HOUSE OF COMMONS

Environmental Audit Committee

Oral evidence: Technological innovations and climate change: green steel, HC 1093

Wednesday 20 April 2022

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Watch the meeting

Members present: Philip Dunne (Chair); Sir Robert Goodwill; James Gray; Ian Levy; Clive Lewis; Caroline Lucas; Jerome Mayhew; John McNally; Dr Matthew Offord; Claudia Webbe.

Questions 1-46

Witnesses

I: Frank Aaskov, Energy and Climate Change Policy Manager, UK Steel; Professor Barbara Rossi, Associate Professor and Tutorial Fellow in Engineering Science, Sustainable Metal Structures Research Group, University of Oxford; Ebrahim Takolia, CEO, Green Hydrogen Solutions; and Professor David Worsley, Director, Strategic University Steel Technology and Innovation Network (SUSTAIN).

Written evidence from witnesses:

Dr Barbara Rossi

UK Steel

Strategic University Steel Technology and Innovation Network (SUSTAIN)/ Swansea University

Examination of witnesses

Witnesses: Frank Aaskov, Professor Barbara Rossi, Ebrahim Takolia and Professor David Worsley.

Q1 **Chair:** Good afternoon and welcome to the first of two oral sessions in the Environmental Audit Committee's latest inquiry, into technological innovations and climate change, looking at green steel. I am very pleased that we have had 25 written submissions to this inquiry—it is an increasingly topical subject. We have a panel of four experts in their field to answer some of our questions. I will ask our witnesses to introduce themselves, starting with Professor Barbara Rossi from the University of Oxford.

Professor Rossi: My name is Barbara Rossi. I am a professor in engineering science at the University of Oxford, where I recently started to lead a research group on the sustainability of metals in the construction sector.

Chair: Thank you very much. We are joined online by Ebrahim Takolia from Green Hydrogen Solutions. Welcome, Ebrahim. I think you are calling in from South Africa, so we are particularly grateful to you for making the effort.

Ebrahim Takolia: No problem. Thank you very much. At Green Hydrogen Solutions, we focus on electrolytic hydrogen, and we were recently awarded an innovation grant by Innovate UK, so we have done some projects in the sector. We are mindful of the opportunities but also of the challenge, and we would like to impart some of that knowledge of green steel to the Committee.

Chair: Thank you very much. Back in the room, we are joined by Frank Aaskov from UK Steel.

Frank Aaskov: Good afternoon, Chair. I am Frank Aaskov from UK Steel. We are the trade body that represents the steel sector here in the UK. I work specifically with climate change, decarbonisation and energy within the body.

Chair: Thank you. We also have Professor David Worsley from SUSTAIN.

Professor Worsley: Hi. I am Dave Worsley, a professor at Swansea University working with a range of UK universities on the SUSTAIN project, which is about transitioning the steel industry to lower-carbon solutions—that is with all five of the main UK steel producers. I also have the privilege of running an organisation called SPECIFIC, which I think links to some of the work that Barbara does, exploring how we use more steel in manufactured buildings and how we can power those differently using printed solar cells and such.

Q2 **Chair:** Terrific. If I may, David, I would like to start my line of questioning with you in the light of what you just said. The Committee has been concluding a report into the sustainability of the built environment, and

clearly the main components of building materials are the steel and concrete used in industrial and commercial buildings. There is growing concern about whether we will be able to meet the kind of decarbonisation ambitions the Government has set to get to net zero Britain if we do not decarbonise the production of steel. Could you give us your sense of how that is going and what kind of timeframes we are talking about? Will the UK be in a position to produce steel in a decarbonised way?

Professor Worsley: I will simply say to start that I think the construction industry is a massive opportunity for steel. It has the advantage over some of the other sectors that steel is supplied into that, for some of the net zero technologies that might be used—be that electric arc furnaces, or certainly more use of scrap—the products are less sensitive to those materials.

I think there is a tremendous opportunity for construction in steel, and it is something that I think the UK industry is particularly well set up to service, because it has British Steel, which makes long products and things like that; the Tata Group, which makes all sorts of cladding materials; and then those such as Celsa, which make the reinforcement bar and so on that is required in concrete.

I think that this is an ideal vehicle to push net zero products through, and it is a massive growth opportunity, particularly when you introduce modern methods of manufacturing into construction and you are able to consider how we make buildings a little like how we make cars, instead of like how we made buildings in the 15th century.

Q3 **Chair:** Professor Rossi, would you like to give an overview of your sense of how feasible decarbonisation of this critical building material is?

Professor Rossi: Your question is about decarbonisation of steel as a construction material in the construction sector?

Chair: Yes.

Professor Rossi: First of all, that was a terrific response from my colleague here. I completely agree with what was just said: the construction sector currently utilises roughly 50% to 60% of all the steel that we need in the UK, so it is one of the sectors that could lead to a lot of decarbonisation. I do think that the way we build our buildings and our structures today is not necessarily hugely efficient. One of the examples I can give you is that today, for instance, when we build a building, we usually over-specify the members—the columns and the beams—that are needed for that building by a factor that can approach two. So there is a lot of work that can be done in the way we utilise steel, because obviously the first thing that we should do is use less steel, before we think about making steel more green. That is something I wanted to underline, first of all.

The second thing I want to underline is that the construction sector is also characterised by the fact that it produces scrap that has some value, because the percentage of contamination in it is very low. I believe it

contains less than 0.1% copper, so there is a lot of interest in making sure we recover that scrap up to a higher level. We already recover almost 90% of the steel that we put in our buildings, so there is not much that can still be done, but I think we can still do something.

It is not only about recovering that scrap and reusing or re-melting that scrap. I think we could reuse the products that we make for the construction sector—for instance, hollow sections, I-profiles and all these products that we currently use on a daily basis in our buildings and have used for the past 50 years. All these products are simply discarded—they are simply shredded, used and re-melted. We could reuse those products. So that is the second point that is important in the construction sector that could lead to massive reduction of our impacts. Then, eventually, the rest of it has to be recycled.

Q4 **Chair:** Frank, could I ask you to explain to us how the current steel process is capable or not capable—the alternative means—of decarbonising or producing green steel, just as a descriptor?

Frank Aaskov: Yes, of course. I am happy to do that. If we look at the steel sector as a whole, there are basically three approaches to decarbonisation of the sector. First of all, you have the electric arc furnaces that melt scrap steel. It is already an existing technology; it has worked for over 100 years. It works really well, and there are more and more steel products and steel grades that you can make with that technology. Really, the limitation is only about the business case for doing more in the UK.

Then you have carbon capture and storage, where you capture the emissions from the existing blast furnaces. That allows you to continue to make virgin steel. From a global perspective, we need more virgin steel. Overall, again from a global perspective, the demand for steel increases every single year, and we do not have enough scrap steel to rely solely on electric arc furnaces, so going down the CCUS route will continue to allow us to make more virgin steel. Again, that is very needed for certain products where contamination requirements are very strict.

Finally, you have the more novel technology, which is hydrogen-based steelmaking. This is where, instead of using coking coal to reduce the iron ore, you go in and use hydrogen as the chemical element to reduce the iron ore into the more pure form of steel. That is a more novel technology. From our perspective, some of the limitations there are about the supply of hydrogen and the affordability of it. Fundamentally, from our point of view, it is less a question of technology-readiness today, and more a question about having the right policy framework in place and having a business case that is attractive enough to attract all this investment inwards into the UK. With some of these transitions that the steel companies are having to make to meet net zero targets, you are talking £1.5 billion to £2 billion per kit, and this is not something that is done without substantial Government support. Really, a Government-industry partnership is needed.

Q5 **Chair:** We will come on to that in a second. I am going to bring in Ebrahim about the hydrogen solution in a moment, but is there anywhere in the world that you are aware of that is currently investing in hydrogen capacity as you have described—the £1.5 billion to £2 billion per plant?

Frank Aaskov: Yes, we are seeing a number of plants making that advancement. The primary one among them is the hybrid plant in Sweden. That has been ongoing since 2016 but, again, that was started with support from the Swedish Energy Agency and received EU support—innovation funding and so forth. There are also a couple of plants around, in Canada and Germany, but they are all doing the initial step of investing in what is called a direct reduced iron—DRI—plant, which allows them to use natural gas initially until the hydrogen supply is available. Once that is available and affordable, they can start making the switch over. It is a less common form of producing steel today, but it is available, and companies are making those steps across Europe.

Q6 **Chair:** Thank you. Ebrahim, would you like to comment on the hydrogen potential? Perhaps you could explain what it is that Innovate UK has invested in your business to do.

Ebrahim Takolia: I concur with a lot of the comments that have been made. Hydrogen will be used in direct reduced iron. One of the challenges that exists today around hydrogen from electricity—what we call electrolytic or green hydrogen—is that the electricity price is the biggest driver of the cost of the hydrogen, and you need a substantial portion of renewable electricity to make the hydrogen price cost-competitive relative to other options. We do see that natural gas with carbon capture will be the first step as we work on the process to get hydrogen costs lower.

The project that we were looking at with Innovate UK is not related to ironmaking, but to hydrogen production for marine use. However, we managed to get a lot of information out of that project, looking at the various options around hydrogen production. At today's prices, it is not competitive with diesel in the marine sector, and we also found that it is not competitive with natural gas. At a point in the future, if there are much more substantial investments in renewable energy—for example, if the UK goes to 30 to 50 GW of renewables—there will be times where you have surplus wind capacity, for example, and those electricity prices will be extremely low. At some points in time, due to contracts for difference, those prices could be negative. When you have large volumes of electricity that can be available at a very cheap price, green hydrogen could be very competitive, but that will still take a few years.

What we are looking at is pilot projects like the ones that have been done in Sweden and, I think, one or two other countries as well. They have managed to produce steel from green hydrogen, but the cost is the challenge. A first step is to maybe do a pilot project that has buy-in from industry generally, from both the hydrogen side and the steelmaking side, and then to proceed from that to build out something more substantial, because the investment required is quite large.

Q7 **Chair:** Thank you. Barbara, from what we have heard, we are in the very early days of developing a decarbonised approach to steel in this country. The Government have set a target of 2035 to achieve decarbonised steel production. Do you think there is any chance of that being achieved? Around what principles was it based?

Professor Rossi: There is obviously a big challenge here, because the steel industry in the UK is still responsible for 10% to 15% of carbon emissions. We could close virtually all steel production plants in the UK and our emissions would be zero, but that would be an unviable solution for many different reasons, one of which is that we would just displace our emissions to another place in the world.

Bouncing off the responses of my colleagues, one of the solutions—electric arc furnaces—is completely scalable today, readily available and can be immediately put in place. I believe that it can also be combined with the position of the UK, which is in a leading position in terms of the production of low-emission electricity. If we combined those two ideas and put in place a redirection of steel production in the UK towards electric arc furnaces, there is a chance that we could catch the train and still be on track by 2035.

Q8 **Chair:** The Government announced back in 2019 a clean steel fund but have since deferred the ability to bid into it—I think until next year. To what extent has that impacted on the industry's enthusiasm and willingness to invest? David, perhaps you are best placed to talk about the industry as a whole.

Professor Worsley: That fund is a critical element, but if I look at what is happening in other parts of the world, it is only part of the solution. I was saying to my colleagues outside that in the green hydrogen world, for example, Spain is just about to spend €30 billion on scale-up of green hydrogen. The amount of funding that we need to put in simply to transition the electricity supply so that it is genuinely green—so that the electric arc furnace is not making carbon over here as opposed to carbon somewhere else—is substantial.

The green steel fund is a very important element. I think it is also related to funding that was returned to the UK from the European Coal and Steel Community, and that is probably as good a reason as any to hand it over to the industry. It is probably just a catalyst, or a nucleation point, for change. There needs to be a substantial long-term commitment to transitioning the sector from all aspects of Government, academia and the industry itself. I see from the industrial partners that they are very keen to do it, and I think the UK's industrial make-up, for the steel industry, is quite interesting because the different businesses have quite different market sectors that they service, but they all genuinely overlap in construction, which is where I think there is a tremendous opportunity.

Q9 **Chair:** During my lifetime—a bit longer than yours, Frank—my recollection of the way the steel industry has progressed is that there has been a pretty steady decline, going through step changes as each plant closes. Is

it your expectation that we can reverse that decline, retain jobs and manufacture in the UK if we do decarbonise steel? Or would it be better if we did not decarbonise steel and just carried on until such a time as it is all imported?

Frank Aaskov: It is a very good question. I think the net zero target sets us a binary choice: either you have a decarbonised steel sector or you do not have a steel sector at all. That is the choice in front of us and in front of this industry at the moment. I know which choice we would like to make: retain the jobs and retain production here. I think it really presents us with a significant opportunity to secure those jobs—a part of levelling up. Most of the 32,000 jobs in the steel industry are located in south Wales, the Humber region, Yorkshire—areas that the Government already want to level up—so there is a massive opportunity here to transition the existing jobs that are, in a way, fossil based, over to green jobs for the future.

This is not something that has already happened that we cannot reverse. Effectively, if the Government provide the right business environment, as is now being created in different countries across the world, you can see investment flowing into the UK, into new electric arc furnaces, into carbon capture and storage, and into new hydrogen-based projects. There is no reason why that should not happen here in the UK. We have significant demand for steel every single year. We have world-leading universities that are doing research on it. We have supply chains that can support it. So, with the right business environment, there is nothing that could stop us decarbonising the sector and even growing it.

Q10 **Chair:** Does that rely on continuous production of coking coal domestically, or can we rely on imports of coking coal while we need it?

Frank Aaskov: In terms of coking coal specifically—I know that there has been some debate about potential domestic mining of coking coal—at the moment the UK steel industry buys its coking coal on the world market, and it will continue to do so in the future. It doesn't necessarily rely on one source versus another. Obviously, the recent invasion of Ukraine by Russia has posed some challenges, because some coal has been supplied from there, but now companies have taken the responsible step of phasing that out.

Q11 **Chair:** What proportion comes from Russia or Ukraine?

Frank Aaskov: I don't recall; I do apologise for that.

Chair: Does anybody know the answer?

Professor Worsley: I'm afraid I don't, no. Russian coal is a relatively small proportion, because it is of somewhat poor quality.

Q12 **Chair:** It's mostly coming from Australia, is it?

Professor Worsley: Yes.

Chair: Thank you.

Q13 **Sir Robert Goodwill:** I recall that when I was shipping Minister, at almost every deep-water bulk port that I went to, there was a massive heap of scrap that I was told was going to be exported to China. Meanwhile, we are bringing iron ore and coking coal from Australia. Is there any reason why we can't have an industry that is more balanced in terms of using our own scrap? Is it the quality or the availability that is an issue? Professor Rossi, perhaps you can comment on why we don't use more of our own scrap and import less iron ore.

Professor Rossi: Yes, I can. I may be a bit in disagreement with my colleagues here, but I do not think that there is today, or there will be in the future, a scrap shortage. We are generating in the UK every year about 10 million tonnes of scrap—undifferentiated, if I am not mistaken—and studies show that this is likely to increase to 20 million tonnes within the next decade, and even more. That is due to the fact that in the 1970s there was a boom in the construction sector. We used a massive amount of steel and so that steel is buried everywhere in our buildings and infrastructure and we are going to have to recycle that steel.

Unlike some other comments that were made, my comment is that there is a point in developed countries where we no longer need new steel, and that point is roughly when we have 250 kg or 300 kg per capita. That is basically why in the UK we are seeing that our needs for steel are stabilising at around 10 million tonnes to 12 million tonnes per annum. So I am a fervent defender of a redirection of the use of our scrap into electric arc furnaces to produce liquid steel. I think it would solve part of the problem—combined with the fact that the UK has a leadership role in producing low emission electricity.

Studies also show that if we were to electrify all our current activities with what we have today, with the green electricity that we produce, we would possibly be able to get 70% of our steel made, and this would lead to roughly 7 million tonnes or 8 million tonnes. If we combine that idea with what David and I were describing at the beginning of the conversation—reducing our need for steel, especially in the construction sector—we could possibly produce all the steel we need in the UK using our scrap.

Q14 **Sir Robert Goodwill:** I recall the ghost ships in Hartlepool. They brought some former US naval vessels in, and there was a tremendous furore about the environmental effect that would have. I presume that there is an awful lot of mobile scrap around the world, in terms of ships that could be broken up. Is one way that we could help fill the deficit by becoming more of a centre for the scrapping of ships in the UK? All our steel plants—well, the big ones—are near the shore. Is one way that we could import more steel by seeing ourselves as a ship-wrecking country?

Professor Rossi: I will reserve my comments on that.

Professor Worsley: The opportunity in the circular economy is absolutely fantastic. As you say, the two main integrated works are very close to deep-water harbours, and—particularly if you consider things like freeport status—that enables them to set up a very effective reprocessing

operation. There are some challenges that we need to address in terms of how the scrap market is controlled. Other countries have introduced scrap export restrictions, particularly around higher-quality grades of material. The problem comes, particularly in the south Wales businesses, with very thin strip steel, because it is particularly contaminant dependent. However, that all comes down to how good the quality is of the material that you are getting in the first place. We have a lot of scrap in the UK that we could use.

Although it is a huge opportunity, we still need to remember that the south Wales grid is currently running at something like 340 grams of carbon per kilowatt-hour. That means that when I charge up my car, if I don't use solar panels, I am sticking 15 kg into the atmosphere. That is something that we need to remember, because we have to take the investment and put it where it makes sense. At the same time, we need a lot more renewable power in some parts of the country to enable that to happen. That will also unlock all the opportunities for green hydrogen. In south Wales, that is exemplified by the hydrogen kingdom work that is going on in Pembrokeshire.

Q15 **Sir Robert Goodwill:** There is also a site at Wylfa, where a new nuclear plant could be built.

Professor Worsley: Nuclear was off the table for some time, but it is very, very sensible. Certainly, small to medium-sized nuclear reactors need a lot of specialty steel to go into them, and the obvious place to put some of those things is around our industrial heartland to provide a level of baseload power to cover off the inevitable eventuality where you end up with some sub-prime moment in terms of the renewables.

Q16 **Sir Robert Goodwill:** Mr Aaskov, instead of having a blast furnace at Scunthorpe or Port Talbot, would it be feasible to have electric arc furnaces there and use scrap as a feedstock? Could we produce the types and quality of steel that way, or is there a problem of contamination with things like copper, as we heard?

Frank Aaskov: There are definite opportunities there. I agree with both my colleagues that there are ample opportunities to have more electric arc furnaces in this country. There are more and more grades that we can produce with this steel—even the grades where there are very strict requirements from customers on contamination and impurity from nitrogen and various tramp elements left over in the scrap. That can in large part be solved—or at least a large part of the process can be solved—by more scrap processing and better processing of the scrap. There are big movements, especially in North America, on what types of steel grades they are now producing via the scrap route.

That said, although I share that optimism, we also have to look at what is holding that back. At the moment, the key thing that is holding back more electric arc furnaces in the UK is uncompetitive electricity prices. As an industry, we pay around 60% more per kilowatt-hour than they do in Germany, and that has been more or less consistent for the last five or six

years. There is a reason why no new electric arc furnaces have been produced in this country, even though we have ample supply of scrap. That is definitely one thing that needs to be resolved now, before we can have more electric arc furnaces.

I want to come back to a point I made earlier about the global perspective. I do not think that I share my colleague's optimism about electric arc furnaces from a global perspective, because only a finite amount of scrap is available. Projections made by the International Energy Agency and the World Steel Association all suggest that about 1 billion tonnes of steel needed to be produced per year in 2015. That is because many more economies globally were modernised and urbanised—they need vehicles, rail, high-scale housing and such. Therefore, the need for steel would just continue to grow. If we install electric arc furnaces here and displace them, we are just processing the scrap here instead of abroad, rather than solving the core issue, which is how to fundamentally decarbonise ore-based steel.

Q17 **Sir Robert Goodwill:** Professor Rossi has indicated that we should reach some sort of equilibrium, where the amount of scrap produced is equivalent to the amount we need. Do you agree with those calculations?

Frank Aaskov: One could look at it from a very domestic perspective and say, "In the UK, there is potential to solve just our own issue for a per tonne amount of steel." From World Steel's data on consumption, at the moment we consume about 16 million tonnes, if we include all the steel that is embedded in products such as washing machines, other white goods and vehicles that are imported. When we take that into account, we produce only about 10 million or 11 million tonnes of scrap, so just domestically we still cannot meet all the demand, and that ignores the complexities around the types and grades of steel. There are 3,500 grades of steel, and some require very few contaminants, where at least ore-based production is necessary.

Q18 **Sir Robert Goodwill:** Professor Rossi, you talked about the high quality of steel in construction, but of course a lot of the steel in construction is embedded in concrete and is quite expensive to extract. Is some steel basically not easy to recover, because of the cost of doing so?

Professor Rossi: It is indeed not easy to recover rebar from reinforced concrete, but we do it today on a regular basis. At all the demolition sites, you can see machines crushing concrete down to little pieces and separating the rebar from the concrete. Globally, from reinforced concrete, we recover about 75% to 80% of the reinforcement, so it is huge. Today, there is absolutely no barrier apart from the cost to recovering that steel. The main challenge that confronts us is to separate the different metals, to differentiate all metals from each other, in order to be sure that we feed the electric arc furnaces with the right material.

Sir Robert Goodwill: Thank you very much.

Q19 **Caroline Lucas:** Apologies if you have said this already, but what kind of percentage of total steel demand could not be met by recycled steel

because—as you were saying—the purity is important for certain purposes? Is it 1% of total demand? I have no sense of that.

Frank Aaskov: I do not have the specific numbers. Also, at the moment, there is quite an opportunity to reduce that amount. There are more and more grades that we can do; especially, as my colleague here said, with more segregation of the scrap and more control of it, there will be more and more grades that we can produce. From my perspective, the problem is with the quantity basis, rather than necessarily the grade, and whether we replace like with like.

Professor Worsley: In the US, where they use a lot of electric arc furnaces already, with some of the very specific grades that are required in high-performance crash positions in vehicles, for example, they have to use anything up to an 80% dilution with directly reduced iron, because of the impurities that are coming in on the scrap. It is important to make sure that we get things right, because what we also want is the products that are produced to have all the properties that we want, which is why we chose steel in the first place.

In the net zero transition, as we move to EVs and have more wind farms and electrolysers and things like that, steel has a role in all of those, whether as a component or in the manufacture. I think there is huge opportunity for electric arc—I absolutely agree with that—but, globally, we need to be thinking about the total CO_2 levels on the planet, because that is the thing that is causing, say, 10 or 15 problems in south Wales now, with potential flooding considerations in all of our areas. We could transition our entire industry over, but if it doesn't map on to what happens in other parts of the world, the sea levels will continue to rise and that will flood the steelworks themselves.

Professor Rossi: In the US, I think they are massively betting on the recycling of steel. They are constructing electric arc furnaces everywhere. Different scrap facilities are joining each other to be bigger and to be spread all over the country. They are producing amazing grades of steel for aerospace applications using electric arc furnaces.

Chair: We are going to come on to international questions in a moment.

Q20 **Ian Levy:** Last Thursday, I spent the afternoon going round a biomass plant in my constituency. I found that absolutely fascinating. I recommend that to everyone on the Committee—go and look round a biomass plant if you have one.

David, biomass feedstocks appear to be one possible way to eliminate the use of coal in steelmaking, yet we don't really hear much about that. Could you expand a little bit on that? To what extent is biomass currently used in the UK steel industry as an alternative to coal?

Professor Worsley: At the moment, not a lot. One of the opportunities in the transition, in my opinion, is that more biomass could be used as you start to phase down the amount of coal that you are using. You are

basically looking for a carbon source that has not been through a geological process and whose CO_2 is not as much.

There are a lot of interesting options, not just the use of biomass. Since the mid-'90s, the Japanese have been using things like palletised plastic waste from factories close to their steelworks to provide a carbon source that is not as damaging in terms of CO_2 as coal, and which also avoids those things ending up in landfill sites. There is a huge opportunity, which embeds itself around this idea of the steel plant being the exemplar for the circular economy.

The circular economy must include natural products. Steelworks are usually surrounded by acres and acres of land. One of the things that could be done is to consider how a fast-growing biomass crop could be put on such land and used.

The HIsarna process that Tata Steel has developed in Holland is something that I think has a mixed feedstock, which also blends in hydrogen. Some of those technologies are not necessarily at the scale at which they could be deployed yet, but they are interesting and are ones that we should look at, because there could be a solution to producing the raw iron in another way that is sort of transitionary from the blast furnace technology.

Q21 **Ian Levy:** So it is more about getting the scale, as opposed to the cost.

Professor Worsley: Scale is important, but so is the function of the blast furnace. One of the things that we need to recognise is that the bits that go into it—the coal and the limestone and all that—form a kind of structure in the tower itself. Just replacing it with something else doesn't work immediately. However, there are things like pulverised coal that are injected in the base. You could easily replace that with biomass.

Q22 **Ian Levy:** That was going to be my next question. What could we do to encourage further use? Does anybody else want to come in?

Frank Aaskov: I am happy to come in. As my colleague said, at the moment we are seeing biomass being used in the UK at very small scale as biochar, and I think there have been a couple of very small-scale research projects being done at both blast furnace sites in the UK. At the moment the issue is that biomass has been aimed mainly at the power sector, so the specification of the biochar that is used is slightly different than it would be for the steel sector. We would probably have questions around whether the supply chain is sufficiently developed.

We must also look at where the incentive is at the moment. Fundamentally, the biomass plants—the biomass power plants and the like—have received a healthy amount of Government support through the renewables obligation scheme. There are no support schemes for using biomass in steelmaking. It comes down to the fact that there simply is not a business case at the moment for doing this in the UK because there is no Government structure to incentivise us to do so.

Ian Levy: That's lovely. Thank you very much.

Q23 **Jerome Mayhew:** You have given us some great evidence about how electric arc is good—in shorthand. We want to do as much recovery of pre-used steel as we can, but we have also heard evidence that there is a residual need for virgin steel. You are quite right: we should be looking at this from a global perspective as opposed to a domestic one. You gave us an estimate of about 1 billion tonnes a year. At the moment I think production is about 1.8 billion tonnes a year. You think roughly half of the current uses of virgin steel will carry on beyond 2050. Let us look at blast furnaces and what we can do to decarbonise them. Am I right in thinking that basically it is, on the one hand, green or blue hydrogen as the carbon input, or it is CCUS? That is basically it. That is the conversation we should be having.

Professor Worsley, starting with you, does CCUS work? Is it ready? What do you think?

Professor Worsley: Well, does it work? I think it can. This is my personal expert opinion. I think it is best if we include the "U" and we utilise carbon. In that way, with accurate carbon accounting, which means that we are not cheating in any way, you could turn the output of two of the largest sources of carbon in the UK into some kind of feedstock for a petrochemical industry that does not then have to get more stuff out of the ground.

Jerome Mayhew: Explain that some more.

Professor Worsley: In other words, you can use catalytic processes. Typically, you will need some hydrogen or water, but you can use those in a kind of water-gas shift reaction to convert the CO_2 into chemical precursors—either alcohols or acetic acid and things like that. That could be a very useful way of considering what are very single-point carbon emissions as a viable economic source to make small molecules that you then use to make all the other things that we use, from plastics to dyes and fabrics and so on.

Q24 **Jerome Mayhew:** Is this currently at the theoretical or pilot stage? Where is it in the journey?

Professor Worsley: I would say pilot stage. There is a company that is looking to put a pilot plant into the Port Talbot works. I think it is called LanzaTech. There is a demonstration facility in mainland Europe. It might be in Holland. That is about using the CO_2 as an additional element that they add to bioethanol to make a version of an aviation fuel.

Q25 **Jerome Mayhew:** My problem is that CCUS always seems to be 10 years away. Ten years ago we were saying that we are going to have commercial grade CCUS technology available, and we have not. This still feels—I will come to you, Mr Aaskov—like that. We are talking about whether we should have a pilot plant. That is 10 years away as well, is it not? What is the industry's view on this?

Frank Aaskov: We do not have a lack of confidence in CCUS. You can buy the kit now from the original equipment manufacturers. They are already capturing emissions from power plants, so why would we not be able to do

the same for steel plants? Again, from the industry's perspective, this is not an issue about technology readiness. These technologies are ready. For hydrogen, you can buy a DRI plant now that is ready to use hydrogen when it is available. You can buy a CCUS kit to apply to a steel site. It is about the lack of business models really.

Q26 **Jerome Mayhew:** We are going to talk about price in a second. Leaving aside price, is the industry confident that the off-the-shelf kit—I am simplifying, obviously—that you can buy now is capable of dealing with the quantities and complexity of carbon capture in the steel manufacturing process, where you have all sorts of impurities and different pressures and temperatures at 10 or a dozen different parts of the manufacturing process? Do you think you can do it now?

Frank Aaskov: It all depends on what kind of capture rate you are trying to achieve. With the current blast furnaces, depending on the site specification limitations—because of land use and so forth that we have to consider as well—you can capture between 50% and 70% of the emissions.

If you transition over to some of the modern furnaces, such as HIsarna that has been developed by Tata Steel in the Netherlands, then in the middle of the next decade you can probably get up to up to 80%-plus capture rates. In combination with biomass, that is where it becomes very interesting.

Q27 **Jerome Mayhew:** Turning to the specifics of the UK industry, we have only a couple of large-scale plants that we are looking at. When do the lifecycles of their furnaces come to a natural end? Presumably that is a known factor. Is it likely that they are going to be replaced and will require replacement within the next 10 years? They have a lifecycle of 40 to 60 years, do they not?

Professor Worsley: There are two blast furnaces in Port Talbot, one of which is probably one of the newest that has been built in Europe.

Q28 **Jerome Mayhew:** Could that get up to the 80% to 90%?

Professor Worsley: The other one is much, much older.

Frank Aaskov: I do not think either of them can get up to 80% to 90% emissions. They would have to be replaced eventually. The whole question is about cumulative emissions. Obviously, the faster we reduce emissions, the better. If we start capturing 50% to 70% now and then later capture 80%-plus, that is much better cumulatively from a global warming perspective.

Q29 **Jerome Mayhew:** I think I know the answer to this, but are you going to tell me that the industry is very engaged in this? Is it right that they are fully engaged in research and development?

Frank Aaskov: Maybe David can answer this, but from our perspective we are very engaged in this. We engage through the industrial clusters—there is the south Wales cluster and the Humber cluster—and many of our

members engage directly with university-led projects, some of which David is probably involved in as well.

Professor Worsley: Yes, the engagement is really good, but we need to create the environment that gives everyone the confidence that they can go to the next level, and there is something else to think about. We have concentrated all our talk so far on CO_2, but there are loads of other things that a steel plant produces that you can use, whether that is the slag materials that are needed in cement or the incredible amount of waste heat. The waste heat from Port Talbot is something like enough to heat 500,000 homes, so why are we not looking at that?

Everything has changed for me recently, because of the energy price. If we had been having this conversation 10 years ago, half of you would be going, "Oh yeah, but we will just buy gas—it's cheap. Gas piped to my house is cheap as anything." Now, people are saying, "Hang on," because of the increase in the gas price and the insecurity issue. If we have a massive heat source, why are we not using that?

Q30 **Jerome Mayhew:** That is a very good point. Ebrahim, you have been very patient. I am sorry we haven't turned to you in the last few minutes. What do you think about the ability to implement carbon capture technologies? We have seen the evidence that they are very location-dependent. For the storage aspect of CCUS, we have heard evidence it makes sense in plants on the east coast, because you have the southern North sea deposits and you can inject carbon dioxide back into the ground. It is much harder to see what you do in south Wales, at Port Talbot. Do you think it is a sensible way forward in a plant like Port Talbot to focus on CCUS, or are there other technologies around hydrogen that would be more appropriate? What is your view?

Ebrahim Takolia: CCUS has applications, but you need to be able to store it. There are technologies being considered where you can produce carbon black and sequester the carbon. You can also use that as a product in concrete, for example. There are various studies around that. One of the major challenges with carbon capture is the cost and scale required. From our perspective, we think there could be some opportunities, but they are very dependent on location. There will be specific locations where you could combine green hydrogen with carbon capture to produce, for example, carbon black. Again, those projects would need to be viable at scale. Carbon capture can work in specific locations, but in others it may not be possible. That is where green hydrogen could come in. Again, as prices come down and as we use more renewable electricity, we think that green hydrogen could be competitive in the medium to long term.

Q31 **Jerome Mayhew:** We keep talking about cost. It is the elephant in the room, isn't it? What impact do you estimate relying on green hydrogen to fuel a blast furnace will have? What impact is that going to have on the cost of steel? Perhaps I will come back to the industry as well. It is going to be a huge increase in price, isn't it?

Ebrahim Takolia: Yes. The best way to approach this is to ask, "What do prices look like today?" We recently did a study based on the current pricing environment. You are looking at a hydrogen price of probably £4 to £6 per kilogram, which is relatively high, but with the recent very high gas prices it has come within range. Some 70% of the cost of that hydrogen production is actually the electricity price, which is also substantially higher because of various factors. That is the situation today. Also, the electrolyser or capital costs are about 20% of the lifetime costs. How will that evolve over time? Based on the current trajectory of renewable energy, it is expected that you will have a lot more renewable energy.

As I mentioned before, the contracts for difference, the time of day of the pricing, the variable power purchase agreements, and all the smart grid technology that is being investigated globally could come into play to reduce that cost, but that will take time and will require a lot of technology. The best analogy to give is that energy is going to undergo significant disruption. We are probably in the equivalent time of 1994, when the internet started to become widely used. At that time, you would not have ever envisaged the iPhone or a Zoom call like we have now. There are things that we know are going to be coming online in the energy space, and there are some things that are being studied that may come online a bit later. I think that costs will come down for all low-carbon and renewable energies, but it will take time.

Q32 **Jerome Mayhew:** Thank you very much. My final question is to Professor Worsley. Are we doing enough research, and who should pay for it?

Professor Worsley: If you ask a university academic if we are doing enough research, the answer is obviously no. I would like to see the research community and industrial groups joined so that we do things in a peculiarly British way, where we do all the technology readiness level developments at the same time. Some of the research that is going on in the labs is probably scalable, but the industrialists need to know about it now. There are various mechanisms that the UKRI has come up with to support industry and universities working together. I think there is a huge opportunity in this sector to do all the TRL developments contiguously. Something else that we must not forget about is training up the next generation of industrial plant engineers and so on. The people that are going to operate this stuff are not going to be old guys like me; it will be a new generation of people who need to be excited about it and drawn into that world now.

Q33 **Jerome Mayhew:** The market for academic spin-off is very strong in this sector, so presumably funding should be coming from the sector, not the Government.

Professor Worsley: If you look at what people do in the rest of the world, it is usually a combinatorial effect, because people see the value of a resource like a steel industry to the whole of the rest of manufacturing. How do you get electric cars? You get steel and make them. How do you get manufactured buildings? You get steel. Like glass and some of the

other foundation industries, it underpins all other aspects of manufacturing.

Q34 **Jerome Mayhew:** Given that the steel industry is a global business and happens to be owned by foreign-domiciled companies in the UK, should that affect the degree to which the British Government should be funding research that could then benefit companies internationally, which are perhaps in competition with us? Do you see what I mean? There is a challenge there, isn't there?

Professor Worsley: Yes, I think we should take a pragmatic approach and see that the material flow supports tens of thousands of jobs in manufacturing. There is an opportunity here for the UK to be a global exemplar, because our economy, industrially, is small, compared with quite a lot of other economies. I often think that if we are able to transition the industry here, we are using quite old kit. When India or China want to transition, their industry is newer and has a lot more time to run before the ROI is there on their gear, so they will follow some of the paths that we have taken, and therefore our journey will have an international impact.

Jerome Mayhew: Thank you very much.

Q35 **John Mc Nally:** My questions follow on from Jerome's and are on hydrogen-based steel production. My first question is to Ebrahim and then to Frank. Could you give us your opinions on how the Government and the energy sector can instil confidence in the steel sector around the availability and reliability of future hydrogen infrastructure?

Ebrahim Takolia: I will talk to the availability and then the realisability. The availability of green hydrogen depends on the electricity supply. In that respect, the trajectory and the commitments to look at decarbonising the electricity supply in the long run are very good. That creates a huge demand to manufacture more wind farms or solar farms, or even to look at geothermal or wave-based technologies to produce electricity. Because of economies of scale and vast manufacturing and other capacity in the country, that reduces the cost of electricity, but it will take time. There are efficiency considerations that need to be taken into account when producing hydrogen, but they can be overcome if you have a very large, sustainable renewable energy supply. Most countries are excited about hydrogen because of that opportunity.

The other option for supply is to look at natural gas with carbon capture. That is more near-term because you have the natural gas. The carbon capture will require areas for storing the carbon or other novel approaches to maybe convert it into products. There is lots of research happening in that area around use cases for the carbon, rather than just sequestration. Those are the two issues, in terms of supply.

There is potential, but it will take time and it will need some degree of clarity and for investment to actually happen. If we get a very large carbon capture with natural gas project ongoing, the second and third ones become easier. It is the same if we look at hydrogen. We need to get

either pilot projects or large-scale projects going, depending on the technological readiness.

You could use the pipeline infrastructure with modifications—the natural gas pipeline infrastructure—for hydrogen. However, there will be some modifications required due to the volumetric difference. Based on studies currently under way, it may be possible to blend hydrogen into natural gas, up to about 15% to 20%, without submitting any modifications. The infrastructure to move hydrogen in vast volumes through pipelines exists; it may require significant modification if it is hydrogen only—meaning you are moving more than 20% hydrogen—or 100% hydrogen.

There is a lot of work being done around compression—moving hydrogen compressed to about 350 bar, which incurs a compression cost and a storage cost but not much else. That is also being looked at. It is currently proven; there are hydrogen refuelling stations that store hydrogen at that pressure. I think that the infrastructure is there. Where there is some novelty that could come into play with hydrogen is by using ammonia or what are called liquid organic hydrogen carriers; those are ways to store hydrogen as well. Those are some of the novel technologies that are being looked at. They stall at the early stage and will require scale to be economically viable.

Q36 **John Mc Nally:** Thank you; that was a really in-depth answer. Frank, would you like to comment? I would particularly like to know what Governments could actually do to nudge along the confidence. The question is, how do you instil confidence in hydrogen infrastructure in the steel sector?

Frank Aaskov: From the industry's perspective, it is still early days. We have seen that the Government announced some targets for the development of hydrogen. They are developing their hydrogen business models; they are not yet finalised, and as recently as a couple of weeks ago we saw the target of how much hydrogen we are going to have in 2030 doubled. The Government are making some positive steps there, but from our perspective it is difficult to decide when to invest. It is similar to the electric vehicle charger debate we are having now; do you invest in loads of chargers without there being demand for those chargers, or do you invest in a big fleet of electric vehicles without knowing if there are any chargers available? For us, it is a similar thing. Would you invest in a big industrial plant that uses a lot of hydrogen—or needs a lot of hydrogen—when you don't actually know how much hydrogen is going to be available? At the moment it is just targets—there are no delivery plans yet and we do not know what the cost will be. Fundamentally, that is the barrier for us to invest.

I also come back to the fact that at the moment we cannot even be certain that we can have a competitive electricity price when compared to our competitors in Europe. Why would we have confidence in getting competitively priced hydrogen? That is really the barrier, because even in the best of cases, such as in Sweden where they have developed a hybrid plant that is the most advanced using hydrogen, they are estimating a

20% to 30% increase in the cost of steel. We do not know how to pass that on to the consumer yet, because we do not have product standards or the carbon border adjustment mechanism—which the Committee has looked at previously. It all comes back to, "What do we need to advance this?" I think a partnership between industry and Government is probably the best approach. The clear equivalent is the North sea transition deal, which set a clear direction, removed policy barriers for industry to invest and allowed industry to commit to decarbonisation. If a similar partnership was created between industry and Government that said, for example, "We will ensure that x amount of hydrogen was available at x price", it would be easier for industry to make that investment decision. At the moment, that is a couple of miles ahead of where we are.

Q37 **John Mc Nally:** That reminds me that one of my colleagues said some time ago that sometimes the Government lag behind the wishes of others—in this case, the various sectors, but also people in general. That certainty of policy would maybe produce certainty of investment; the companies would follow on.

Professor Worsley: I was just going to say something about the role of hydrogen in the integrated steelworks. People often worry about the safety of using a gas that is different, but coke oven gas is 60% hydrogen and so are the blast burners' gases and things like that. The infrastructure that is there within the Port Talbot works and within the big integrated works in the north of England is ideally set up to use hydrogen when it becomes available.

I just wanted to say that, because sometimes people think you will have to replace every pipe everywhere and that it will be phenomenally expensive, but it is not.

Q38 **John Mc Nally:** You are right—it is available to absolutely achieve this at this moment.

Professor Worsley: Because they use these coke oven gases and things now that are so hydrogen-rich, a lot of the infrastructure is already hydrogen-safe; let's call it that—unlike my house.

Q39 **John Mc Nally:** My last question is to David. How developed are the plans to establish hydrogen infrastructure in Wales, compared to those in England? Once that has been answered, I would quite like to come back to the point you were making about what is happening elsewhere in other countries. I know we touched on it before, but I would like to know a wee bit more in depth about what they are doing that we are not doing.

Professor Worsley: The hydrogen plans in Wales are developing quite nicely, I think, based around the idea that there is this infrastructure that goes from west Wales, through past the integrated works and then off into the silicon valley of Wales, where the semiconductor industry is based. A third of our current gas imports come into Pembrokeshire, so that area is ideally suited to becoming a hydrogen centre, and there is a lot of work, as part of the industrial cluster, to cement together relationships between suitable industry partners—the port authority, the local authorities, the

Welsh Government and the national UK Government—to use that as a demonstrator site. The project is called the Energy Kingdom project. The idea will be that you can use the transmission network that already exists to take hydrogen to where the industrial heartland is.

The plan, theoretically, is well developed; it needs quite a lot of practical support to get it off the decks. What is really, really important from the point of view of the planet is that we focus on green hydrogen and not all the various other colours that exist, because we want to ensure that the transition is not just shifting carbon emissions to somewhere else.

John Mc Nally: I think you are emphasising that you need to practise long-termism, but you need to do it now. If you keep going on with this practice of short-termism, we will still be practising short-termism in another 100 years. It is not getting us anywhere that I can see at the moment, and we are getting there too fast.

A term you hear all the time is, "We need to do". I can see us in a year's time saying, "We should have done," and it is quite scary when you think about that. You mentioned earlier the education of children; I hope there will be an announcement tomorrow about that. Educating children will be absolutely crucial in how they understand the whole supply chain of everything that we are building.

Frank, would you like to come back on the question I asked?

Chair: Could I just interrupt you, John? We have got the last set of questions on the international aspect from Caroline.

John Mc Nally: Okay. Thank you.

Chair: Thank you for that, and thank you for reminding us about your enthusiasm for educating the young in all aspects of the work that we do. We are expecting an announcement tomorrow.

Q40 **Caroline Lucas:** I want to come to David first and ask about how the UK's current research compares to progress in other countries. I know we have touched on that already, but is there more you could say on that?

Professor Worsley: Yes. I think the UK community has come together recently—certainly in the last five years, there has been quite a galvanisation, to use a metallurgical term, of the community around the fact that we have some really good research groups at different institutions across the UK, and we have got various things such as Warwick Manufacturing Group and a scale-up centre in south Wales for industrial decarbonisation.

We have all of these things there. It is also the case that quite a lot of the regional funding from European Union sources over the last few years has come into that industrial interface, which is now becoming the decarbonisation space. What is exciting about that is there are teams of people who are experts already and capable of delivering more. A lot of them are younger people as well. That is important because we need to get those people enthused by the idea of what this transition means and

seeing it as a huge opportunity, not a reason to go and live somewhere else or buy a house on a very high hill.

There is a fantastic opportunity. The UKRI investments in steel-related matters do not stack up against, say, investments in Rolls-Royce. If I am honest, there is about £300 million across the steel companies. There is about £1 billion in Rolls-Royce. I can understand why, and some of that comes back to how we engage the industrial partners in supporting their activities, getting funding directly from BEIS to help with some of those difficult bits at the end, which are how you get the commercialised product out. We are always very good at inventing things; we are often slightly less good at actually making the final device.

Coming back to a comment made earlier, which I have been mulling over, I would rather support inward investors who were really keen on staying in the UK than UK-inspired activities that were manufacturing elsewhere. Just to say that is my own view, not that of my employer.

Q41 **Caroline Lucas:** I want to come to Professor Rossi. I know you have already touched on this, but could you say anything more about what we could learn from other countries from their research and progress towards green steel production?

Professor Rossi: Yes. I have collected a few examples that I think are quite impressive and that set the scene about international steel. First, China produces roughly 600 million tonnes per year, and they will build 43 electric arc furnaces by 2021.

Q42 **Chair:** Was that 2031?

Professor Rossi: 2021—that is last year. They got approval in 2021 for construction starting now. They got approval in 2021 to start constructing 43 electric arc furnaces and, if my notes are correct, roughly 50% of China's steel production will be based on electric arc furnaces within the next decade. In the USA, as I have already mentioned, they are producing roughly 60% to 70% of their steel using electric arc furnaces, and they are producing four grades, including the very important grades for aerospace applications.

In France, there is a very good example happening now. The Government have decided to invest €1.7 billion in Fos-sur-Mer and Dunkirk to refurbish these sites to have, I think, two new electric arc furnaces, combined with direct reduction of iron—what my colleague described a few minutes ago. Then there is India, which is committed to building up 300 million tonnes per year of additional blast furnace capacity. This is to give you a view on the competition that blast furnace is currently facing worldwide.

Q43 **Caroline Lucas:** In terms of what we can learn from that, is it about political commitment to put the resources in or is it about something more than that?

Professor Rossi: I think what we can learn from that is that it is happening everywhere. It is time to do it here in the UK. That is what we can learn from that collection of examples worldwide.

Q44 **Caroline Lucas:** Are there practices used for collecting, sorting and processing the scrap that those other countries are using that we could learn from as well, or is it straightforward?

Professor Rossi: I am not an expert in that matter, but in the US they are much better at sorting their scraps than we are. If I am not mistaken, here in the UK we just collect it all together and we melt it. That is it. In the US, it ends up in sorting facilities where you have different kinds of bins and, robotically or manually, sort the scrap into aluminium, copper and other elements. It is something that is indispensable if we want to produce high-quality steel using electric arc furnaces.

Q45 **Caroline Lucas:** This is my last question. You have all answered it, in a sense, but what action do you think the Government should take to ensure that the UK steel market does not fall any further behind its global competitors?

Frank Aaskov: If you take a step back and look at the larger question, steel is fundamentally a very carbon-intensive and trade-intensive sector. That means that if you invest in lower emission products that have higher cost in terms of producing steel, you face the real risk of being out-competed by imported steel that is high carbon but lower cost because they simply do not pay for their carbon. That leads to a need for government intervention in the market to ensure that that carbon is paid for by the competitors abroad.

What we see abroad, where companies are making great strides on this, is heavy government intervention. My colleague mentioned the French investment of €1.8 billion, announced only a couple of months ago, and the Canadian Government has invested over $200 million in hydrogen-based and $400 million in electric arc furnaces. I also mentioned the Swedish one earlier. That is all in addition to the fact that they have more generous programmes for hydrogen development, they have competitive electricity prices—much lower electricity prices than we have here—and they are developing CBAM policies in the EU.

All that is in place in addition to the generous government intervention in this, because it cannot happen without government assistance. We need to have a government-industry partnership. I do not want to repeat myself, but the North sea transition deal is an excellent example of what we really should be doing to make sure that we do not fall behind, because that would enable us to actually attract the investment inwards. We can remove all those barriers to investment putting in the new plants, and that would enable us to keep up and be the leader in this area. It is not too late. We can easily be in the vanguard of this development if the Government provides the right leadership.

Q46 **Caroline Lucas:** Do you think a CBAM is essential?

Frank Aaskov: It is either that or product standards. From an industry perspective, we talked about the cost aspect of hydrogen before, and the best estimate from the Swedish plant, which is furthest along, is a cost increase of 25% to 30% in terms of their products. Capturing carbon also

costs quite a lot, so how do you pass that on to consumers if they just say, "Oh, we will just buy the more carbon-intensive steel from abroad." You need to have some kind of leveller to make sure we have a level playing field. CBAM does that, and product standards is another option. They are complex policy tools and we definitely need to be aware that other countries and markets are developing, but we are not at the moment.

Chair: That concludes our session. I am very grateful to everybody for your concise questions and answers, because it means that we will be able to wrap up just before we all have to go and vote. I thank the panellists, in particular Ebrahim Takolia, joining us from South Africa, and those in the room, Frank Aaskov, Barbara Rossi and David Worsley.