogen is very new for us as an energy source. In the HYBRIT initiative we are developing hydrogen storage technologies. Hopefully, that will create possibilities for other sectors to get access to large-scale hydrogen. We believe that, if we can work together around areas that can get the benefits of future hydrogen that will be available when we develop the whole technology, that will be beneficial to everyone.

Chair: Thank you very much indeed, Rebecca. Thank you to our witnesses today, Dr Pei, Dr Leese and Mr Booth. It has been very helpful to understand some of the possibilities of hydrogen, especially in the steel sector, in mineral products and the chemical industry, which is very prominent on Teesside.

The Committee will continue its inquiry. Our next session will be diving deep into the use of hydrogen in modes of transport.