



Select Committee on Economic Affairs

Corrected oral evidence: The Economics of UK Energy Policy

Tuesday 15 November 2016

3.35 pm

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Members present: Lord Hollick (The Chairman); Baroness Bowles of Berkhamsted; Lord Burns; Lord Forsyth of Drumlean; Lord Kerr of Kinlochard; Lord Lamont of Lerwick; Lord Layard; Lord Sharkey; Lord Tugendhat; Lord Turnbull; Baroness Wheatcroft.

Evidence Session No. 7

Heard in Public

Questions 103 - 117

Witnesses

I: Mr Hugh McNeal, Chief Executive, RenewableUK; Mr Michael Liebreich, Chairman of the Advisory Board and Founder, Bloomberg New Energy Finance.

II: Professor Sir Richard Friend, Cavendish Professor of Physics, Cambridge University; Mr Simon Daniel, Chief Executive Officer, Moixa Energy; Mr George Grant, Managing Director, Stag Energy; Mr Stephen Tindale, Director, Alvin Weinberg Foundation.

Examination of witnesses

Mr Hugh McNeal and Mr Michael Liebreich.

Q103 **The Chairman:** Gentlemen, welcome to the House of Lords Select Committee on Economic Affairs and to our inquiry on energy. Could you please give us your view on whether you expect renewables to be competitive without government subsidy? I particularly noticed your comment, Mr Liebreich, in the *Financial Times*, that, “renewable energy ... is now competitive with conventional power sources ... if it is allowed to navigate a planning system increasingly tilted against it”. With that in mind, will you kick us off?

Michael Liebreich: Thank you, first, for the opportunity to be here today. My chicken are coming home to roost. The answer is that it can be fully competitive today. The problem is that these are complex systems, so the fact that something is competitive at a levelised cost—I listened to some of the previous evidence—is in some ways the wrong metric; it should be about system costs. So, yes, the lowest-cost new generating capacity—we see this around the world—is now renewable energy as likely as not. In this country, the National Audit Office pulled together a report around the time of Hinkley which confirmed that.

Hugh McNeal: I have three thoughts about this, and thank you again for the opportunity to give evidence this afternoon. The best sites for onshore wind in Britain are probably in Scotland. However, the issue is not whether we can be competitive but whether there is a route to market, and, purely in market terms, that we do not have something that demonstrates the price for electricity that is generated from the new-build capacity that we want. It is a number of different marketplaces.

What might that figure look like? It is not a good time for conjecture on possible futures, but if you were to run a CFD auction for onshore wind, for example, I would expect that to clear in the £50s, which would probably give you a levelised cost of energy in the £40s—so at the low end of what the Government said last week. We are not at that point for offshore wind yet, but I would not be surprised—indeed, I would expect, in the light of the auctions announced last week in Europe—for offshore wind to clear below the Hinkley price.

I know that you only want short answers, but I have one further point to make, if I may. It is a shame that we often think in terms of cost and subsidy when we think about this task that we are engaged in. Michael and I last saw each other a few weeks ago in Hamburg at the big European wind event. It was a big exhibition. There were seven conference halls full of businesses doing business at that event. Unfortunately, in the main they were not British or British-based businesses. They might have been had we taken different decisions in the past. Of course we want renewables to be cost-competitive, but we are trying to achieve other things as well.

The Chairman: So you think we are close to a position where without government subsidy they would be fully competitive.

Hugh McNeal: For onshore wind, there is no question that the issue is the route to market. Even the Government's figures last week suggest that they recognise that onshore wind at the best sites is cheaper than any other form of new generation for generating electricity in our country.

Q104 **The Chairman:** We have heard many witnesses talk about the need for back-up when you have interruptible power. Who should bear the cost of that, and do you factor that into the calculations and the comments you just made about pricing?

Hugh McNeal: I will answer the second question and think about the first one, which is a difficult question to answer, as it is a public policy question. A new report has been published today by Imperial that says similar things to previous reports. There is consensus that the tipping point appears to be that if 50%, or just under 50%, of our electricity is generated from variable renewable sources, the cost of that on the system is up to about £10.

The direct answer to your question about the cheapness of onshore wind at the best sites is yes; if the Government were to take the cost of new gas build, reflect carbon costs and then take away the cost of systems effects, you would still find that onshore wind at the best sites is cheaper than any other form of new generation.

Michael Liebreich: I will take the first part of the question and who should pay. First, I got to watch Michael Grubb's evidence. Essentially, what he said is very much how I see it. Reliability is a system property; it is not the property of a piece of the system. So you could ask the same question about any power station: what happens when Hinkley comes on stream and requires maintenance, scheduled or unscheduled? Do you expect Hinkley to bear the cost of what has to happen next—the back-up to Hinkley, to CCGT or to coal? Every form of generation has times when it does not generate. You pay to make sure that the whole system can fulfil the demand of the whole system.

You then have the question: who should pay for it? It is no secret that the sun does not shine at night but generally does during the day, and you can forecast the weather; it is forecastable, and the forecasts are now very good. You have variable renewables; those who say that each element of the renewable generating capacity must meet its own variability costs are generally trying to put barriers in the way of renewable generation.

If you say, "We must socialise it, because renewables are just a good. They are a good in everything and all so virtuous that everybody should pay for the downside", that is the other end of the spectrum, and that is generally people who want to move to renewables for whichever non-energy analytical reasons. The answer is that it is a negotiation between

those two extremes. I do not envy you, because you have to figure out a point on that spectrum.

The Chairman: Do you have anything to add to that, Mr McNeal?

Hugh McNeal: Just that I agree with what Michael just said. When I am challenged on the variability point and the systems cost point I hold a date in my mind. The last time we had a system 4 impact in the country—in lay terms, the lights going out—was 27 May 2008, which was when Sizewell B and Longannet both tripped within five minutes of each other. Therefore, when we think about the system we need to think of single points of failure and variability. I add that I have been in this role for seven or eight months. One of the things I have learned and have been surprised by is the speed at which wind can be controlled on the system, and how quickly you can shut down a wind power station and have it up and running again. We are talking about seconds, which is a very different world from the world of cold-start gas plant, which is 30 minutes-plus. It bears thinking about that as we move beyond subsidy to how that can help benefit the system.

Q105 **Lord Kerr of Kinlochard:** Can you tell us how the levy control framework works? Mr Liebreich, in your famous letter to the *Financial Times* you said, “Around the world, renewable energy has crushed wholesale power prices around the world, but only in the UK does that drive up its apparent level of subsidy, due to flaws in the design of the Levy Control Framework”. Can you tell us what the flaws were?

Michael Liebreich: First, when I say that this is happening around the world, there are two reasons why renewable energy pushes down wholesale prices. One is that around the world renewable energy has been the beneficiary of support mechanisms such as feed-in tariffs, renewable portfolio standards and tax breaks. The policy-makers, the law-makers, have been encouraging renewables and more capacity has been built than otherwise would have happened. So you have overcapacity. You also have demand in many cases that, because of the recession, has not grown at the forecast speed. So one reason is just supply and demand.

The other is that because renewable energy—wind, solar, geothermal—has no or very low variable costs, it gets dispatched first. Sometimes, by the way, this is supported by legal frameworks that say that it must be dispatched first. So the market clears at a lower wholesale price than would otherwise be the case. Instead of using a gas or diesel peaker at the margin, which sets the price, that is now pushed off the network, because there is this chunk of renewables.

Literally everywhere I go I see that the wholesale price of energy has been coming down—almost explicably, because supposedly everything is becoming high-cost, green-blob this. But the wholesale price is being pushed down by renewable energy and the levy control framework counts as a subsidy: the difference between the wholesale price and the contracts for difference price. So if the renewables push down the

wholesale price, that subsidy suddenly gets bigger. So that is one flaw; the successful contribution of renewables to pushing down the wholesale price penalises renewables, which is very unfortunate.

The other thing is that the whole method of setting the levy control framework is driven by wholesale prices and so fails to give the long-term signals that Hugh's members and companies need. One year it can be low. Then there can be a problem with nuclear power stations in France and suddenly the wholesale price goes up and the subsidy, apparently, has gone down. So then we are going to do more wind, so we start planning a project. But then of course something else happens. You cannot plan infrastructure on the basis of short-term fluctuations like that in commodity prices.

Lord Kerr of Kinlochard: Tell us what would have been better than the levy control framework.

Michael Liebreich: I have two potential answers. One is to say: look at all the modifications that Professor Grubb talked about. You can tweak in various ways. One simple thing with the levy control framework would be to set the amounts further into the future. We do not know what will happen after 2020, so we will set it up for 2030 and then turn it into a number of megawatts or gigawatts and not look at it any more—or look at it in retrospect—rather than let it go up and down and have these short-term fluctuations.

My other response goes back to Dieter Helm's testimony: you cannot be a little bit pregnant. Once you start to get a little bit into the market and manipulate this price and that price, you have got to a point where effectively there is one buyer of energy. Prices, thankfully, are now set by reverse auctions, by the contract for difference, but volume and location and all those things are decided essentially through a kind of centrally planned process, and it will never work particularly well. So my other answer to your question is: start again and think of this perhaps more like we thought about telecoms in the 1980s. Those are your two answers: tweak it and make some modest improvements, or re-regulate—and, by the way, many countries and states in the world are now saying, "We need to fundamentally rebuild the regulatory environment from the bottom up".

Lord Kerr of Kinlochard: So you are basically saying that somehow we have to get back to a real market.

Michael Liebreich: If you define "real market", I can probably agree with you.

Lord Kerr of Kinlochard: All right. Let us ask Mr McNeal. His whole job was running a rigged market: that is what he did.

Michael Liebreich: A bull market.

Hugh McNeal: I am a little more sympathetic to the idea of a levy control framework. It is perfectly reasonable for the Government to say

that they are willing to spend a certain amount of money on a programme on this sort of scale, especially when it is affecting both consumer and business bills. I agree with Michael about the flaw in it. Assuming that that was the purpose of the levy control framework, the framework itself is spuriously accurate: you have hundreds of projects moving around all over the place, trying to be caught on a year-by-year basis. It is not just the wholesale price moving around; all these other things are moving around as well. So let us not pretend that we can predict the future with that degree of accuracy. We cannot.

Again, I agree with Michael that one of the things that is odd about it is that when wholesale prices fall, the impact on the LCF is the opposite; you suddenly have less to spend. That seems to be something that is slightly odd about the framework, and if you were to redesign it you would want to think about that.

The thing that most bugs me is why we have so much focus on the levy control framework but seem to care less about the costs of the capacity market. The capacity market is not caught within the levy control framework. I do not know whether Cornwall has given evidence to you. Cornwall economists believe that the cost of the upcoming auction in the capacity market will be £2.1 billion a year. That is a significant sum of money. Why is that any different? It is to do with bringing forward new capacity but is not specifically meeting our carbon commitments. Why is that different from the levy control framework? I do not understand that. I have more sympathy with the idea of trying to have some degree of control, but I wish they had had some sort of range and that we had taken account of more of the factors that Michael spoke about over a longer period of time.

Q106 Lord Layard: Could we look more closely at the contract for difference? Is there any way in which you think it should be improved or changed?

Hugh McNeal: As an association, there is only one thing that we have been asking for, which is to do with British businesses. We think that there is a case for extending what is called the milestone delivery date by about six months, from 12 months to 18 months. We think that that could help British supply-chain businesses, some of which are members of mine. We are in business in the offshore wind market.

The issue is not necessarily with the contract. It is complicated and a variety of bodies are overseeing different aspects of the system, but the issue is that it is still politically determined. When will we find out whether we are going to have an auction? We will find out when the politics allow us. One thing I am sure you will expect me to say, and which I will say, is: when might we have some form of route to market for onshore wind, now that we have moved on from the politics of recent years? The answer is that we now have a de facto freeze. The problem is not the contract; the problem is that we have a created market mechanism—a price discovery mechanism—that we apply to some technologies but not to others.

Lord Layard: And how would you change that?

Hugh McNeal: You would have to try to persuade politicians to give up some of their power in order to say, "Look, we're rolling our sleeves up here and we're involved in a very challenging task that we have started but not yet completed—only on the electricity side, before we even get into heat and transport. It is a long task. It will take a decade or more, and it would be wise, given the amount of investment involved, if we were to hand over some of the political control and power to some other body, system operator or whoever—other people cleverer than me will think of that sort of answer—that provides not certainty but regularity for investment to come in to fulfil the prospect that was seen in the framework as it was set up".

Lord Lamont of Lerwick: Could you explain what powers the Government have over CFDs?

Hugh McNeal: The Government's key power is whether or not to run the auctions and when they might be run. Also, they have secured the power to separate out different types of technology. That makes sense in the time we are in. We have what are called less established technologies: offshore wind is in that pot. We also have more established technologies: the ones that, I would argue, as I said earlier in relation to onshore wind, are market competitive against gas. The Government are choosing to run auctions for the former but not for the latter, and there are a variety of other quite complex aspects of the legislation. Yes, I was in Parliament at the time but I cannot remember it all.

It seems to me that the key point is the control over the timing and the ability then to have people expect that there will be an announcement: we all get ready, we get our teams going and we are going to invest. But we have had quite a lot of political upheaval in recent months, so things have been delayed a bit more. As I said, at the moment there is no route to market for the technologies that are cheapest—and I would argue, on carbon grounds and security of supply grounds and a variety of industrial grounds, that it would make sense to try to find a way to bring those to market, too.

Lord Turnbull: It is a pretty bold claim that low cost and decarbonisation can now be met and that the price of renewables is now sufficiently low. You quote as evidence a table from an NAO report. There is a little footnote that says, "Levelised costs exclude the wider system and external costs typically associated with intermittent generation". It is a bit like a builder's estimate that does not include the VAT. The economists would say, "We accept the logic of the externality of fossil fuels and therefore a cost has to be imposed, although you have to argue about the level it should be at". But I do not quite understand what you said about the Government taking away the system costs. Renewables impose some system costs on the rest of the system, so there is an externality. How do you allow for it? I see the point about not charging everyone individually, but surely something has to be included.

Hugh McNeal: For me, this is a very simple calculation. You take the cheapest clearing price for gas, probably from the capacity market, you add its carbon cost and you take off the delta for the system effect. In the calculation of the delta, you use the growing body of evidence, including the report from Imperial—the Government have their own report, which has not yet been published, on systems cost. As I tried to say earlier, there seems to be a consensus that as long as you do not have variable renewables over about 50% penetration in the British market, the costs are below £10. Given the framework that we have, you then run an auction with that as the maximum price that could be paid. So you are making a direct comparison, taking account of the carbon cost of gas but allowing for the system integration costs as they are now understood by a variety of independent experts.

Lord Turnbull: When you say “take off”, you are talking about gas price plus tax minus—

Hugh McNeal: Gas price plus carbon minus system cost, as the ceiling for any form of market-based mechanism. That is the obvious thing to use, but if there is another way to do it, fine.

Lord Turnbull: The next question is: does this system cost get bigger with the share of renewables? If the balance between traditional generation and renewables shifts so that more generation is adding system costs and there are fewer others to bear it, do you get to the point where the non-renewable generation cannot bear the costs of providing the system costs of support to the renewables?

Michael Liebreich: When I started the business that I built in 2004, the thinking was that you could do about 2% or 3% of variable renewables, but if you did more the lights would go out and bad things would happen. Then, of course, the leading countries in the region went through 5% to 10%. Then the thinking was that you could not possibly do more than that; you could not do 15% or 20%. That process has gone on over the last 12 or 13 years and now some countries and regions are at very deep penetrations—and we are talking about large countries, not some hamlet somewhere. There is no reason why that will stop. The costs have not become exorbitant. Hugh mentioned some of the costs and Michael Grubb talked about adding 10%. Even if you choose back-up, adding 10%, if you are talking about wholesale prices of 4p or 5p per kilowatt hour, you add a penny and you have dispatchable equivalent power.

The important thing is that it is a dynamic system. As an example, most of the car companies that I talk to are launching electric vehicles. They have figures of the order of 20% or 25%—Volkswagen is aiming for 25% electric cars by 2025, I think. All the car companies are looking at that. Electric cars are great, because they feed directly into a demand response. You do not have to charge them when you first plug them in; you can wait until everybody turns off their television set.

So the answer to your question is that it is dynamic. Over time we are moving to a smart, flexible grid. The UK has already moved very far in

that direction. If we are to meet the climate obligations that we need to, we need to move further in that direction. A number of different trends will self-reinforce along the way, electric vehicles being one of them. There are all sorts of demand response—low-cost power storage will be another. If you want to go to 100% renewable, that would be a foolish thing to do and the costs would probably go up, but the answer to whether you could get to 30%, 40%, 50% or 60% without exorbitant balancing costs is yes.

Lord Turnbull: Can you just clarify the VW figure? That is on the basis of its sales, not its stock. How long would it take for the stock to get to that point?

Michael Liebreich: You are right, because cars tend to last 13 or 14 years. Bloomberg New Energy Finance figures for 2040 are between 35% and 47% of new cars. At that point, the stock would be somewhere around 20%. So yes, the stock lags behind the new cars.

Lord Layard: It must be the case, as the spread of renewables happens, that storage becomes a more important issue. What is your perspective on the prospects for cheaper storage?

Michael Liebreich: The costs of storage will come down at similar rates to the way in which the costs of solar, and indeed wind, have come down. It is an engineered product and it will follow an experience curve. We have seen 60% reductions in the cost of batteries in the last five years. It will flatten out over time, but it is a nice experience curve.

The only thing I would caution is that it is not correct to say, "Because variability, therefore batteries". There are lots of ways of managing variability. The cheapest will be demand response, because it is software—bits are always cheaper than kit. If you can switch on and off some commercial refrigerators or charge some cars, you will do that before you start to do storage. There is pumped storage and all sorts of other types. There are also the interconnectors that are being built to neighbouring electrical systems. The short answer is that I am very bullish, but that does not mean that this will be the only thing that gets attached to the system.

Lord Turnbull: I have a supplementary to that. You used the phrase "route to market", Mr McNeal. Can you just explain what you mean? Whose route, and from where to where?

Hugh McNeal: For someone who is going to invest in a new piece of capital to generate electricity in our country, where is the price signal and the vehicle that enables us to know the price for electricity that is generated from that new bit of kit? Our wholesale price, which I know you have discussed, reflects fully depreciated forms of capital. So the route to market that is available to us at the moment, to cut to the chase, is the CFD route, and the Government are choosing not to take advantage of that route.

Lord Burns: Why are the Government not choosing that? Is it simply because of the unpopularity of onshore wind among the electorate? What is stopping it?

Hugh McNeal: First, onshore wind is a very popular technology, but there are people who are very passionately opposed to it.

Lord Burns: Is that why there is a standstill?

Hugh McNeal: That is one of the things I have gone out of my way to say since taking on this role. There was a commitment in the Government's manifesto. The pledge said that there would be no new subsidy for onshore wind and a change to the planning system. I would argue, and have been arguing, that because of where prices are now, I do not think you can legitimately say that something is a subsidy. It would be rather odd to say to people, "Look, we are stopping a subsidy for a technology, which will make your bills more expensive". That would be a very odd thing to say and claim. However, the argument is made that if there was any form of government involvement in this, it would break that commitment.

Lord Burns: So basically you are saying that this is a political decision because of the unpopularity of onshore wind. Why else is this commitment in the manifesto?

Michael Liebreich: I would add the word "perceived" to "unpopularity".

Lord Burns: Why do you use the word "perceived"? The Government thinks that it is unpopular.

Michael Liebreich: It is "perceived" because survey after survey shows that people want renewable energy—and top of the list are solar and wind. They do not like fracking, for instance. I am perfectly fine with fracking. But the point is that there are some very vocal groups, including some groups in the Conservative Party, that are against wind, and at the moment they are being listened to. That is what is happening.

Lord Burns: Even in the north of Scotland?

Michael Liebreich: Scotland is very keen and moving ahead with this stuff. It is the only place where it is being done.

Q107 **Baroness Bowles of Berkhamsted:** To go on to offshore wind, we have been told that we are not necessarily comparing like with like when we say that offshore wind projects seem to be cheaper in other countries. Obviously there are some things that are unavoidable because of geography: how deep the water is and how strongly the wind blows. Then there are things that we may or may not be taking into account, such as connections to the grid. Then there are the UK-orientated things, such as how difficult it is to get planning and at what stage you get it. Taking those factors and anything else into the mix, what is the comparison?

Hugh McNeal: Let me start and then Michael can help. We need to wait for the outcome of the auctions that were announced last week. We have seen three very cheap clearing prices from auctions in Europe this year: one in the Netherlands and two in Denmark. On paper those prices look as though they are very cheap: €72, I think, in the Netherlands and around €50 in Denmark—much lower than our projects. But they are for projects that are due to reach completion in the first part of the next decade.

For all the other reasons you mentioned in your question, grid connection costs are not included in those auctions. So let us see what happens in the first auction that was announced last week, which is for delivery in 2021-22. If we see it significantly clear the Hinkley price and get into the £80s, we will see a similar effect to the one we have started to see in Europe. There may, though, be something inherently less risky in the models that are being used abroad, in which case there may be things we can learn in that regard.

Baroness Bowles of Berkhamsted: So your answer at the moment is that you are not sure and you do not know, but you do not inherently think that there is a hugely expensive UK add-on.

Hugh McNeal: It is not as simple as saying, “Add on the grid transmission costs and others and then you will get the answer, which shows that there is a problem in the UK”. The timing of the projects, when they are due to be completed, is different.

Baroness Bowles of Berkhamsted: And is the planning process a big cost?

Hugh McNeal: The planning process is a big cost, but also in effect we have a rights-based system: people buy the rights to develop a site, whereas in Europe with these other examples you have a tender process. You buy the rights and then you have to invest your own capital—it is often tens of millions, and I can think of one case where it has gone into hundreds of millions—before you have any hope of getting your route to market. This comes back to an earlier part of our conversation. So the process may be inherently more expensive than a tender process.

Hugh McNeal: There are a couple of differences. First, we are going to see in the current round considerably cheaper offshore wind. All the signals and all the experience in Europe will translate in engineering terms. There are some differences—deep water, shallow water, those sorts of things—and what grid connections are included.

I would highlight two others: the cost of capital and the supply chain. This is not a specifically offshore wind point. The more uncertainties we have, for instance over whether there will be an auction or a levy control framework that distorts the system post 2020—I could reel off a list of uncertainties—the more they will drive up the cost of capital. They will also reduce the propensity and the enthusiasm of manufacturers to invest in a market that might or might not be there. As a result, that will drive

up costs in the UK. Sadly, we could end up being the country that commits and spends a lot of money and effort to push the modernisation and transformation of the energy system without capturing the benefits that we should in the supply chain and with cheap electricity because of the uncertainty of the process.

Baroness Bowles of Berkhamsted: How easy would it be to switch to a different model where we are not pumping up the cost of capital?

Michael Liebreich: That is a largely political question, so I will leave it.

Lord Forsyth of Drumlean: I am just trying to follow the argument that you have just put. Essentially, you are telling the Committee that technology and innovation are reducing the costs of renewable and wind energy, and that there is a danger that we could lose out, having spent so much money on it. Could that not be put the other way around? Did we not make a mistake by going in too early and subsidising it? If it is a global industry, would it not have been more sensible to let others do that and not spend the money on subsidies?

Michael Liebreich: It is entirely possible. First, let me come back to whether we could have sat this out and waited. I will make a couple of observations. First, to get cheap, clean energy, you need technology. You also need the logistics and scale, both in manufacturing and in the value chain of installation, and you need cheap capital.

Lord Forsyth of Drumlean: We could have used gas while we waited for these costs to come down.

Michael Liebreich: Absolutely. But my second point is that you have past dependencies. If you use gas, you build an entire infrastructure around gas, and then you will have everybody saying, "Of course, we could not possibly rip that out. It has not fully depreciated. It is doing this. It is doing that". Could we have followed a different strategy? Could we have gone in much earlier and tried to get all the benefits? I would have been against that. Should we have left it right to the end and said, "We'll sit this out and at the end we'll get wonderful, cheap everything"? That, too, would have been a mistake. So we are somewhere in between. Does that feel completely wrong? No.

Lord Forsyth of Drumlean: Why would it have been a mistake? We would have had cheaper energy and been more competitive.

Michael Liebreich: We would have had cheaper power in the short term, but we would then have had huge pressures not to change that because of all the stranded asset incumbency issues. We would not be on track to hit any of the early carbon budgets that we are hitting and are on track to hit. There would also be enormous knock-on implications for skills and associated industries, because we would not be—how can I put this?—working in the same direction as pretty much every other country in the world that is shifting to flexible, smart, digital and much more distributed

energy and transportation. You can sit that out if you want, but it does not feel to me like the sort of place we should be in.

Hugh McNeal: With great respect, I disagree with that argument, and from a historical perspective. I do not think we would have had cheap electricity. Look back at 2008 and 2012. What is going to happen next year? Our country is overly dependent on global gas markets over which we have no control. The impact of the shift in those gas markets and what they do to businesses is not normally drawn out when we have the conversation about subsidy that we started this afternoon. If you look at those moments and what happens to people's bills and how those are then re-anchored, we could take a one-way bet that gas prices will for ever be low, but the LCOE figures do not capture the moments when you have these quite significant shocks.

We have not raced ahead, frankly. We have to replace our ageing, quite clunky power systems. We would have to have done that anyway. We have a phenomenal task ahead of us; we have done rather better than people realise. That is not just a carbon story; it can yet be an industrial story for us. It needs to be a balanced story, and of course gas is part of the solution to that. Of course, nuclear is likely to part of the solution. However, I do not think we could somehow have decided a decade ago to rush ahead with gas and that would have been, and would have proven to have been, a good choice for us.

Q108 **Lord Burns:** I go back to this issue of intermittency and the cost of backup. Might we be able to get to a position where there is some agreement about what these costs are? Could there be some work to look at the variability of other forms of energy and intermittency, and breakdowns, as you have described them, to get some idea of how those costs will change as the proportion of renewables rises? We have sat here week after week and had different answers from different people. It seems that this, as a subject, should not be beyond the competence of people to analyse it and come to an agreement about some orders of magnitude on what we are looking at.

Hugh McNeal: I agree with you, and I think there is a consensus, but I have not listened to all the testimony that you have listened to. It seems that the tipping point is somewhere between 40% and 50% variable renewables, just on the electricity system, and the cost of that is up to £10 on the system.

Lord Burns: But I would like similar figures for other forms of energy too, against which one can compare it, as you have sought to make the point.

Hugh McNeal: I made the point, but I go back to what Michael said earlier: that you need to think about it in terms of the system and what it will be, and what we will ask of our electricity-generating plant in the future. We will not just ask it to generate for us; we will also ask it to be very flexible at local level and to respond very quickly to things. So it becomes a little more complex. However, in simple terms, up to about

50% is manageable, and the cost of that appears to be the cheapest way to do the things we want to achieve. If you go beyond that, you start to hit tipping points.

Michael Liebreich: I will reinforce that. The answer is, yes, it can be calculated. It needs to be done on the system basis, not the individual basis. That also means that you have to define what you think the system will look like, such as electric vehicles, or Hinkley being there in 2025 or not. You have to do it with a specific system in mind, and the answer will then drop out. Imperial has just done some work on it. Every time I have seen it, the numbers are of the order of 1 cent to 2 cents per kilowatt hour. Therefore it is not zero, but it does not double the costs of power or anything like that.

Lord Burns: Can I move on to the wholesale prices, which we also discussed earlier? Is this not a classic economics problem about marginal cost versus average cost? Are we in a position where wholesale prices are becoming increasingly irrelevant to this debate?

Michael Liebreich: I would not say that they are irrelevant. The problem is more market design and where there is liquidity in the markets. You are moving from a system that worked very nicely with a simple heuristic: you have baseload; nuclear is the cheapest on a variable basis, then comes coal, then you have your peat, and it all works. The markets that were put in place and then evolved organically dealt with that, because they cleared at the marginal price, which tend to be gas, and that was all fine. Now you have more and more technologies and more and more of the capacity, which is a near-zero marginal production cost, but paradoxically it also needs a 15-year contract, plus or minus, to be built. If I am allowed to think about what regulatory system might create a market around that, it relates in a sense to the cost of intermittency. You have the trilemma of cost, cleanliness and reliability. You want to regulate for clean and for reliable, and let the market figure out costs and create whatever markets it needs over whatever time periods, buying 15-year forward wind to ensure a big chunk of very cheap, long-term purchase, then layering the other things on top of it. That would be a very different market design, not a trivial tweak to what we are doing now.

Lord Burns: We noticed that in 2015 Amber Rudd said that she wanted to see a competitive electricity market. Are you suggesting that if we had some figure for the carbon price and a figure for the intermittency cost, we might be able to move towards a situation where we had competition that was neutral between the different forms of energy?

Michael Liebreich: You could do it through a carbon price. You could equally do it through an intensity measure for utilities that says, "If you want to sell electricity, this is the amount of carbon per kilowatt or megawatt hour that you are allowed at this point and then into the future". You can squeeze carbon out in lots of different ways.

On the intermittency cost, it is not just about intermittency. Intermittency is a weapon used in a particular type of combat against renewables. Call it reliability or whatever you want, but it has to cover planned and unplanned maintenance, interconnectors that fall over, unexpected and expected weather events, and so on. But, yes, if you could regulate those two things, largely, we could get back to having proper markets.

Lord Burns: And having some competition. This is one of the questions we have been trying to get to over the weeks. You talk about the route to market. Is there any route back to a market? That is the sort of question we are trying to ask. It seems to be a collection of individual decisions, most of which are taken by government.

Hugh McNeal: On that last point, if you ran an auction in the way we discussed earlier, under the CFD process, or you found another way to do it, that would be a price discovery mechanism and you could say that that was a market for low-carbon capacity. If you can bear to think about the current markets, you have the CFD mechanism and the capacity market. What you do not have is the market that we will need to see more of: the auxiliary services market—the flexibility.

One thing you might look at is how we now develop a market in that space so that the Government do not get themselves as involved in that space as they have previously done in these others. That would be worth looking at. It is also worth saying that we can overpush the wholesale price point. When it comes to business decisions about building these bits of kit, someone somewhere in a boardroom will have a look at future wholesale prices, and someone is still making money trying to predict what the future doing that will look like.

Q109 **Baroness Wheatcroft:** We have talked about renewables and have largely been talking about wind and solar. Can you gaze a little further forward and talk about what further innovations we might see that could dramatically alter the marketplace, and are we investing enough to find them?

Michael Liebreich: There are a few questions there. I would like to flag one thing, because this is a good point among the points that you raise, or a good hook. We have been talking a lot about electricity, which is about 18% of final demand. It could go up enormously from that with electric vehicles and, crucially, heating. Broadly speaking, for low-carbon heating you insulate everything you can, but then you either go for biomass biogas, electricity or geothermal—there are a number of different solutions.

I am tempted to come back to Dieter Helm, who has this thing about some miraculous renewables that happen at some point in the future. That is not the way it works. If you look, first, at wind, there are thermodynamic limits to how much you can harvest. Will we get bigger turbines? Yes, if they are allowed to be built onshore or even offshore.

The experience curve will continue, but there is no sudden rupture in that trend that will either slow it down or accelerate it.

In solar, there are materials called perovskites, which are very interesting. They might be more efficient than the silicone-based solutions that are currently out there, but even if they are 20% to 30% more effective—in other words, instead of 20% efficiency they have 30% efficiency, or even 35%; pick a number somewhere within the laws of physics—of course that will reduce the cost of the panels but it will not make the sun shine at night, and it will not necessarily make installation any cheaper. We are seeing these incredibly cheap solar projects in the sun belt of 3 US cents per kilowatt hour, or 2p per kilowatt hour. Even in this country you can see that we will get to 5p or 6p per kilowatt hour. Even if it was 3p it would still not solve all the system problems. There is still the cost of integration, and you have to figure out how to deal with that.

We will see innovation in heating, whether it is biomass, biogas or geothermal, and we will see innovation on experience curves. I would look for game-changers in storage. A lot of the breakthroughs will come with how we manage the system. When we get to 20% electric vehicles, that will enable us to do some really interesting things.

I have not managed to say yet that the capacity markets are a machine for destroying innovation. The incumbents love them, and there is a reason for that. If you really want innovation, you will not go down that route.

Baroness Wheatcroft: Other countries are doing a lot more with geothermal than we have done so far. Why is that?

Michael Liebreich: We have had cheap gas for a long time. France has done lots of heating with electricity because it has nuclear power, which you cannot switch off, so you might as well use it to heat your homes. We have cheap gas, so we have a system that is very committed to using gas. Other countries with similar conditions have used a lot more air-source heat pumps and geothermal ground-source heat pumps. We are where we are. Should we use more of that? Absolutely, but it is not a silver bullet.

Baroness Wheatcroft: Mr McNeal, should we be investing more in finding other ways of creating energy?

Hugh McNeal: That is a very difficult public policy decision that takes me back to my civil servant days, I am afraid. If I can, I will make a different point. Some of what we have seen in offshore wind, because of UK leadership, has been pretty remarkable in recent years. The doubling in the size of turbines and the 40% reduction in cost are not what you associate with multi-billion pound infrastructure projects; it is what you associate with TVs and computers.

Are we invested enough? Should Innovate UK have more money? In another capacity, I am an executive director of the Offshore Renewable Energy Catapult. I am sure it would want more money, but everyone wants more money and pockets are tight. What sort of things are interesting and what are we seeing? We will see bigger turbines, floating wind, more experience coming from oil and gas.

I completely agree with Michael about software. Some of our most interesting members—they are all interesting, of course—are the people who do pretty amazing things to control our grid system with software. We even have someone who is trying to develop a new drive train generator for turbines that does not use rare-earth materials but uses ferrites. That could be a huge breakthrough and would be a wonderful industrial story were it to come off. There are all these things. Is it dramatic or the exciting breakthrough that one wants? No. It may be incremental, but I still find it quite exciting.

Baroness Wheatcroft: But in most technologies the trend has been for things to get smaller.

Hugh McNeal: Yes, that is true.

Baroness Wheatcroft: Can you see any way in which that will happen on the energy front, instead of talking bigger?

Hugh McNeal: I do not know.

Michael Liebreich: There are a couple of areas: appliance efficiency and nuclear. Appliance efficiency you see very clearly. The solar miracle, particularly in the developing world, is actually an LED miracle, because suddenly the solar panel that you need is not yea big; it is a little thing. We are seeing quite dramatic improvements in appliance efficiency. There are programmes that are also bringing in R&D, governmental and corporate to radically improve the energy efficiency of everything: fans, fridges, sewing machines and so on. A lot of that is driven by middle-class developing world needs, but that flows out into other areas. It is helping to drive energy efficiency, because that is a lot of volume.

The other is nuclear. Yes, we should absolutely spend more on R&D, and orders of magnitude more on leapfrogging to smaller, modular, rapidly deployable, failsafe technologies on which much of the rest of the world is doing a lot more than perhaps we are.

Baroness Wheatcroft: Some of our universities are, though, are they not?

Michael Liebreich: Yes, but how can I put this? We do not have 30 years, so I think we should be moving much more rapidly.

The Chairman: We come to the last question of this session.

Q110 **Lord Lamont of Lerwick:** This may relate partly to what Baroness Wheatcroft asked about. Earlier on, one of you used the phrase "smart

flexible grid". Would you describe exactly what you would ideally like that to be and how different it would be? That presumably has a great impact on what you call the capability market.

Michael Liebreich: Yes. I will start with a description of how the grid has been. It has been about large centralised generators, because the bigger you build them the more efficient they can be. Then we have the transmission grid, and then distribution grids. Broadly speaking, we got reliability through overcapacity: just build more of everything and that is how you manage it.

We are already much more distributed. The number of generators, not just solar but wind, is enormously increased. It is also attached to the distribution grid and not just to the transmission grid. Something like 20% of generating capability—it may be a bit more—is now attached to the distribution grids, the local grids, not the transmission grids. Because of the now 25% of renewable power, you have lost control of dispatch to a certain extent. You cannot just say, "Switch that generator on now", and then "Switch it off now", and control it largely fully.

Now, however, you have much more ability to control the demand side. You can switch things on and off. There used to be just a few large energy users, which could be controlled. Somebody could telephone them and say, "Please don't do this or that for the next hour, because we've got some maintenance", or whatever. Now you have much more control on the demand side, and that will increase radically and dramatically as everything goes digital—and it will go digital just through the asset cycle, with no incremental costs anyway. Every substation, every resource, every piece of infrastructure—transport and energy—will be digitally sensor-profuse and controlled, so we will get more and more ability.

We will lose control of dispatch and gain control of the demand side. That will enable us to fulfil reliability not by massive overcapacity but ultimately by smart routing, in a similar way to telephony when we moved from the centralised system to IP-based telephony and you could route calls and packets whichever way and get much more capacity utilisation and much more efficient use of your capital as a result. Bring in electric vehicles and cars, bring in some of the demand side, and you will start to have heat pump-based heating for some proportion of the country and start being able to store things with batteries and to have thermal storage. Digital control is absolutely critical to that. You cannot do it using the 1970s and 1980s technologies. They just would not allow you to get this whole thing going. Think telephony in the 1980s and then identify where that does not work as an analogy, rather than saying, "Oh, it's all different and it doesn't work".

The Chairman: Gentlemen, thank you very much indeed.

Examination of witnesses

Professor Sir Richard Friend, Mr Simon Daniel, Mr George Grant and Mr Stephen Tindale.

The Chairman: Gentlemen, I welcome you to this Committee. We will start with a question from Lord Tugendhat.

Q111 **Lord Tugendhat:** A completely straight-up question: can you please explain the work you are doing and how it fits into the UK energy system?

Professor Sir Richard Friend: I work substantially in the area of solar energy—improved solar cells. Earlier we heard that the cost of solar has come down; I think it has the capacity to go a lot lower than it is at the moment. We have seen a factor 10 reduction in the last 15 years. That is a bit like Moore’s law—we are not used to that in the energy sector. Moore’s law carried on working for far longer than we expected it would, and there is every chance that that may happen with some of the renewables.

With solar, the topic I am most interested in is that silicon solar cells are not very efficient. They use only a fraction of the solar spectrum efficiently. They are very good in the infrared, but in the visible part of the spectrum they throw most of the energy away as the photons have too much energy. If you can slice up the spectrum and deal with different colour ranges separately, you can raise efficiency considerably. That is a huge opportunity. If you can double the efficiency of a solar cell, that carries over to at least 50% of the fixed costs—the insulation and running costs, most of them scaled with area. If I get more efficiency, I win. Therefore there is a huge opportunity.

On my own work, we have a slightly long-range project to take a visible photon, do some magic quantum mechanics with it and split into two photons in the infrared, which will then be absorbed in the silicone solar cell below. If it all works, we will be able to put just a thin layer on top of today’s solar panels and get a significant uplift in efficiency. However, I would not wish to push my own work or the work that is going on in my group in Cambridge as the unique solution to that. I stress that because the opportunity is so large, many possible solutions are in play. It is at that stage in the development of the technology. We heard earlier that the materials with a perovskite structure that came out of a group in the University of Oxford have gone from zero in 2012 to more or less matching silicone in four years. I can report that the UK is in the lead in that. That came quite unexpectedly, and it turns out that these materials can make so-called tandem cells, which can deal with the spectrum better.

Simon Daniel: Hello. I am in energy storage. We are interested in putting millions of batteries behind the meter in homes as fast as possible to give an aggregate grid-scale storage facility. Energy storage is on a global trajectory as it fixes a number of issues with renewable

generation, solar and wind producing energy intermittently or at the wrong time of day. Solar might be a liability to a traditional grid system, whereas storage is an asset to it, and solar plus storage makes solar asset-class and sustainable.

To date we have delivered quite a lot of batteries in the UK behind the meter as part of a number of pilot projects supported by DECC and Innovate UK—around £4 million-worth of projects under the energy storage demonstration and innovation fund and other localised energy community funds. That demonstrates the value of storage in a home for the whole system, whether it is in the home for solar self-consumption, to store excess solar, to reduce curtailment costs, to shift energy to the evening peak or to reduce grid evening costs and customer bills, or managed as an aggregate for a network benefit locally to displace capital or as an aggregate for the grid scale system. If I put 1 million batteries into the UK by 2020, that looks like a virtual Dinorwig plant, so it can get Dinorwig-level income as well as network deferral costs and customer income. If you have a battery at the grid edge, it gets much more income and gives both a local and a national benefit. However, it is a distributor and asset class, which needs managing over time. So that is storage.

Globally, there seem to be a number of movements. We are a bit like a Tesla light battery—our interest is in every home, urban homes, social housing, utility customers. A lot of the international batteries favour prosumer homes, where batteries may be a luxury in trying to get the house off grid. The economics are optimised if a battery complements a grid, maybe powering a third of the day. The grid is pretty good at managing peaks and spikes but the battery can help balance it. We also take a view that the role of storage is critical for good infrastructure. If we view Germany as the ghost of Christmas future, showing the UK landscape what happens in seven years if we put lots of renewables in, we end up with a grid that switches off during the day when solar and wind are generating, and as a result the costs double for the infrastructure in the evening to recoup the cost of running the system. If you use batteries well in the system, you can run a sort of flat grid, which goes into some of the smart and flexible technologies Michael Liebreich mentioned previously.

George Grant: I feel a bit like a black sheep in this esteemed company, as the focus is clearly on new technology. We at Stag Energy and Watt Power tend to focus on delivering largely existing technology but with a focus on energy security. We have looked at gas storage and gas fire generation principally. Although innovations are coming forward and we are all keen to support those, the sort of challenge Lord Burns mentioned a moment ago is what we are dealing with today.

There was a good example of that about 10 days ago. We have about 10,000 megawatts of solar capacity on the UK system at the moment and a little over 15,000 of wind. We had a system stress event warning 10 days ago and prices went through the roof. Out of that 25,000 megawatts, which would have cost between £25 billion and £30 billion,

300 megawatts were operating. It was between 5 pm and 6 pm at night, so there was no solar, and it was calm, still and cold, and we had very little wind.

Some of the technologies that we will talk about today will help to alleviate that problem, but we have some challenges today. Should we invest a little more in gas to tie this over? As Lord Forsyth said earlier, that is another question. I can help to focus on technologies today and on the challenges of raising finance and uncertainty in the market. We have a market that is broken and the Government are the central buyer, a situation that is not sustainable. The perspective I can bring to the panel today is very much about what we have to do today and how we can make sure that we can finance the assets going forward.

Stephen Tindale: I work for two days a week running the Alvin Weinberg Foundation, which is the only pro-nuclear charity in the UK. Specifically we are pro-advanced nuclear generation for nuclear—fast reactors. We have tried fast breeder reactors in the UK at Dounreay, and that did not work economically. We now need to look at fast burner reactors, because there is no shortage of plutonium and so on. That is one form of advanced nuclear. The other is molten salt reactors, one of which Alvin Weinberg, the US physicist after whom we are named, was building in the 1960s and early 1970s until President Nixon shut it down. It is an advanced technology—it is not just a paper reactor—but it has not been implemented or built more recently, so there is much work to be done there. The rest of the week I am a consultant, and I work particularly for Tidal Lagoon Power. You have just had a discussion about possible new forms of renewable energy. I would say that tidal lagoons are a very good example of that, and I am very happy to talk about that.

Q112 **Lord Sharkey:** Can I ask you two more questions about technology? First, what impact do you expect your own technologies to make over the next 10 years? Secondly, which other technologies will have the most transformative or disruptive effect on the energy sector and which areas should be priorities for research, apart from your own technologies of course?

Professor Sir Richard Friend: Globally, solar will expand massively in the next 10 years. There are installations in sunny parts of the world that appear to more or less match fossil fuel costs—I think 3 cents a kilowatt hour is probably a bit ambitious, but prices are falling, and the scale of solar will increase massively. I hope that our own work will be one of the significant steps that produce a large drop in the cost, probably of silicon-based solar. I see what we are doing in that global context; we are looking around the world to see where solar will make its largest impact.

Simon Daniel: Obviously we have a bias towards storage, given its benefit to solar and wind and to system. Storage itself is falling in price quite significantly, with chemistry innovation prices dropping 10% a year and integrated system costs dropping in line with prices and volatility rising. Indeed, the recent June event has created a rise in retail prices and volatility, and the interconnects are now going backwards, reducing

the capacity margins; it is cheaper to sell energy to Europe than buy it from Europe. So storage as technology, particularly given the momentum of the business case, is getting stronger, and it goes through a hundredfold trajectory in line with the trading that solar did a number of years ago.

The second is control technologies. We see that in how we control storage today in fleets. If I turn on every laptop in the country at a certain time or every EV at a certain time, or if I go to China—there are 150 million electric bicycles there, which constitute around 40 gigawatts a day of free charging—that is shiftable demand with a control technology. In the next 10 years, control technologies, for cyber and with good or bad benefits, are a key technology. Today, nothing stops me putting out 1 million batteries in the UK and controlling it as a power plant. You do not need a licence, you can do it very quickly. Control technologies make a whole range of things work.

An issue with control technologies is the persistency. Traditionally, when something in the ground in a grid system is an asset class, you have to make software that lasts decades, so while there is an opportunity for control technology to control the world today, can one reliability cancel the future infrastructure projects based around software being repeated and updated across decades? That is a key challenge for distributor technology. However, as with telephony and IP history, there are mechanisms by which infrastructure-class things can be managed with control. That is probably the largest growth centre and the thing that would be the most rapid disruption to traditional grids, and grids need to use these technologies to survive and cover other new business models.

George Grant: I have a fairly easy position here in that I do not have a particular technology to promote. All the technologies that are being talked about here will have an important role to play in the future.

On solar and storage, I agree very much that control technology and information technology will play an important role. Flexibility will become increasingly important for managing and balancing the grid. The overarching challenge for government is to ensure that there is a market that will facilitate a reliable, secure system. We talk about the energy trilemma of affordability, security and low carbon, but those are not necessarily easy bedfellows. It is a challenge to ensure that the market structure brings forward these new technologies and does not end up with the Government being asked to choose technologies and set targets. It is about how we establish a market structure that will enable these technologies to come forward in a competitive way.

Stephen Tindale: Over the next 10 years, advanced nuclear will not be a major player in energy systems. Commercialisation is possible over the next 10 years, but there will not be many advanced nuclear reactors operating in 10 years' time. That does not mean that we should go slow on it, because over the following 10 or 20 years they could become major players, but a decade is too short a period. One of the companies I am working with, Terrestrial Energy, a Canadian-based company, has said

that it aims to commercialise by the mid-2020s, so it is possible, at least in its view. That is why further generation 3 existing reactor designs are necessary as a kind of bridge technology to get us to advanced nuclear, which will be a major player not only in electricity but in heat. Industrial heating cannot be delivered by electricity, as I understand it, so some other form of heating is necessary. Bioenergy is possible, but that has lots of downsides relating to land use and biodiversity, so advanced nuclear for industrial heating seems a sensible way forward.

The other company I mentioned, Tidal Lagoon Power, could be a major player in the next 10 years. I very much hope that following the Hendry review the Government will authorise and support the pathfinder proposal for Swansea financially through a CFD. That is necessary, learning by doing and so on, but the company says that it will then build a 3 gigawatt lagoon off Cardiff, and the Welsh Government are very supportive; they have given it a commercial loan. It is therefore possible that by 2026 more than 3 gigawatts will be generated by the Severn.

Lord Sharkey: Briefly, is Elon Musk ahead of the game in storage technology?

Simon Daniel: He is definitely a useful advert for our sector, as he has made visible the retail value of storage as a technology. The defect of Tesla's take-home off-grid and grid model is that it is a luxury model, in the same way that a high-price vehicle is a luxury model. However, when he launched his mass market vehicle he sold \$8 million-worth of that overnight, so the opportunity for storage is into the mass market in every home. Certainly, if you make storage in a low-carbon factory with solar panels on your roof, you have a lower embodied energy cost to storage. If you make solar panels and batteries in China, you have a high carbon cost, so strategically making and manufacturing energy technology using low-carbon resources ends up with a low energy cost. Energy storage is not a carbon-free carbon technology. It might be, say, 50 grams a kilowatt hour today, so solar plus storage is 100 grams. Nuclear might be rated as low carbon. So he is definitely a poster child for it.

However, competing against the traditional grid, which is a multi-trillion dollar global infrastructure, with an app or a single product, is the wrong way. You should complement the grid. We therefore position ourselves as a friend of the utility. We undersize our battery to power a third of the day. If you go above that, the economics start to go south, as you want to use the grid to power your kettle and your washing machine, which on average are rarely on, whereas using a battery to power the things you use in your home is critical. Energy demand is rising in electricity for all the low-power electronic stuff; the internet of things has 50 billion devices are always on and always on at peak.

No price can change the behaviour in houses in relation to that technology. In Glastonbury, people spend £3 to charge their mobile phone. No grid price will get people to change their behaviour on domestic technology. You might for a white good but not for an electronic good that is on at peak. That is the critical opportunity we see for

batteries. In California, a battery is a solar battery. In Europe, a battery is a solar battery in the summer and a winter battery in the winter, because it deals with managing the peaks. Europe is also a domestic-driven peak, so while homes are about a third of the electricity use for non-heating over a year, they are about two-thirds of peak. Therefore reducing demand in a domestic property in Europe that might involve a battery that does not require a behavioural response is, in our view, a critical technology. Tesla's focus today is more on the CNI element, and the models do not port from California as well, but he is definitely an encouraging influence. My CTO calls him Iron Man. A friend of mine who works there who runs the AI division calls him Willy Wonka. He is certainly an interesting character.

- Q113 **Lord Layard:** I wanted to ask you about Britain's record in clean energy research compared with other countries', and in particular about the implications of the Government's announcement in the spending review that they would double public expenditure on clean energy research by 2020. How would that money be best spent? What kind of co-ordination is needed to produce value for money from that kind of expenditure?

Professor Sir Richard Friend: First, research in the UK is good, and all the indicators suggest that we perform exceptionally well and deliver very good value for money out of the universities. The most important aspect of a future landscape of technologies is that we get people who have the right abilities and skills, who can see careers ahead in the new energy technologies. Looking it from my university perspective, that is one of the largest challenges we face. A graduate can still see a great career in an oil company, but it is much harder to see where that trajectory for a fantastic career might lie in solar or wind.

On where the money gets spent, I have to say that I am still unaware of where any of it might get spent. I hope we might manage to learn how to do what is done well in Germany in the Fraunhofer institutes; we have some catapult centres but we lack that ability to regularise and prove principles—the early scale demonstration that other developed countries tend to have through their national laboratories. We have to address that if we are to allow the creativity that is there in the universities to be able to be drawn through and to be able to support what I hope will be significantly more private capital that will chase after our talent.

Lord Layard: Is there anybody we should be talking to who has thought about how to make sure that this money does get well spent? You mentioned that there are different institutional structures. As I understand it, we do not have any kind of national policy on clean energy research or any single group that has an overview of it. There are about five or six separate different budgets, which do not talk to each other.

Professor Sir Richard Friend: That summarises the problem very well. I do not see a clear ownership or a clear determination of that government spend to make that impact.

Lord Turnbull: With respect to the question for Professor Friend, how

important is latitude? For instance, take an area of land in the Sahara in daylight hours and that will produce 100 megawatts. What will the same area produce 54 degrees north? In other words, is solar great in some parts of the world and a waste of time elsewhere?

Professor Sir Richard Friend: Fifty-four degrees north gets up to Manchester or Edinburgh, does it not? I know that Cambridge is at 52 degrees. It is a factor of two. If the cost of solar drops by a factor of two, it becomes quite competitive here, and that will happen. The problem that everyone spoke about previously is intermittency—the problem that the sun does not shine for as long in the winter as it does in the summer. However, we can still harvest quite a lot of sunlight, even so close to the North Pole.

Lord Turnbull: You also have cloud, of course.

Professor Sir Richard Friend: We do not have the same advantages, but in terms of integrated solar radiation falling on the land, it is only a factor of two or so below very sunny parts of the world.

Lord Turnbull: This battery in every home—how big is it and how much does it cost?

Simon Daniel: It is about the size of a briefcase; it is a 2-to-3 kilowatt hour, all-in-one-battery system. We looked at the Sky business model of deploying a Sky box in a third of British homes in 10 years. It did that by having a small product, which could be fitted in an hour, so we followed that. Obviously Sky is sexy because it gives you sport, and energy is unsexy, but high energy bills and an absence of energy is very unsexy. So it is a slightly different customer proposition, but as a physical item it is designed to go quickly into the homes.

With my colleague from the lagoon project we could deliver a lagoon annually, given the right economic marketplace. We can physically make and deploy millions of batteries in the way Sky did. To date, it costs about £2,000 to install it on the wall. If you buy it through retailing it is more expensive. If you are given it free as part of a utility smart deal it will be cheaper, and the economics are getting better by the day. As retail prices rise, we are on a different trajectory going forward; battery prices are falling, peak costs are getting more sensitive, so the economics will get better and better for the role of storage as a domestic proposition.

Stephen Tindale: I just wanted to respond to Lord Layard's question on research. In the nuclear field, the UK remains quite good on research but not good on research and development, or at least not on the development bit, because we have built no nuclear power stations since the early 1990s. What is needed now is to co-operate with the US, depending on what happens there; certainly the Obama Administration was allocating money and giving it out to research and development for advanced nuclear, and the Trudeau Government in Canada are doing likewise. It would be good to talk to Oak Ridge National Laboratory, for

example, to learn how to make progress on delivering advanced nuclear in a way that not only helps with energy security and climate protection but is a major economic opportunity.

Baroness Wheatcroft: One of the reasons why we have not developed any nuclear power stations over the last decades is presumably because there was a perception that the public were not in favour. We are told in your biography that you spent two decades campaigning against nuclear. Can you tell us where the change of heart came from?

Stephen Tindale: That is a perfectly fair question. Indeed, I spent two decades campaigning against nuclear and drafted the Labour Party's environment policy in 1994, which said, "No new nuclear". It took Tony Blair in No. 10 and Gordon Brown some time to shift away from that. I then went to work for Greenpeace. I was always worried primarily about the weapons proliferation risk of nuclear rather than radioactive discharges or waste. At least the nuclear industry is required to look after its waste, whereas the fossil fuel industry just puts it out into the atmosphere. I remained concerned about weapons proliferation. My change of heart occurred in August 2006, when the permafrost in Siberia had a massive melt and released vast quantities of methane, at which point I thought, "Oh dear"—to put it politely—"What can we do about this?". I then concluded over several months, during which I ended up leaving Greenpeace, that we needed to stop arguing only for "the best", which in terms of energy supply would be renewables, but we need the good as well. Nuclear, because it is low carbon, is in this sense good.

Baroness Wheatcroft: Climate change trumps nuclear arms.

Stephen Tindale: Correct.

Q114 **Lord Forsyth of Drumlean:** An easy question: should the Government treat investment in energy technology as part of their so-called industrial strategy? If you think they should, do you really think that government is well placed to start picking winners and deciding where that money should best be deployed? I just wonder whether the experience to date with the very generous subsidies for renewables may have deterred some of the work that should have been done on new technologies.

Professor Sir Richard Friend: One of the virtues of most renewable technologies is that most of the cost actually falls locally, so it creates jobs. The cost of installing and maintaining solar cells is rather larger than the cost of buying them from China. Compared with taking gas from some terminal in Milford Haven, where we just have to pay for the gas, most of the cost of solar installations or wind is paying people to work in the UK. It therefore helps to re-engineer the economy. That is also true for nuclear. It is a point that Sir David King makes repeatedly, and I agree with him.

Picking winners does not work. I am certainly not an economist, but my general sense is that we need to set up the ecosystem so that what should win has a fair chance of winning. Maybe the most important role

for government is to make sure that the regulatory structure has not biased things unintentionally and is appropriately quick to respond when it appears that things are not quite right. I hope that the commercial sector in the UK will be more interested in that opportunity. We have to engage it.

Lord Forsyth of Drumlean: Could you develop that point about the regulatory structure?

Professor Sir Richard Friend: From what I read, I understand that there are many possible plays in, for example, storage. Most of them are enabled through the intelligent grid. I hear that some aspects of that grid are not quite as intelligent as they should be. We should allow as many experiments as possible to be played. Obviously that would be at the investors' expense, but if someone can find a way to trade energy they should be able to do so.

Simon Daniel: The alignment in BEIS of the DECC and Innovate UK research agendas is sensible. To address Lord Layard's comments, if you align everything, you miss opportunities of innovation. Having some chaotic cross-triangulation of research ends up with true research. Certainly when DECC had an innovation programme that was open call, it ended up with a far greater range of innovative projects than mandating that a body must look like this and do that. Similarly, when the LCNF spent half a billion of customer money testing technologies to see whether there was a cheaper way to spend £177 billion on infrastructure, it was done from the lens of a network operator or of a distributed network operator, which gave a result for those participants, but not a full system. The research agendas need to be lined up before systems solutions can arise from the innovation pot. The UK is very good at the early-stage TRL development innovation in the chemistry, through to the company, through to the product. It is less good in the commercial scale-up, partly because of the local market versus some of the offshore countries that have a stronger domestic market.

Light regulation helps. Certainly, the removal of a range of energy policies creates a cleaner marketplace. We certainly had more solar because of the feed-in tariff. On the other side, we have nearly as much solar installed in homes as America does, which creates a very interesting ecosystem—890,000 homes in the UK have solar, and there are 1 million in the US—for doing something that is next-stage technology. Despite not having the scale-up market, we probably have one of the best regulatory markets for flexibility, grid services and deregulated utilities to build some of these new models and demonstrate them within the Petri dish of the UK and then export them.

On greater clarity on regulation, in particular on storage, the consultation launched on Thursday is a helpful step to ask questions of the industry about which regulations can be made easier, in particular for grid-scale assets and for flexibility and aggregators. That will give feedback to the Government as to which regulations to switch off or stand back from to enable the marketplace to grow, and certainly for having some targets in

place. For example, California had a mandate for storage and set an end goal, without picking winners and saying either technology A or technology B. It just said that it is a good thing. One of the mechanisms the Government could provide, rather than providing direct finance, is, with something like the National Infrastructure Commission, to provide guidance on the asset finance or the investment class treatment, as the problem is really how these things get monetised in time. Making regulations for doing things like that more easily would accelerate the marketplace.

George Grant: On your question as to whether infrastructure should be a central plank to the Government's strategy, it absolutely should. Is there a market structure that would support that? There certainly seems to have been some discussion of late about removing the carbon floor price, which would be a big mistake. If we are concerned about moving towards a lower-carbon environment, we should maintain the carbon floor price and a rising carbon tax, because that will ultimately put low-carbon technologies in a more competitive position. We need to get coal off the system.

Gas is often referred to as a transition fuel, and we need to acknowledge that over the next 30 or so years there will be investment in the technologies that we are talking about, but also in gas to provide flexibility for the system. Regarding gas security as well as electricity security, one of the other issues the Government very much need to focus on is that the Rough gas storage facility, which is about 75% of our gas storage capacity, is over 40 years old. I do not know whether it has come back online, but it has been offline for three or four months. It will close in the next five to 10 years, which would leave the UK with 1.5% of annual gas consumption in terms of domestic gas storage capacity. That is equivalent to about five days; France and Germany have about 100 days. That position is irresponsible if we let it continue. An area the Government very much need to focus on is infrastructure and security of supply, which will have a role over the next 20 to 30 years.

Stephen Tindale: I agree that energy has to be a central part of the industrial strategy. That is why I welcomed the creation of BEIS. Many of my colleagues in the climate movement were very unhappy that DECC was abolished, but in my view the name of the department is less important than its clout in Whitehall. BEIS has the potential to be a significant player in Whitehall, with I am afraid DECC never had.

Industrial strategy should cover not only the job creation potential of energy, or how to promote energy security, but, crucially, innovation. On innovation, as well as the issues I have talked about, carbon capture and storage should be restarted. George Osborne's cancellation of that competition not only was bad in content but sent appalling signals to the potential investors—actual investors in that case—that there was no regulatory stability in the UK. This is one of our major challenges and obstacles: that energy policy changes too often, even when there is no change of Government. To reinsert carbon capture and storage, maybe

not for coal but certainly for gas, would be very good not only to protect the climate and keep up with other countries that are developing CCS but to reassure potential investors.

On picking winners, if the market was working well, it would not be necessary for the Government to pick winners. By “working well” I mean if all relevant externalities had been internalised—so not only a carbon price but toxic pollutants, such as sulphur dioxide and nitrogen dioxide. We are nowhere near that. The carbon price floor in the UK can be argued many ways, but it is about a third of the external costs of greenhouse gas emissions. The EU ETS is about a tenth of the cost, so it is a complete waste of time.

So we are doing better than continental Europe but not nearly well enough. In my view, the major achievement of the coalition was the emissions performance standard—the regulation to prevent new coal-fired power stations without carbon capture and storage. It is not low enough in that it allows unabated gas to be built or to continue, and it does not use a regulatory system to shut coal down quickly, but the market appears to be doing that for other reasons. The role of the Government, given the lack of sufficient carbon prices and other green taxes, is to set the framework, which is what Greg Clark said in his speech to Energy UK earlier this week.

Q115 Lord Forsyth of Drumlean: Can I just ask Mr Daniel a question, which is slightly off this issue, about his batteries the size of a briefcase that you can put in everyone’s home? Given certainly my experience with batteries in a marine environment elsewhere, or given people’s experience with batteries in their telephones, how realistic is it that the battery life—the ability to maintain the life of the battery and its charge—will not be very limited? They are also very expensive. That is one of the problems that we have with electric cars at the moment. Are your briefcase batteries different?

Simon Daniel: There is a range of different chemistries that have improving cycle lengths, so they can last from seven to 20 years, depending on what price you pay for them. In our view, a battery is a bit like an ink cartridge: you should put one in today at a median point of a seven to 10-year point, which might cost you \$400 per kilowatt hour, and replace it in seven to 10 years—

Lord Forsyth of Drumlean: So your £2,000 briefcase lasts—

Simon Daniel: You would place an upgrade of the battery as part of our service model, so you would guarantee a performance, and then we would upgrade the battery. The cost of upgrading the battery has fallen in line with the economics. Because we manage the battery as a grid service, it is in our interest to make sure that it always delivers performance.

Lord Forsyth of Drumlean: Forgive me, but you have not really answered my question. People pay £2,000 for the briefcase. How long

does it last, and what do they have to pay after that?

Simon Daniel: That will last about 10 years. Then we will replace the battery, which we have included in a service contract to last another 10 years. If I put a battery in today which lasts 25 years, it might cost me £1,000. If I put one in that lasts me—

Lord Forsyth of Drumlean: So you never actually own it. You are into short business model pricing—

Simon Daniel: In effect, the best models are lease models. However, chemistry cycles are improving, and with different prices you get different performance. This is a key question. This chemistry is very predictable because of colleagues such as Richard on my right. The software of maintaining distributed energy assets is a harder problem. The key thing is to manage the battery every day, working it as hard as possible to make it run out as quickly as possible. Then it will deliver the maximum benefit to the house, the network or the system.

Lord Forsyth of Drumlean: There is no prospect of the technology of these batteries getting away from those problems.

Simon Daniel: The chemistries are improving from a number of different sources. If you overspend today on a chemistry that has a longer lifespan, that will be quite a premium. If you replace it in five or 10 years, those costs are significantly better than batteries that have higher performers. So it is a slightly odd model, but it is like a service model, where we manage it over a period of time.

Lord Forsyth of Drumlean: It is not very green, though, is it?

Simon Daniel: There is a cost per cycle that has a green value, and most batteries have a recycle value, but it is at a tipping point, from moving from an early adopter phase to a mass market, and some of those questions are critical to win it as it goes through an inflexion point and into a mass market. We think that will happen before 2020 with regard to installation with smart meters and other benefits.

Q116 **Lord Lamont of Lerwick:** Mr Grant, I think you said earlier—I hope I am not misquoting you—that “the market is broken and the Government are the buyer”. A lot of us agree with that and would like a more neutral and more competitive system. However, you went on to say that “the system is not sustainable”. That is a strong phrase. Did you mean just “not competitive”, or something stronger?

George Grant: I suppose the system could be sustainable in that mode if the Government were comfortable maintaining a role as the central buyer. We are seeing that nothing in the electricity sector gets built without some form of government support, be it nuclear, wind or tidal lagoon, and now the capacity market is having to provide support for conventional and is supporting coal, gas and existing nuclear. That system has precipitated a vast number of lobby groups, each looking for a specific answer for specific technologies. We definitely need to get away

from that. It is a question of how brave the Government in making a radical change, and how quickly. For instance, we are signing up to contracts for Hinkley that will see us through to 2060. There is a system of grandfathering which the investment community would clearly be disturbed to see disappear. So we are making commitments today that will be with us for some years to come. However, to continue in that vein without trying to move to a more market-based system, be it with a carbon tax or mechanisms of that nature that would allow technologies to compete and for the Government to step back—I certainly get the sense that the Government would prefer that, but they need to move forward with open eyes with regard to where we are at the moment.

Simon Daniel: That is an interesting comment about the Government as buyer. We produced an interesting model about the energy cost in retirement. Typically, pensioners spend about 10% of their income in retirement on energy costs, and this is rising, creating hardship and fuel poverty. However, if you take the view that the Government are the buyer, DWP is spending £100 billion on pensioners, of which £10 billion of that is written from the Treasury to the pensioner to give to the big six, to give to a yield co to pay for an infrastructure. In that context, if you made energy free in retirement and capped the usage so you did not waste it, and made government the central buyer, which in effect it is, interestingly you would certainly do things differently.

In managing the cost of retirement, it is much better to give someone a low-energy lightbulb than to give them money to spend on fuel. If you look at the cost of energy in retirement on an individual basis, a pensioner needs about a £35,000 lump sum to have a £100 income to pay an energy bill. If you knew you had a £35,000 liability, which the Treasury does, in effect you might spend some of £2,000 on solar panels or on some of my storage batteries, or £2,000 on efficiency, and instantly write down £15,000 of your liability.

Indeed, we did a model for the former PM where we looked at the UK cost. I think the UK has a forward £700-billion liability in the pensions system, which is unfunded and which in effect goes to forward energy costs. Europe has about £5 trillion and the global system has about £10 trillion, so the money is sort of there to fund infrastructure improvements or energy efficiency improvements. It is sitting in a balance sheet called DWP, and it is sitting as a cost in BEIS called infrastructure. If you could switch it around and do some radical policy, it is all there, but that is not the current strategy. Economically, however, today efficiency pays more than gilts.

Lord Turnbull: I just want to clarify the point about batteries. The answer is that no one actually pays £2,000. You basically have a monthly or yearly payment.

Simon Daniel: Effectively, yes.

Lord Turnbull: So how much is it to rent the briefcase per year?

Simon Daniel: Ultimately, when the market is functional, the value of the briefcase to the grid system—to the system operator in displacing capital and to the network operator in the utility in managing its imbalance—means that the battery could be free to the end tenant. It is on a trajectory, so it is like a free zone model. You could have a free battery model as long as you get paid properly by the value of the assets. Certainly Lord Adonis produced a model where if there were several gigawatt hours of battery, pumped hydro or lagoons in the grid system by 2020, that could save £8 billion a year from the system value, which is currently paid for in national grid upgrades and so forth.

Lord Turnbull: What does the household pay?

Simon Daniel: Ideally, in the future it will pay nothing, because the grid pays for it, but it is a stage model, so today they would pay a lease fee for it and tomorrow they would pay less if the grid prepays for some of it with a smart meter deployment.

Q117 **The Chairman:** Next time you appear in front of a Committee, you should bring your briefcase. Can I bring this session to a close by asking you what steps you think the Government need to take to encourage private investment in your particular businesses and in the sector generally?

Professor Sir Richard Friend: In the area I work in, as I said earlier, we see ourselves in a global market. What happens in the UK is important. As with many other areas of emerging technology, the Government appreciate that we are quite good, but they need to make sure that we remain competitive. It is particularly that piece beyond the universities that we need to keep testing. We need to work out how we live in a world where we have fewer large corporates that are UK-based than, say, Germany does. The Government have a role to help our infrastructure to play a significant role.

The Chairman: Would that help to crack the problem of moving from research to development?

Professor Sir Richard Friend: We ask small companies to do a lot of heavy lifting. We need larger companies around too. A government strategy that understands what that ecosystem is and what it may have to become, and some clarity and commitment that that is the trajectory we are following, would be very valuable.

Simon Daniel: Storage is an emerging asset class. It is good infrastructure, but it does not yet benefit from some of the regulated asset class structure. If National Grid is allowed to own storage and network operators are allowed to own storage and finance it at a 1% or 2% rate, that is a good model for financing storage to scale.

On some of the regulatory change that enables different people to own storage, storage is pretty similar to how smart meters are treated as a meter asset provider, but it is regulated so that there is a secure income

stream. Solving the asset finance and regulating for it would be very helpful.

Energy prices are obviously sensitive to customers. With prices rising, a Marmite moment is about to happen. It will come back very quickly when people see energy costs rising in their pockets as a result of the oil price and other changes geopolitically. People will start to think about efficiency. The solutions out there will surface themselves. Having a reduced energy policy to let the market work itself out is helpful. I do not need to price a political risk to feed-in tariffs disappearing because they have already gone. You have to build a business model that is resilient to a no-tariff, no-subsidy environment, which is one of the benefits of the UK: we are not forced down a route of doing something temporary, we try to solve it technically.

The Chairman: Have any of the electricity supply companies talked to you about a joint venture to put batteries in homes?

Simon Daniel: In effect, all of them have. We have delivered projects with British Gas, Scottish Power and others of the big six, and with Good Energy and the Co-op. Most of the new utilities need storage as their business model, either for a green reason to make 100% green energy, or for a smart tariff reason. You do not really want the smart tariff guy coming with a smart meter to your home if you work during the day, as with a power shower and a smart water meter, but if they install a battery you can benefit from smart tariffs.

Equally, people want to be connected in the home and to finance assets over term. Storage sits at the epicentre of trying to solve utility models. Because all the big six utilities in Europe can look at Germany as a ghost of Christmas yet to come horror story, they know that their business model and grid system are dead unless they get into storage. As result, the principal investors in the US companies, such as Stem and AMS, are big utility companies. One of the challenges domestically to the investment question is that, because policy has been a bit reactionary to tariffs, the local investment market is not so strong for storage, but internationally, when you take a pan-European view, technologies such as solar and storage are being factored into infrastructure on a global basis because the economics are just so good, but really as a complement to the grid.

George Grant: The Government need to look at the short term—the next five years or so—and the long term, to try to resist making too many radical changes, otherwise you will lose investors. We need to maintain the carbon floor price. There need to be some changes to the capacity market, but not radical ones, to ensure that new investment is brought forward.

I mentioned gas security. That needs government focus to ensure that there is price security for customers and the industry.

The Chairman: On that, has Ofgem taken the point and decided to try to

intervene to ensure there is sufficient capacity?

George Grant: It is something that BEIS is looking at. Currently it has a gas security study under way. That will feed into its strategy and policy, which I expect it will announce in the spring.

Stephen Tindale: On nuclear, the Government have started on the right course with their promise of £250 million over five years on nuclear R&D innovation funding. That is part of the mission innovation commitment which the UK has made in the international climate agreement context. It has made a start and it is now running two competitions, but the experience of potential investments in carbon capture and storage competition, as I said, was not great. The Government need to set out a timetable and make some awards as soon as possible—give some money. That will encourage investor confidence. There is no lack of potential investors, but there is too much regulatory uncertainty and instability at the moment. The Government definitely need to counter that.

The other thing the Government could do on nuclear is encourage the Office for Nuclear Regulation to assess some of these generation 4 designs. Clearly, the Government cannot tell it to say yes, but they can indicate that they are priorities for UK energy policy: that some of these generation 4 reactor designs should be assessed by the Office for Nuclear Regulation.

On tidal lagoon power, again there is no shortage of potential private investors because it would last 120 years, so pension funds and the insurance sector are very interested in investing, but we need to build the pathfinder, which is what the Swansea lagoon would be. We need from the Government either a contract for difference or at least a statement in the Autumn Statement that they are minded to support Swansea.

The Chairman: It seemed that there was a lack of enthusiasm to invest in what turned out to be Hinkley C. The Government have ended up paying a very high price for it.

Stephen Tindale: Indeed. My view of the European pressurised reactor—the design that might be built at Hinkley, and now that the decision has been made I hope it is built—is that it does not have a great track record. It is quite an old-fashioned design and very complicated. More and more safety features were added to it, rather than a more holistic approach of starting from scratch and building safety intrinsically into the design.

The Chairman: So we are paying a high price for yesterday's model?

Stephen Tindale: Yes.

Lord Burns: What prices are you expecting for the Swansea lagoon?

Stephen Tindale: Are you asking about the strike price?

Lord Burns: Yes.

Stephen Tindale: It is roughly £120. Okay, that is higher than Hinkley, but it is a global first of its kind. I know that the Treasury does not like talk of global firsts of a kind, but La Rance, the barrage in France that uses broadly the same turbines, was built 50 years ago. Turbine technology has advanced somewhat. We need to test it. That is why the argument that we should go first for a three gigawatt one, to invest in an undemonstrated technological approach, is asking investors to be a bit too brave. If the Government wanted to do three gigawatts, they would probably have to provide all the capital themselves. That is not, apparently, on offer.

The Chairman: Gentlemen, thank you very much for a fascinating session.