



Economic Affairs Committee

Corrected oral evidence: UK energy supply and investment

Tuesday 10 May 2022

3 pm

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Members present: Lord Bridges of Headley (The Chair); Viscount Chandos; Lord Fox; Lord Griffiths of Fforestfach; Lord Haskel; Lord King of Lothbury; Baroness Kramer; Lord Livingston of Parkhead; Lord Monks; Baroness Noakes; Lord Rooker; Lord Skidelsky; Lord Stern of Brentford.

Evidence Session No. 17

Heard in Public

Questions 209 - 220

Witnesses

I: Marco Alverà, Hydrogen Energy Expert; Matt Harper, Chief Commercial Officer, Invinity Energy Systems.

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Examination of witnesses

Marco Alverà and Matt Harper.

Q209 **The Chair:** Good afternoon. Welcome to this meeting of the Economic Affairs Committee. Thank you both very much indeed for coming. Would you like to introduce yourselves briefly, please?

Marco Alverà: Good afternoon. Thank you for having me. I spent 20 years in the energy industry, working in the UK a lot, upstream, downstream, in trading and refining. I was with Enel of Italy and then with Eni. Recently, I was the CEO of Snam. I left Snam a few weeks ago to start a new company called Zero, which plans to accelerate the race to zero by building large cross-border projects on renewable energy and hydrogen.

Matt Harper: My humble thanks to all noble Lords for the invitation to participate this afternoon. I am chief commercial officer with Invinity Energy Systems plc. Invinity manufactures something called a vanadium flow battery.

To kick off my remarks, our company is focused on the fact that wind and solar are today the lowest-cost form of generation on the UK grid. As we continue to chase decarbonisation of certain elements of industry, including transport and heating, the demand for electricity will only go up. Those low-cost sources are already renewable and fundamentally intermittent, so there will be a need to support a grid that was designed in the era of fossil fuel generation with devices that can manage the intermittency that renewables bring. Our view is that that is a classic supply and demand gap, and having a variety of sources like batteries, hydrogen and others that can fill the gap between supply and demand is critical to achieving the low-cost energy-secure future electricity grid.

Q210 **The Chair:** Thank you very much for those introductions and thank you both again for coming.

We will start by addressing hydrogen. This is a basic question to Marco Alverà to start with. Looking at the UK, how do you see hydrogen being used in a decarbonised energy system? More specifically, when you look ahead, how much might the UK need by 2030 and then by 2050? Crucially, given that we are looking at investment in this committee—that is the main focus of our inquiry—what level of investment is required to achieve those targets?

Marco Alverà: I think we are looking at a global mix that has hydrogen in a fully decarbonised scenario of anywhere between 20% and 35%, and I think the UK is right there, so let us say about a third, which means between 300 and 450 terawatt hours. This is by 2050. This equates to between 30 and 45 billion cubic metres, for those who use cubic metres.

The main use and the first use will be for heavy industry, those hard-to-abate sectors that are now running on coal or natural gas, which need either very high temperatures or hydrogen as a feedstock. These are the “no regrets”. There is no debate right now that certain sectors like steel,

where you are reducing iron ore, or certain cements or certain heavy transport like shipping, will be using hydrogen. When I say hydrogen I also include ammonia or e-methane. E-methane is a blending of CO₂ and hydrogen to create synthetic methane, so it is a renewable methane. That is a 2050 outlook.

I think there will be hydrogen in heating and in passenger mobility, but the jury is out as to where and how much. When I say the jury is out, a lot will depend on the advancement in battery technology and repurposing of some of the distribution grids. What I do know is that we will have hydrogen as back-up power for long-duration storage, for example when we have entire weeks without wind. I see batteries being very helpful in the short and medium term, but when you look at seasonal types of storage and even weekly repetitive duration of storage, it is very hard to beat a molecule.

On the nearer term, the UK is planning to have about 5 gigawatts by 2030. That equates to 40 terawatt hours, more or less, by 2030. This is in the current hydrogen road map. The recent European response to what is going on in Ukraine, the REPowerEU package, is a lot more ambitious in relative terms. That asks for the European Union to have around 700 terawatt hours of hydrogen by 2030. That is about 15% of gas consumption. If we apply the same parameter to the UK, the 40 terawatt hours I mentioned before could go up to 100, which is a very tall order.

When we look at the investments that are necessary, it really depends on the technology cost curve, which we see coming down quite significantly. There has obviously been a supply chain-driven inflationary pressure upward in the last several months, but the trend is of significant cost decline, especially when it comes to electrolyzers. Electrolyzers right now—when I say “right now”, I mean looking at 2021 data—would cost around £1,000 per kilowatt. Some people estimate the cost getting to below £200 within this decade.

The absolute cost of hydrogen produced from either a very sunny or very windy place, ideally where you have both sun and wind like in Morocco or Chile or other very blessed parts of the world, the all-in cost of hydrogen production is today about £80 per megawatt hour, falling to below £20 per megawatt hour within this decade. Right now we are importing natural gas into this country and to other gas importing countries around Europe at prices that on average have been around £100 per megawatt hour in the course of this winter, so we are looking at a solution the cost of which is falling rapidly and can fall to levels that are considerably lower than the prices we are paying today.

The Chair: Brilliant. That is a wonderful overview. We will probably come back to some of the topics that you picked up.

Q211 Lord Livingston of Parkhead: Could I address you, Matt Harper, on long-duration storage with batteries? What level of long-duration storage do you think we need? I think that Aurora reckons about 24 gigawatts. Is that what you think, more or less? Can you contextualise that within

expected UK energy usage? How much is that? Will that be half a day's worth or whatever? I would be interested if you could put it in the context of what part and how much batteries will play in dealing with long-duration storage.

Matt Harper: We were involved as contributors to that report, so we broadly support a lot of its conclusions and outcomes. It is important to note, following on from the point that Marco made earlier, that Aurora has bundled together different forms of long-duration storage, everything from what we think of as medium to long duration, the kind of batteries that we build, through to weekly or even seasonal storage, for which solutions like hydrogen will be a very good fit.

Overall, the total quantum of investment that they talk about—having in the order of 30 gigawatts worth of capability available within the early 2030s and then adding another 25 to 30 gigawatts in the 20 years following that—we think is broadly in line with the trends that we see on the demand side of the market. As I was saying earlier, the critical question is not only how we will provide for the electricity needs of today but, as we decarbonise transportation and decarbonise heating as examples, how much the demand on the electricity system will go up. Aurora has done a good job of assessing what some of those demand side impacts will be, and we broadly agree with its view on the total quantum of investment that will be required.

Lord Livingston of Parkhead: Your company supplies a lot of countries and a lot of individual projects. It would be helpful for us to understand who the real exemplars are. Where can the UK learn from in looking at the technology you have and the integration of battery storage into a decarbonised electricity network? I am interested in who you would point to and say, "There is stuff you can learn from them".

Matt Harper: Absolutely. I am from Vancouver, Canada, and we look a lot at the US, simply because it is in the same time zone and it is easy to see what is going on. As we have been doing more work in the UK in the last couple of years however, I have been very interested and excited to see the degree to which there are some very progressive market-based mechanisms that are in place here that, in my view, are far ahead of what we see in California or Australia or other jurisdictions.

In looking at the quantum of the problem and understanding what some of the solutions might be, certainly regions like Australia are a good place to look at, because such a huge proportion of their total energy demand is currently being served by renewables. For example, in Australia we see days when you are regularly paid money to take electricity off the electric grid. So-called negative nodal pricing has become very common. There are definitely lessons to be learned about the impacts that has, not only how the market operates but how people make investment decisions into those markets.

Q212 **Lord Stern of Brentford:** My question leads on from the line of argument that you have begun there. We can see that costs for long-

duration storage and for hydrogen—obviously they overlap—have been coming down quite quickly as people recognise where the future will be and what it will look like.

Could you say something, in those two areas of long-term long-duration storage and hydrogen, about what kind of markets you think will accelerate that still further? One thing that we know about all this is that we are in a desperate hurry; 2030 sounds quite soon, but practically, given the emissions that we have to cut, we have to do 40% or so this decade. So acceleration of that cost reduction is absolutely centre stage. Could you say something about the market mechanisms that could move that still faster?

Matt Harper: Cost reduction is critical. If you look at the cost curves that my company has seen, that other comparable companies have experienced and that hydrogen is experiencing, we are on a trajectory that gets us to the point where this becomes the least-cost way of balancing intermittency from renewables on the grid.

The flipside, and where it touches on the market side, is how we take these technologies and turn them into investable solutions. The number one way we can do that on the market side is to make the flows of remuneration into these projects investable, bankable and durable over the time that it takes to pay these things back.

We enjoy such a low-cost reliable electric grid because the investments that we made decades ago are still benefiting us. We need to be investing over those time horizons to continue to achieve that low-cost, highly dependable electricity delivery. That means that we need the durable market mechanisms that will stand behind those solutions so that private industry can make the investments that will be required to fill those needs.

Lord Stern of Brentford: My question was: what are those market mechanisms?

Matt Harper: There has been a lot of discussion around two things. One is capacity markets and whether they can be expanded to include zero-carbon versions of existing capacity markets. We are very much in support of that. Blending the existing capacity markets with technologies like ours that operate on a low-carbon basis is not ideal, because in our view you want to be able to pull levers on those two separately from one another.

We have also seen significant discussion with regulatory agencies and in industry about a cap and floor mechanism. Again, we think that the cap and floor mechanism is a good way of deploying some of these technologies, especially in the early stages, to make sure that there is bankability of these solutions—that when they get deployed there is some floor on the remuneration that will fall to these projects which the people standing behind them can ultimately bank on to make sure that there are reasonable levels of returns.

Lord Stern of Brentford: A floor in terms of the return on capital or on price?

Matt Harper: On the way these projects would be compensated for operating on the electric grid. If you have a cap and floor mechanism, essentially the regulator will be saying to people investing in these projects, “Yes, there will be a market-based mechanism that you will be bidding into that you will be paid for participating in, but because those mechanisms are in flux we will put a minimum level of return on these projects so that they are, in effect, investable in the short term while the markets themselves are stabilising and maturing”.

Lord Stern of Brentford: The floor in that case would be the return on capital?

Matt Harper: That is right, yes.

Lord Stern of Brentford: Thank you, Matt. Marco, would you like to say something?

Marco Alverà: Yes, please. With wind and solar, 15 years ago four countries—the UK, Germany, Spain and Italy—essentially singlehandedly and heroically put subsidies at levels that were necessary at the time, and these subsidies have weighed almost £1,000 billion on the collective bills for these countries. Putting £1 trillion on people’s bills is regressive and unfair. When it comes to solar, which is what I am closest to, these resulted in China building 12 factories that have competed with each other and over a period of 15 years brought the cost of solar from about £800 per megawatt hour down to £10. It took 15 years, it took £1 trillion of subsidies put on the wrong end of the social spectrum, and all the jobs were there.

I think that a market design should start with manufacturing and demand being built at the same time in the UK and in Europe. We can do that. If you look at the amount of capital that was required to build these factories, it was probably in the order of £10 billion. We spent £1,000 billion to build £10 billion of manufacturing in China. That is my macro starting point.

It is quite straightforward to get the manufacturing side going. There is a lot of competing technologies and a lot of brilliant technologies in the UK as well. The entrepreneurial ambition of many people to build these gigafactories is there, the financing is there. What we need is demand.

We can do three things to create predictable demand. There are clusters, which are already a part of the hydrogen design, which are a great way to get going and to get the low-hanging fruits served first. The second is to have contracts for difference, either CfDs or CCfDs—carbon contracts for difference—to support the supply side and the demand side in very direct, precise terms. The third is using the pipelines to blend green or blue hydrogen into the gas grid. This is a great way to create immediate

demand up to 10%, 15%, 20%. You do not really need to change anything in the system and you can create overnight demand.

The beauty of this blending model is that you can dial the percentage up or down. We have seen this work with the European fuels directive. When we fill our car with diesel or petrol we have a certain blend of biofuels in there and very few motorists are even aware of this. It is an invisible way without taxes to create demand overnight. As demand grows in the clusters or in the heavy industrial uses or if there is a season like we had last winter with very little wind, you can dial the demand back down and use that hydrogen for other means.

The Chair: That is really good. That is very clear, clusters, CfD and pipelines. If you had to put ticks beside the ones the Government are actively addressing, which of those three would get the tick? All of them?

Marco Alverà: I would say clusters and CfDs, yes, the blending less so. So two ticks.

The Chair: Can you be a bit more expansive? When you say "less so", what do you mean by that?

Marco Alverà: I do not think it is seen as its full potential of a priority.

The Chair: How big a problem is that by not addressing it now?

Marco Alverà: I think that it is a missed opportunity. It is not a problem.

Q213 **Lord Fox:** I have two questions about your manufacturing point, which I think is interesting. First, you mentioned that we have a lot of technologies here. Do we have access to sufficient technologies in the United Kingdom to start that process of manufacturing, and are all the technologies available that we need or is there stuff still to be invented? Secondly, what is the lead time? If you were to start the investment process now, when would we start to see hydrogen emerging from that?

On the blending point, what is the limit on blending? I am assuming that you cannot separate domestic consumers from industrial consumers in that blending process. At what point as a domestic consumer do I start to see differences in performance with blended gas?

Marco Alverà: Let us start with the last point. Consumers should not feel any impact from the blending, in the same way that car drivers did not really feel an impact from the percentage going from zero all the way up to around 10% in the fuels. We have blended up to 20% in Italy and delivered hydrogen to industrial use, which did not have an impact. I would say that 10% is a safe number to avoid any consequences on the residential side, on households.

When it comes to methane, there are different degrees of hydrogen in nature. When you say 10% blend, you are essentially saying that it is still methane. Methane is CH₄. You just have a little more hydrogen in that molecule, so it does not really change anything. I think 10% is a safe

number and that you can blend up to 10% without any change, and 10% is already a big number.

Maybe we will address this later, but when you have to go to bigger volumes, you need dedicated 100% hydrogen pipelines. The great news is that most of the quality of the steel that has been used to build the natural gas pipelines is consistent and compatible with 100% hydrogen transported in the same pipe.

Lord Fox: There is still some cast iron in some places.

Marco Alverà: In some places, but that is being replaced by plastics. That is downstream. That is on the low-pressure distribution side. I am talking about the big trunk lines.

Blending is technically feasible but is not the end game. The end game will be a three-partite pipeline system where you will have pipelines taking away CO₂ from big CO₂ clusters or even CO₂ districts. You will have a pure hydrogen pipeline, and then you will have fossil methane and biomethane, which is a CH₄ pipeline. The good news is that in most of our systems there is enough flexibility using the regional grids, the national grids, the distribution grids, without doing too much work to have this three-partite system, which provides a very resilient backbone.

The Chair: The first two bits of that question are about investment and technology.

Marco Alverà: I will be quick. On technology, we do not have all the solutions. A lot of R&D is still needed and needs funding. I am talking specifically about electrolyser technologies, and a fuel cell is basically an electrolyser working in reverse. A lot of the work that you do on one can be transmitted to the second. The real frontier to bring the cost down is to work out cheaper materials and less rare materials and metals to avoid some of the geopolitical and inflationary consequences of having to be overly reliant on some metals.

I think the UK is a very attractive business market, so if the demand for hydrogen is there and some policy aspects could make that demand available as a matter of priority for equipment that is built in the UK, you can attract other technologies to come to the UK, if you see what I mean.

Lord Fox: What is the lead time on all that?

Marco Alverà: It is quite quick. There is a lot you can do in 36 months. You build these factories digital, they are native digital, and you can get a lot done in three years.

Lord Stern of Brentford: Are you thinking of a structure where these three pipelines run more or less in parallel?

Marco Alverà: Yes, they can run in parallel. On the cost of transporting molecules, for example, just to put it into a number, we said before that the cost of green hydrogen will go down to £20 per megawatt hour. That

is a production cost let us say in a sunny place like Tunisia. To move that hydrogen from Tunisia through all of Italy to Germany with a pipeline would cost between £5 and £10. It is a great distance, and it is not that much of a cost if you think that we are paying £100 on natural gas today.

They do not really need to be parallel. If I have an unused oil pipeline, for instance, I can repurpose that quite easily to turn it into a CO₂, a methane or a hydrogen. What National Grid has and what we have in Italy and in many other countries is the right of way. In today's nimby environment the right of way is perhaps worth more than the steel you have.

Lord Stern of Brentford: That is why I said in parallel, because that is the big cost. We have had contracts for difference for our electricity supply. Would you want the contract for difference defined over the hydrogen supply?

Marco Alverà: Yes. You go to a hydrogen producer and you say, "We cover the difference in the cost of production". Then you have the carbon contract for difference, where you go to the end user and you say, "I give you the benefit of that CO₂ you saved if you are producing steel from hydrogen, not from natural gas".

Q214 **Viscount Chandos:** One of the major European renewable energy fund managers is raising a hydrogen fund. It says that it does not see hydrogen for storage as an application in the lifetime of that fund, so through to the end of this decade. Do you agree with that assessment? If you do, could anything be done to accelerate the development of storage?

Marco Alverà: I am not aware of the specific fund, but I have worked in private equity. When you have a 10-year horizon for the fund, you need to have invested, grown and divested within that timeframe. I think that 10 years is a reasonable timeframe to see investments beginning and ramping up, but I understand why someone would not want to invest now in that specific aspect of hydrogen, because it will come later.

There is great news when it comes to storage. The company I was formerly CEO of was the first in the world to prove that you can store 100% hydrogen in the existing depleted gas reservoirs. The UK is blessed with a phenomenal geological opportunity. I know the geology in the North Sea, a lot of beautiful reservoirs that can be converted into hydrogen storage very cheaply. That is the good news.

To store hydrogen in these reservoirs, you need all the things we mentioned before to be sorted out. You need the electrolyzers, the steam reformers, the contracts for difference and the blending. You need the clusters to be built.

Matt Harper: I would emphasise that these technologies tend to evolve at a comparatively slow pace. The innovations that we are deploying to the grid for the first time today were first in the lab 10 to 15 years ago. That is a life cycle that is incompatible with some of these types of funds.

It is also incompatible with trying to get to the targets that we are all looking at achieving by 2030. If we are looking at targets that are within eight years, we need to be looking to the solutions that are currently available to us today. That means deploying the kind of solutions that have already been proven on the grid at a utility scale.

I will add to that comment and address a little bit of what you were getting at, Lord Fox. When we talk about the technologies that are needed, it is not just a new battery chemistry or a different kind of solar panel. The integration of these things together into a cohesive system is equally important. There is a localised component of that, a market-based component of that and a financial and contractual part of that. That is innovation that can happen within the eight to 10-year window that we have immediately in front of us, and that is where I think a lot of the UK-based innovation that we intend to drive over the next short number of years will come from.

The Chair: Is that joined-up thinking taking place across government to support this at the moment?

Matt Harper: To varying degrees, yes. We are seeing pockets of that thinking emerge, but we see a lot of focus on so-called industrial innovation in bringing things into the forefront. There has been a lot of discussion around next-generation nuclear power as an example. I am a huge believer in the capability of nuclear ultimately delivering low-carbon, highly secure electricity. It will not make a dent in our needs between now and 2030.

Marco Alverà: I will be a bit less politically correct. I do not think that any Governments around the world are thinking about this next frontier of energy, which is the system integration. The energy system as we know it today is broken up into silos: you have the coal silos from the mine to the plant, you have the natural gas from Russia into Holland, you have the oil from wherever it is to the refinery and into the petrol station, and then you have the power sector. These are all independent.

The energy system of the future will be taking electrons, turning them into molecules, putting them into batteries, putting them into pipelines, taking the CO₂ out, blending it. It will require a degree of system integration. That is where a lot of the value will be and that is where the Governments that get it right first will have a superior energy system. It will mean that policies need to be designed with this system integration and this sector coupling, which no Government in the world, to the best of my knowledge, is getting right.

The Chair: That is very interesting.

Lord Griffiths of Fforestfach: Marco, I want to come back to something you said in answer to a previous question. I think you put a limit of hydrogen for business and industry at 20% and for households at 10%. To what extent is there an element of safety or of risk with the households that clearly you did not see with business?

Marco Alverà: That is a great question. I am not an expert in the distribution business. I am more an expert in high-pressure transport. When I say 10%, if we blend 10% anywhere in the grid, that is essentially like methane, so zero risk. The dual-fuel gas boilers to burn the hydrogen—safely produced boilers from Bosch, for example; the hydrogen version runs on methane and on hydrogen—cost 5% more. There are ways to get to 100% hydrogen with no safety concerns whatsoever. It is just that to do that the boilers need to be upgraded.

I do not know if the power prices will come to a level, and the heat pumps will come to a performance level, where it will be better to move to a hydrogen boiler and 100% hydrogen in the home or to a heat pump, or maybe, again, going back to what we were saying earlier, to a hybrid system where you use the boiler for just the very cold weeks and otherwise you run on electricity. The ideal home or factory of the future will have hydrogen coming in, electrons coming in, and will be able to do some of the system integration itself.

Lord Stern of Brentford: The inefficiency of green hydrogen is that essentially you lose about half the energy when you transform it from the gas to the electricity. Does it not make sense to use electricity for heating?

Marco Alverà: Yes. If you look at it from an energy efficiency point of view, absolutely it does. We will do that and a lot of people are doing that. When there is no wind, like we had way before the Ukrainian crisis last winter, you get to power prices that are 10 times more than they were just a week before or a month before.

I see a system where we have electrolyzers. We can store the hydrogen. When you have excess wind, when you have the curtailed energy, you will be producing hydrogen and storing it. Let us say that the price of power will have a floor of around €20 per megawatt hour, whenever it goes below €20 or €30 you will start producing hydrogen. Then the power prices will have a cap, which is the cost of taking that €30, throwing away half of it and going back to €60. The power markets will trade in a very nice band from between €20 or €30 to €50 or €60, including that inefficiency in the system, but it is a lot better than what we have today, which is that some weeks we have £2,000 per megawatt hour.

Q215 **Baroness Noakes:** I want to switch on to a slightly different subject. The UK's hydrogen strategy is called a twin-track strategy, because it focuses on both blue and green hydrogen. This is a question primarily for Mr Alverà. Do you think that is the right approach for the UK? Does it not spread the demand between different types of hydrogen and, therefore, not help to accelerate the cost curve reduction that concentrating demand on green hydrogen would do?

Marco Alverà: For the UK and Scotland and the North Sea, there is incredible human talent in the oil and gas industry. Probably some of the best talent in the world is in this country. Hydrogen requires a lot of the same skills, and the offshore wind industry requires a lot of the same

skills, that you have in the offshore oil industry when it comes to supplying vessels, maintenance and people willing to venture out into big storms.

When it comes to the dual track, I think it is the right approach to play from the UK's strength as an historical gas exporting country. When you look at blue hydrogen at today's gas prices, it does not make sense, because, as I said, the green hydrogen cost can go down to £20 a megawatt hour. We are importing into the UK natural gas at £80. If you have to turn that into hydrogen, you go to £100. It does not make any economic sense today, but my longer-term assumption is that prices will go down. For a country like the UK that has an oil and gas industry, has some reserves still here and can become a hub for Norwegian gas, that dual track is good.

Dual track also means that you will develop a CCS industry, a carbon capture industry, which you need regardless of hydrogen to take CO₂ out of gas-fired power plants. Every IPCC model has a growing amount of CCS in there anyway. When you talk about blue hydrogen, you are essentially talking about CCS, which is something that we need anyway.

Lord Fox: I am assuming that green and blue hydrogen uses different technologies. Given that there is a journey here from blue to green, is there not a danger of stranded assets in what you use to make blue hydrogen?

Marco Alverà: What I said earlier solves the stranded assets question, in the sense that if you can use the same gas pipelines that you use for gas for hydrogen and you can use the same reservoirs for storing gas and storing hydrogen, certainly it is even simpler when it is blue and green. It is the exact same molecule.

Lord Fox: In this transformation, the technology you use to make that molecule will be different, surely.

Marco Alverà: I will be using CCS technology. That is where the bulk of the investment for the blue hydrogen is. I will use that CCS technology and storage and CO₂ pipeline to take CO₂ away from the gas-fired power plants anyway. So I do not see the risk of a stranded cost. If anything, I see the opportunity here in that we are building infrastructure that will no longer be subject to an energy transition. Once I have connected the offshore wind through a system of batteries, electric cables, pipelines, CO₂, when it comes to taking that out of a power plant that is burning natural gas from Norway, that system can be permanent. That infrastructure will be upgraded in terms of technologies, but the import routes will last for ever.

Lord Fox: The business model for producing blue hydrogen and for CCS might be different, so the operator will have to look at this in two ways when they are investing their money.

Marco Alverà: Yes. When I look at the period between now and 2050, we need all the above. We need the blue, we need the green, we need the CCS, we need everything. When I look at the world after 2050, we will need great amounts of direct air capture. When you are thinking about the investment in blue hydrogen, essentially the bulk of that investment will go to CCS, which you will then use for different things. You can use it first to make blue hydrogen, then you use it just to take the CO₂ out, and then you will finally use it to take CO₂ out of the air directly.

Q216 **Lord Rooker:** I have a supplementary to that, in a way. What you have just said about carbon capture and storage in the last few minutes has probably been more positive than what we have heard from any other witnesses. By and large, we have heard that there will not be the time space to do the research and the construction to get a return, because we will end up not having to do it. Yet you are incredibly positive in seeing it as a positive investment and that there are many years of use for it. Do I have that correct?

Marco Alverà: I think you are correct. There is a lot of resistance to CCS and it comes from a long time ago. It comes from when it was seen, maybe also for some of the right reasons, as a way for the oil and gas industry to continue supplying fossil fuels. When the discourse was more wide open and more polarised, the oil and gas industry was saying 10 years ago, "There's no problem. We can keep burning oil, because we'll have CCS". The NGOs, the utilities and the electricity movement were saying that it made no sense. Now that we have converged to a model where we need everything, every scientist I talk to will agree with what I said, and even some of the people who were against CCS are now recognising that there is an urgent need to scale up. The costs are high, but the technology itself is quite simple.

Lord Rooker: Thank you very much. That is very helpful. Matt, to my question, could you explain to us the advantages of flow batteries as an energy storage system, as opposed to other batteries? How do the costs compare with pumped hydro or hydrogen? I freely admit that until I had looked at my briefing I was pretty ignorant about flow batteries and the differences. It had not figured highly in my reading. I have read a lot of positive things about it, but what are the advantages?

Matt Harper: The biggest advantage is that we manufacture our battery from raw materials right here in the UK. In tailoring the technology for and serving domestic needs, that is a huge advantage over something brought in from overseas.

On what the technology does, fundamentally a flow battery splits apart the two key components of a battery—the part that stores energy and the part that generates power. By separating those two elements, we are able to optimise those vis-à-vis one another. In a flow battery, the flow refers to a liquid electrolyte that is the element that holds the energy. Then we take the liquid electrolyte with the energy in it and put it through a system that converts the chemical energy back into electricity.

That whole system has been designed from the ground up to serve the electric grid. This is not a technology that you will ever see in a car or a mobile phone, or anything like that.

Part and parcel of doing that design from the ground up has meant that we have been able to develop a technology that fundamentally does not degrade over decades of use and tens of thousands of charge and discharge cycles. Anyone with a mobile phone will know that after a couple of years of plugging it in every day your battery is significantly degraded. This is a perfectly adequate solution for the high-tech devices that we replace every couple of years, but it is not fit for purpose for the low-cost, highly reliable solutions that our electric grid will need for the next decades.

Today, we are deploying vanadium flow batteries into applications that require very high cycle counts and very high throughput over their project lives. By making sure that we pick the opportunities where our batteries are not just providing a few cycles as and when needed but cycling multiple times per day to serve the electric grid, we are putting higher amounts of energy through the battery than, for example, the lithium batteries that we see serving other portions of the electric grid.

That throughput is important, because, to the core of your question on the relative costs of some of these technologies, our batteries are slightly more expensive today than the incumbents serving the electric grid, but measured by the cost of delivering a single megawatt hour out of the battery over its life, we are already at a lower level and continuing to accelerate to ever lower positions from there.

Lord Rooker: Where does the vanadium come from?

Matt Harper: Right now, 90% of vanadium is used around the world for strengthening steel. We get it from countries that do a lot of steel manufacturing. Currently, we get it from South Africa or China. There are domestic sources, not sources coming from primary mining but sources that are recycled out of other forms, primarily out of the oil and gas industry. When you refine heavy oil, you often get a very high percentage of vanadium as one of the wastes that comes out of that refining process. We are working very actively on trying to shift all our supply chain from the virgin material sources that require digging holes in the ground to repurposing those industrial waste streams so that we are solving not only our supply problem but a waste problem on that side.

Lord Rooker: Is it just South Africa and China in the main for the bulk?

Matt Harper: No. We have got a lot of our material in the past from Japan and Brazil. One of the interesting things that is happening in the energy world overall is that there are two competing forces. One is that the sources of oil out of the Middle East are becoming more sour, meaning a higher sulphur content and often more entrained vanadium; as you refine the oil to pull out that sulphur, the vanadium comes with it. At the same time, we are seeing the shipping industry shifting to a lower

sulphur requirement for offshore fuels. Again, as those fuels are being refined more and more to remove the sulphur, vanadium is extracted in parallel. You end up with more and more of these industrial secondary feedstocks that have a huge amount of vanadium in them, and that is present anywhere in the world where you have significant refining capability.

Lord Rooker: Finally, I am thinking about reliance in 20 or 30 years' time, a bit like we found ourselves reliant on Russian gas and oil. I have nothing against the Chinese, but it is an autocracy. They are not exactly our friends in that sense and we have to have trusted forms of supply.

Matt Harper: A hundred per cent. Ask anyone in Japan about the availability of rare earths a decade ago when China cut them off. It is a definite challenge.

Vanadium is one of the most common metallic elements in the earth's crust. It is more common than copper and nickel. It is available absolutely everywhere. We look for the lowest-cost ways of extracting it. Extracting it from industrial wastes is very low cost, not only because it is a waste product that we are using but because the secondary impact is comparatively low. Ultimately, there will be a tremendous number of sources of the material from all over the world that we are able to access as we need more and more of that material over time.

Q217 **Lord Monks:** Each of you is championing a particular technology as an important part of the green future. Do you see the two technologies that we are talking about today as complementary or competitive, especially as far as attracting investment is concerned and the choices that Governments and individual private investors will make? Are you competitors or complementary?

Matt Harper: Absolutely complementary. When we think about the need for storing energy for the electric grid and for decarbonisation in general, it exists over a landscape of timeframes. Lithium batteries are already serving the electric grid to solve problems in the order of minutes to hours. The batteries that we at Invinity are building we are looking at how you fill in the missing hours of power overnight when the sun is not shining or in the middle of the day when the air is still, and doing that over a number of hours of use. When you start to get into weeks or months of storage, which will be required to make sure that the ample wind generation in a storm in November can heat homes through a still couple of weeks in February, that timescale is absolutely where we need to rely on something that is based on molecules—to your point. It is such an effective way of shifting over those long periods of time.

How that manifests itself in the investment in those different solutions comes back to the question earlier about market structures. Investors will look at putting money behind these technologies only to the degree that they are supported by long-term, durable, investable markets. The number one thing that we are looking for your help with and the Government's help with in general over the coming decade is how to

build those long-term, investable mechanisms so that the private sector can do its work and get those projects built.

Marco Alverà: I agree that it is totally complementary. There is also an industrial complementarity. As we think about the electrolyzers that are turning solar power, for instance in Tunisia, and water into hydrogen, when the sun is not shining, I will be relying on a flow battery to fuel that electrolyser so that it does not sit idle for the whole night.

There is also an industrial integration. When we think about the heating, which is a big part of the energy, when we look at industrial energy consumption, a lot of industries are now using gas for heating as part of their main industrial process. In absolute terms for the UK, winter demand is five times greater than summer demand. Right now, that swing is covered by natural gas. If we have to take that swing away, we need to cover it with molecules. If you take Matt's battery that is designed for 10,000 cycles, when you look at seasonal storage you are essentially filling up in the summer and discharging in the winter. That means a cycle a year, and it will take an investor 10,000 years to amortise his battery, which is not a very efficient use of capital.

I think that the complementarity is very robust. The requirement for seasonal storage is not properly understood in many parts of the world, because it was a commodity business. The utilities were doing it just by having gas storages filled up in the summer and emptied during the winter. To the specific point, the UK, which does not have its own storage, is in a weaker position than countries that do have their own storage. We have strategic petroleum reserves that we do not need at all that were built in the 1970s, but we do not have strategic gas reserves, which are more strategic and necessary.

The Chair: Do you see storage as a fundamental part of an effective energy security strategy?

Marco Alverà: This is linked more to natural gas, but it will also be linked to hydrogen. Europe, and I hope the UK, is part of this, and I am working with the Commission on this even after having left Snam.

I think that Europe should build a central bank for storage. This winter, we, including the UK, spent £400 billion extra for energy than we did the previous winter. That is not all to do with the tensions in Ukraine. It has to do with the structural competition with China. The Chinese are getting out of coal in their homes. They are adding 15 million homes to the grid every year; a market the size of France is being added every year.

Europe, the UK and China compete during the winter for winter LNG. This competition is limited to a few number of ships, but call it £5 billion worth of extra cost for the ships full of LNG. In China, it is the government companies, the state-owned enterprises, that take the hit. They buy at £100 a megawatt hour and sell back into the market at £20, and they take that hit. The way the market is designed in Europe and the UK is that the full market takes the hit and it spills over into the electricity

sector. Something that costs China £5 billion costs Europe and the UK £400 billion. This is a long-term issue that we will face every winter from now to 2060, which is the time horizon China has to completely exit coal in the home and move to natural gas.

The only solution we have for this price crisis is to build more storage than what the market would buy in the summer, and to have central purchasing that buys incremental storage, and to release it in the winter. The beauty is that in the summer no one needs natural gas; if you look south of the equator, there is no gas market. When it is winter, it is winter for Europe and China—I say China; I really mean Asia—at the same time. When it is summer, prices collapse because the cargoes do not have anywhere to go. The people with the storage can buy this gas. Sorry, we went a little bit off.

The Chair: No, you are inciting lots and lots of questions.

Lord Livingston of Parkhead: On the amount of hydrogen storage that we would need to deal with seasonality—I am assuming that batteries cannot deal with seasonal—can you give us an idea of how far away we are not just from the excess of demand for heating in winter but from the maybe one in 10-year or 20-year event of the frozen fog over the UK that lasts for two weeks? You said that we are geologically advantaged. Are we that geologically advantaged, or is it just too much to place the burden on the shoulders of hydrogen alone?

Marco Alverà: No, we absolutely have enough geology here to serve the UK and, if we want, to serve export countries or neighbouring countries. Those reservoirs will be in very hot demand. If you think of a fully decarbonised UK at 500 terawatt hours of hydrogen, you need at least a third of that to be held in storage, which is very doable. That means probably about 45 to 50 billion cubic metres of storage, which is very doable looking at today's sites. But we are nowhere. No one has started doing this in the UK, so we have to start from scratch.

Q218 **Lord Fox:** In an earlier answer you painted a picture of a fragmented industry while at the same time talking about the need for systems integration. You just talked about the need for some central idea about how we deliver storage. Where does that guiding hand come from? In the past, it has been the unseen hand of the market that has not been doing that. Is it the Government, or is there a need for a future systems operator, as we have heard from other witnesses, that sits over this industry and delivers the strategic investment that is needed to create these things?

Marco Alverà: I think there needs to be a market that is designed for the sector coupling, for the integration. There needs to be a system operator. Despatching, capacity markets and storage will all require very sophisticated market designs. It would be very challenging to have different designs in different neighbouring countries. The markets are all interconnected when it comes to power and gas, and even more so when it comes to hydrogen. The UK and Europe should collaborate on the right

market design for this sector coupling. There are a lot of great thinkers and good ideas already out there on paper, so it is not too difficult.

Lord Fox: It can be done by a regulator and by market design without necessarily having a commercial operator doing it.

Marco Alverà: When it comes to storage, for example, there can be a mandatory obligation to store, which is a market design, or there could be a joint purchasing entity like they have in China, which is probably more effective, but both work. It should work as long as a market is designed for the sector coupling.

Matt Harper: There are three legs to the stool. You talk about the system operator, you talk about market design, and then you talk about the entrepreneurs and companies that will come in and fill those two needs. My view is that part of an appropriate market design should include a system operator that will come in with a light touch and make sure that, for example, capacity values and renewables targets are being set in an appropriate way.

Making sure that the developers who will deliver innovative projects can maximise the value of those market reforms is also absolutely critical. It is about removing barriers to things like interconnecting new and innovative projects on to the electric grid. We see a lot of hesitation about installing batteries on existing solar and wind projects, for example. Why should that be? Why should there be a barrier to adding flexibility into those resources? Some of those fundamental questions and giving that latitude to the private sector developers are absolutely the third leg of the stool.

Lord Griffiths of Fforestfach: Back to Marco, to me, the key institution at the heart of things is not a regulator. It is more like the conductor of an orchestra, saying a few more violins here, a little cello, a little flute here. Is this splitting of the national grid into two parts and the part that is more "regulatory" the beginning of something like that in the UK?

Marco Alverà: I always used to say that, around the world, the national grid was a great example of sector coupling and integration, and now it is being split. However, as long as you keep the mind together, that orchestra director does not necessarily need to sit in the asset company. I think that the two things can co-exist. It is important for that orchestra director to have the powers to conduct, not just to passively implement what the regulator is saying. When we think about an independent system operator that has purchasing power, that can go in and pay for the capacity market, pay for back-up power, give price signals, we are talking about a funded system operator that has the levers to make that orchestra play.

Lord King of Lothbury: On the theme of integration, let me pick up the orchestra analogy. I have two questions. First, think of me as a confused consumer. Can I hope to have just one CD player to hear all the instruments, or am I at risk of converting my study into a room that has

my existing gas boiler, a new hydrogen boiler, a heat pump and a big cupboard full of batteries? If not, if I have to choose between them, how will we give the right and simple incentives so that households make the right decisions? Secondly, for business use, how much money is involved in converting what they have today into the equipment they would need to use this range of different sources of energy in the future?

Marco Alverà: The consumer should not be forced to make any adjustments. It should be a seamless transition for the consumer. If you move to a heat pump, you must redo the home because it requires floor heating, you cannot use the radiators that you have, and it is a complex process. But it is a healthy one anyway. It is moving to a more advanced technology. Every home already has a gas connection and a power connection, so the ideal boiler of the home is a box. Bosch is working on this—I say Bosch, but many suppliers are—where you have a battery, a heat pump and a boiler and they work seamlessly, the way an iPhone can interact with dozens of apps at the same time and you do not really notice as you switch from one to the other. That is the ideal household.

Industry is more complex. If you use natural gas for heating, you can switch to hydrogen without changing anything in your equipment. If you are Pilkington of the UK making very sophisticated flat glass, that glass is burned with hundreds of burners that have been optimised in decades of work for methane. If you switch that to hydrogen, they have to redo most of the factory. It is sector and company dependent.

Matt Harper: My comment is primarily on the consumer side. I do not think that any solution that further complexifies your study will fly. Possibly the biggest opportunity for simplification is that a lot of residential consumers in the future will have only one or maybe two sources of power, including transportation. Once you integrate your electric vehicle in your front yard charging through the same systems that are powering the rest of your home, you have a lot of opportunity—to your point about the iPhone—behind the scenes. You have seamless ways of managing the flows of electricity and doing things such as providing back-up power to your home, providing the ability for the grid operator to extract some of the power from your automotive battery to do some balancing work on the grid in the local region.

Yes, there is work that must happen behind the scenes, but from the consumer perspective we are on a path towards simplification.

Q219 **Lord Griffiths of Fforestfach:** There are two parts to my question. Regarding hydrogen-specific issues, we are trying to encourage investors to invest and not to deter them. Are there any hydrogen-specific issues such as industry standards, contractual arrangements, liability or planning that need to be resolved? Secondly, is there an example of a country that you feel is doing it extremely well at present that you could put to us as an example that we might follow?

Marco Alverà: We talked about the contracts for difference. Those are necessary. Defining hydrogen standards is critical: what we call green,

what we call blue, and what it means. That is a necessary precondition to start trading it so that it becomes a global commodity. To allow for hydrogen exports and imports is another key opportunity and key lever. Ecolabelling will become increasingly important. We can easily check how many calories are in a product, but we still talk about CO₂ in gigatonnes. No one can relate to a gigatonne. If you start having CO₂ labelling, you can start having CO₂ offsetting done at the consumer level, which will generate significant demand.

Then there is a policy that we call PPWS—put the panels where it is sunny—and not having the Black Forest of Germany full of solar panels, but, rather, moving them to countries such as Egypt, Tunisia, Libya, Algeria, Morocco. These countries are burning a lot of natural gas in very old inefficient plants. We can save that gas by putting the solar panels there and bringing that gas here, and it is neutral, if not an improvement from a CO₂ perspective, because we have much higher efficiency gas turbines here than we have there. Those panels can then become the basis from which we generate hydrogen as well.

There is a lot of opportunity. The country that is being forced to race to get this right is Germany. Germany before Ukraine had the very tall order of exiting coal, nuclear and diesel because of Dieselgate, and this is a country that runs on coal, nuclear and diesel. It was deciding to exit these three, relying heavily on Nord Stream 2 and Russian gas. Now it is faced with the Russia effort as well, so it has no option but to double down on a hydrogen strategy, a hydrogen economy, and it will deploy billions and billions of euros into these subsidies. That is a country to follow, because it has put its mind to it. It has a coalition Government who will focus primarily on this.

Matt Harper: Briefly, on energy regulation and testing in general, the two strategies that we see around the world are based on performance standards or on prescriptive standards. There has been a general shift towards performance-based standards. They are quite good in general, but when you have specific problems that you are trying to solve, very prescriptive standards can be extremely helpful.

I will give you an example. One of the biggest concerns in the energy storage industry is fire risk. Lithium batteries have proven to be problematic, given their ability to cause fires. There have been different approaches to that around the world, but the US regulators have been very prescriptive, with a specific set of tests whereby, if the electrolyte inside your battery does not burn, you pass, full stop. That has given absolute clarity to what the standards need to be. Technology such as ours that does not have that flammable characteristic has been hugely advantageous in being able to deploy into projects and regions where fire safety is a significant concern.

Q220 The Chair: The final question is from me. In one sentence, try to pick one thing that you think the UK Government should do to accelerate the long duration storage of hydrogen. We have covered a vast array of issues. Maybe we could start with Matt.

Matt Harper: In one sentence, deliver long-term investable market conditions.

Marco Alverà: Set aside serious money, because Europe is coming with the European strategic recovery plan. There are tens of billions of dollars, and the debate with Treasury on these issues is such that if you look at a business as usual situation, you are just not giving enough oxygen to fuel this revolution, because it is a revolution. The race is on and you do not want to be left behind.

The Chair: That is a very good note to end on. Thank you both very much for joining us.