HOUSE OF LORDS

Science and Technology Committee

Corrected oral evidence: Long-duration energy storage

Tuesday 17 October 2023

10.15 am

Watch the meeting

Members present: Baroness Brown of Cambridge (The Chair); Lord Holmes of Richmond; Lord Krebs; Baroness Neuberger; Baroness Neville-Jones; Baroness Northover; Lord Rees of Ludlow; Lord Sharkey; Viscount Stansgate; Lord Wei; Lord Winston.

Evidence Session No. 5 Heard in Public Questions 39 - 45

Witnesses

Ita Kettleborough, Director, Energy Transitions Commission; David Gray CBE, Former Chair of the Gas and Electricity Markets Authority.

USE OF THE TRANSCRIPT

This is a corrected transcript of evidence taken in public and webcast on www.parliamentlive.tv.

Examination of witnesses

Ita Kettleborough and David Gray.

Q39 **The Chair:** I welcome our witnesses to the committee's fifth evidence session for our inquiry into long-duration energy storage. This morning we will hear from David Gray, who has held a number of roles in the energy sector, including that of chair of the Gas and Electricity Markets Authority from 2013 to 2018 and current chair of Mutual Energy and of EIC. We will also hear from Ita Kettleborough, director at the Energy Transitions Commission.

The session is being broadcast on parliamentlive.tv. A full transcript will sent to you shortly after today for you to make minor corrections. If you think of anything that you do not get a chance to say, any data that you think it would be useful for us to have or any other background material, we would be very pleased if you would send it to us after the session and it can be included in our formal evidence. With that, we will proceed.

Ita, could you start by outlining the role that you see long-duration energy storage needing to play in a fully decarbonised grid?

Ita Kettleborough: As we move towards a fully decarbonised energy system, the vast majority, probably in the realm of 60% to 70% of generation, will be met by variable wind, solar and other renewables, but with a very dominant role for wind and solar. We think that a renewable-dominated system is absolutely feasible and cost effective. The important thing to be aware of with that system is that it looks fundamentally different, obviously, from our system today, which is primarily a fossil dispatchable system, and it therefore has very fundamentally different challenges in managing at the system level.

There are three key storage challenges that a renewable-dominated grid would face. The first is the daily balancing challenge. The sun shines in the day, but we want to use the power in the evening. We need to store that power and be able to use it overnight.

We then have the predictable, seasonal storage challenge. This is a much longer variation, season by season. We know that in the winter we will have greater heating needs, for instance, which will increase in a decarbonised economy when we are likely to be shifting a large proportion, if not all, of our heating needs towards electricity-based heat. In that case, we will have big demands for heat. The sun does not shine as much and we might not have as much wind and solar generation, so there will be a bigger gap. There could be a seasonal storage gap.

The third gap that we will have in the system is the unpredictability, week by week, where we know that things will happen, but we cannot know with any forward certainty when they will happen or how long they will last. The Germans call it the Dunkelflaute, which is a prolonged period of not very much sun and very little wind. That could be at any point during the year. If you had that over a week or two weeks, it would be very

difficult for a system based primarily on wind and solar. We need to think about meeting storage needs across those three types of storage.

This answer is a bit longer as it frames a lot of the needs. It is worth noting the relative size of those three buckets. From the work we have pulled together based on systems across the world, we expect that the balancing challenges that we have talked about might, on average, be a daily challenge for roughly 10% of the hours in the year; roughly, 10% might be a seasonal challenge; and 2% to 3% might be unpredictable week by week. However, it very much depends on the actual country, the system, the weather and the demand patterns, so in some cases it could be a lot bigger. You could have more like 20% seasonal balancing challenges; in some cases, it could be smaller. We think of a 10% to 25% balancing challenge for the grid as a rule of thumb.

As a commission, we are global, so we look at lots of different systems. To give a sense of the UK system, the CCC is looking at around 9% to 10% of hours in the year that need seasonal dispatchable storage. To give you an idea, we sit around that average. The daily predictable seasonal gap, and the unpredictable week by week, can be minimised through how we design the system. It might be interesting to come back to that. There are some quite interesting things on interconnection and overbuilding renewables that could make that smaller.

As to how you meet those three gaps, obviously storage becomes critical. For the daily storage challenge, from a technology perspective you are really looking at the lithium-ion battery as the forerunner technology—batteries plus renewables. The costs are declining so quickly, accelerated by the growth of EVs, which use a similar technology, that we are getting economies of scale. The scale at which renewables and batteries might be able to play is ever growing. We are becoming more confident about the daily challenge.

The other thing to note on the daily challenge is that we can do some very important and interesting things with demand-side response, which I am sure you have heard about. In terms of shifting when those peaks are—for instance, where you are using power—at the moment, at times when the sun is not shining or the wind is not blowing, we can consume power when we have those renewables. A really good example is hot water storage in houses; you can have variable heating and it can heat through the day and hold it in a tank. Obviously, we have EVs and vehicle-to-grid charging.

The daily challenge is not what we are talking about today, but the good news is that we feel very confident that there are both some forerunner technologies and a range of other technologies, which we can talk about, that can play a role there.

The much more significant challenge for the renewable-dominated grid is the predictable seasonal and the week by week. With predictable seasonal, we are really talking about a need for long-duration energy storage. We have some system answers. We can use interconnection. That would be one way of solving it. We draw on renewable resources produced in other countries where the sun is still shining or the wind is

blowing when we have a greater need and we have fewer resources. We can overbuild renewables. If renewables get to a significantly low enough cost, we could build more renewables than we think we need and assume that the capacity factors are even lower. Basically, they are more expensive because the amount we use them decreases. That would be a way of meeting the predictable seasonal bump.

We can also use dispatchable generation or long-duration storage. The dispatchable generation options that we have available can obviously be burning fossil fuels, which is not low carbon—the addition of CCS. Gasable CCS would be a very important dispatchable generation. We can also use hydrogen in CCGTs. The reason why hydrogen is so interesting in a renewable-dominated system is that if we produce excess renewables, as we think we will in a renewable-dominated system, there will be times of the year and the day when we produce more power than we need.

At the moment, we do not have many options for what to do with that. We could curtail it. In the future, we will be using it to store in batteries—for instance, for the short term, the daily challenge—but there is also a very important and exciting opportunity for using that excess power, which will potentially be very cheap, to make hydrogen via electrolysis, which itself can be stored. It could be stored at quite large scales—for instance, in salt caverns—and could be burnt later on. It is a dispatchable generation, but it is a form of long-duration storage, with hydrogen as the energy storage carrier.

There is an opportunity to use more of the medium technologies that sit between the very longest durations and the shorter durations. Pumped hydro is obviously very important here. There is also compressed air as a technology and some of the molten saline flow. We can talk a little more about where those might fit. Effectively, we need to ensure that we have a clear view of how we will meet that regular, predictable, seasonal demand gap.

Finally, we will need to be able to meet the week-by-week challenge that I outlined. With that challenge, the real issue is being able to store the energy in sufficient volumes. If we need to draw on that resource—for instance, for the entire system needs for a week—that is a huge amount of energy storage. Again, we are probably looking at a dispatchable zero carbon generation, which is likely to be a combination of fossil for CCS, long-duration storage via hydrogen and potentially a role for BECCS.

Overall, there is a very important role for storage to help us to manage the daily challenge and to place some role on the more seasonal and week by week, but for the dominant long-duration storage we probably need to be thinking about the hydrogen-type routes.

The Chair: Thank you very much. David, is there anything you would like to add to that, or any different views you might have?

David Gray: No. I would not disagree with any of that. I think Ita has set out the need for storage very well. Perhaps I could add a little bit of historical context.

We have always needed flexibility to cope with daily and seasonal demand changes. In the past, in the case of gas, it has been provided by flexible supply, most obviously from the Morecambe field and by storage with the Rough field. Neither of those facilities is operating to anything like its historical extent now. We have lost that flexibility in the gas system.

In electricity, it came from coal-fired generation, which can be turned up and down very quickly. Now, as coal-fired generation is phased out, it is provided by gas-fired generation, which is less economically efficient and therefore requires the capacity market and capacity payments to make sure that we have enough gas-fired generation to do the job.

We are in a world where two things are changing, and have changed, which make the lack of storage capacity in our system more of a problem. One is that Ukraine has demonstrated the need for strategic storage, which Ita did not really mention but is implicit in what she was talking about. The other is the intermittency of renewable generation, which adds a new unpredictability to the existing seasonal and daily storage.

We need more storage. It is very difficult to see how we can run an effective energy system without it now. We need it regardless of decarbonisation. We need it for the system as it is. We will need it even more for a decarbonised system.

The Chair: Do you have any sense of what scale of additional storage and long versus short we need for our current system? Do you have a figure?

David Gray: For long-term storage, Ita mentioned a figure of 10%, ranging up to 25%. One of the companies I am involved with now is Mutual Energy, based in Northern Ireland. We did an analysis of the Northern Ireland requirement and came up with about 10% there as well. The higher figures that you see, particularly in a report recently from the Royal Society pushing a range from 10% to 20%, tend to cater for more and more extreme events, long-term weather variations and so on. Most of the time, 10% sounds about right.

Lord Winston: What would that be in measurements in gigawatts?

David Gray: I can never remember the statistics, despite having spent most of my career in the energy sector, so I will not quote figures to you, I am afraid.

The Chair: Should we look at it in gigawatts or terawatt hours? Is it an amount of energy stored?

David Gray: It is in terawatt hours.

The Chair: The current electricity system is—

David Gray: It is the amount of energy storage that is required. A guide of about 10% is probably the right order of magnitude.

The Chair: We use about 300 terawatt hours of electricity per annum in the UK, not in Ireland obviously. That would be about 30 terawatt hours.

Ita Kettleborough: I had a quick look at the CCC numbers just before this session. It also has around 10% for the UK in its 2050 fully decarbonised system, where it is looking at around 780 terawatt hours for the system. Obviously, from a power system perspective, in a decarbonised world we will be using electricity for many more use cases. A rough doubling of the system is what you are looking at, and then around 10%. You are looking at around 70 terawatt hours of dispatchable low-carbon generation in the CCC numbers.

The Chair: David, to clarify, you think we need about 10% storage currently as a strategic positioning and for the balancing needs.

David Gray: I do not think we need that at the moment. We have historically run our system through having flexibility of supply, and we still have that through the LNG import market, in particular, although you would worry more about that now from the security of supply point of view. The two things leading to a requirement for storage in the longer term are security of supply and the increased requirement from decarbonisation. The figures we are talking about are for a largely decarbonised market.

Lord Krebs: Ita, you said the CCC suggested that we might need 70 terawatt hours of storage capacity by 2050.

Ita Kettleborough: Low-carbon dispatchable generation, of which one of the forms could be hydrogen, which is a form of long duration. It is slightly different.

Lord Krebs: Okay. If you look at a much shorter time horizon—say, 2030 or 2035—how much long-duration storage capacity do we need by then?

Ita Kettleborough: I do not have the numbers at my fingertips of exactly how much you would need. The energy security perspective is a slightly parallel, related but separate, issue. From the perspective of the renewable-dominated system, it will grow as our penetration of wind and solar as a share of our generation grows. The more wind and solar we have generating our electricity, the more storage we will need to manage that system.

I do not have the exact curve of where you would get to, but on the journey of increasing wind and solar, if we are not also thinking about increasing our daily storage, which is a simple way of doing it but is critical—utility-scale batteries are an example—and thinking about the seasonal and unpredictable, effectively it becomes very challenging to manage the system. What often happens, as we have seen in the short term, and what we want to avoid on the journey to a low-carbon power system, is that in the context of growing renewables, without storage in place and a more strategic vision of how we will manage the system, the technology that comes in at the margin to help balance the system is dispatchable fossil. Obviously, it is important to stabilise the system at the moment, but if we are not bringing those storage options through, we will rely more on the fossil dispatchable system, which, if we are trying to decarbonise the grid, is a problem.

Q40 **Lord Sharkey:** My questions are all about hydrogen. I have one high-level question and four subsidiary questions. We may arrive at an answer to the high-level question by addressing the subsidiary questions. The high-level question is: what role do you see for hydrogen overall in a net-zero electricity and energy system?

The subsidiary questions are: what policies need to be put in place to ensure that enough hydrogen from low-carbon sources is produced domestically in the UK? Secondly, how can we encourage a greater fraction of hydrogen production to be green rather than blue? Those are not political labels, of course. Thirdly, what role, if any, do you see for imported green hydrogen? Finally, how could energy policy ensure that green hydrogen, produced as a long-duration energy storage reserve, is not simply sold off for some other purpose or to meet some other need?

Ita Kettleborough: I will say a few words on your overall question of the role for hydrogen in a net-zero electricity and energy system. As we think about what is required to meet Paris aims to decarbonise our energy system, it is important to start with the energy system side of that question before we think about the power system and the electricity side.

If our aim is to decarbonise all sectors of the economy, the challenge is often the so-called harder-to-abate sectors of the economy—heavy-duty industry, steel, aluminium, cement, and heavy-duty transport such as shipping, aviation and long-duty trucking. The harder-to-abate sectors are so called because they are hard to electrify. Simply switching to electric solutions that can be decarbonised by the decarbonisation of the power system is easier.

We have done quite a lot of work, sector by sector, on what it would take to decarbonise all the harder-to-abate sectors. In many of those sectors of the economy, but not all of them, we think that hydrogen will play a critical role in decarbonising them. For instance, in steel we think that hydrogen direct reduction is a way of moving away from coal and a fossil-based system. In shipping, for instance, using ammonia derived from green hydrogen and burning that in ships is probably one of the technologies that we have to decarbonise shipping.

I say that we should start there, because if we believe that we will need hydrogen for other sectors of the economy, we have to start believing that there will be a hydrogen economy, there will be efforts to create clean hydrogen, and that those will be developed for the harder to abates. In that case, and at the same time as you have a rapidly decarbonising grid that is using more and more wind and solar, at times that will generate more electricity than we need and can consume. You basically have the conditions whereby it is likely—we think it is desirable and needed if we want to decarbonise—that that hydrogen production will get radically cheaper. To be clear, that is clean hydrogen production. It is either green hydrogen using very cheap excess electricity that we might have that would otherwise be curtailed and have no value, or electrolysers where the costs are decreasing rapidly and are expected to decrease around 80% by 2030. You basically have a source of very cheap

green hydrogen. We are also looking at decarbonising industry and needing to use CCS, so potentially there is the opportunity to decarbonise existing production of hydrogen, which is produced from steam methanation of natural gas.

We potentially have an opportunity to get cheaper blue or green hydrogen—that is, hydrogen where we have captured the carbon produced. In that world, you might expect that you would have cheap hydrogen, and we could then store that cheap hydrogen and use it as a form of long-duration storage effectively for the power system. We think that will be a really important use of hydrogen, but it is worth framing that; it is not that we would not be developing cheap hydrogen for the power system itself but within a system that is trying to decarbonise. Increasing access to cheap, clean hydrogen opens up new opportunities for the electricity system to provide the ability to store large volumes of energy for long periods.

In terms of a net-zero electricity system, what we would be looking at is similar to the gas storage that we have previously relied on. If we want to use hydrogen to help to decarbonise the electricity system and meet the seasonal balancing challenge, we would likely need to be looking at large-scale development of hydrogen storage in salt caverns in the UK, because the volumes that we would need to be able to release are very significant. Storing them in tanks would be prohibitively expensive, so it would not really be possible.

David Gray: I have a very high-level comment to support all of that. I think the potential uses for hydrogen are many and varied and are likely to outstrip our ability to supply it. The constraint on a hydrogen economy will be on the production side rather than on thinking up ways to use it. It is very applicable in transport and potentially in domestic heating as a replacement for natural gas in parts of the network for high temperature heat processes in industry. There are all sorts of things that you can direct hydrogen to. The constraint will be producing and storing enough of it.

The Chair: Ita, you suggested that you would not produce hydrogen specifically for storage on the power system. I wondered why you might not, particularly for the unpredictable, week-by-week potential variation, which could get worse as climate change develops.

Ita Kettleborough: I was not very clear. Let me clarify that. What I mean is that if we were sitting here today and there were no other uses of hydrogen for other sectors—we were not looking at hydrogen in shipping, aviation, building heating or high temperature heat for industry—and we were therefore just looking at the costs as we see them today, it would be a very expensive option if we were to look at all the options and say, in the absence of all the other development, that we were only doing it for storage.

What I was trying to get at is that, when we look at the role of hydrogen in the power system, we get a benefit from the massive amount of development that is driving down costs independent of whether we need it for power storage. We get to benefit from the wind and solar that we

know we need to build anyway and where, as we get to higher volumes, we will have excess. The hydrogen that we will be using in the power systems of the future will be far cheaper and, therefore, will be competitive with the alternative, which is gas and CCS.

Lord Sharkey: Is there not a slight chicken-and-egg problem? I understand the need for hard-to-abate sectors to use hydrogen. I am not certain about what volumes are involved and over what timescale. How will we be able to supply the need for the hydrogen for those sectors if we are not actually building?

Ita Kettleborough: Indeed. My own numbers on that are global and not for the UK. Today's production of grey hydrogen is around 115 million tonnes. In a fully decarbonised economy, we are looking at up to 500 million tonnes, roughly a five times increase, and potentially up to 800 tonnes when you take into account high-case assumptions. It is a very significant increase in the volumes we need.

I agree that there are lots of places where we can use it, and I very much agree that, in the long term, supplying it will be the challenge. In the short term, however, I think the challenge that we face is a challenge on the demand side. At the moment, while costs are starting to come down towards $2 a kilogram—that is a threshold that a lot of the people who are very excited about the hydrogen economy are looking at, because when we reach $2 a kilogram it unlocks a lot of other uses—in order to get there, there is very much a green premium in using hydrogen versus the fossil alternative.

In steel production, for instance, if you want to do green steel hydrogen direct reduction, with green hydrogen, there is a premium of around 30% versus the fossil alternative; I can double-check this and come back to you.[1] That is very significant from a business-to-business perspective. It is relatively trivial when you pass that all the way through to the end consumer in terms of what the price of that increase in steel cost does to the price of a house. Once you filter it through the economy it is low, but from a business-to-business perspective it is significant. In unlocking the hydrogen economy, for other sectors and for hydrogen in the electricity system, it will be an absolutely crucial role.

The demand-side policies that effectively enable people to start using it now, even though there is a green premium, can be a form of contracts for difference or buyers' clubs' voluntary green premiums; we have seen a lot of industry clubbing together to say that they will pay more. If it is carbon price and carbon taxes that bridge that gap, in the short term we know that we can start producing either blue or green now. There are lots of projects going ahead. In the short term, it is who will pay for using it when it is a higher cost. That is absolutely the chicken and egg. We need to start using it in order to drive down the cost.

Baroness Neville-Jones: It is the politicians' problem.

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[1] There is a premium of +40% per tonne of crude steel versus the fossil alternative. Please see ETC: Making the Hydrogen Economy Possible (2021) for further details.

Q41 **Baroness Neuberger:** Assuming that how you see the future is correct, could you set out the regulatory issues with novel projects such as long-duration energy storage, which you have been talking about, entering the grid? Which regulatory or planning authorities have a key role to play in enabling long-duration energy storage to be deployed on the grid?

As a subsidiary, because we are short of time, are those regulators actually doing enough? Is there sufficient capacity in the regulators at present to assess, and indeed develop, commercial and regulatory arrangements for different storage technologies? A very short answer, please.

David Gray: I would like to raise and then pass on from one very quickly, which is the planning system. It is not an area in which I am an expert, but it is a major obstacle to any large-scale energy infrastructure.

Baroness Neuberger: To anything, actually.

David Gray: I have no magic silver bullet for it. I spent some time on the board of a company that was trying to develop a natural gas storage site in north-west England using old ICI salt caverns, and I was absolutely staggered at the extent of local resistance for a facility that, once built, would be pretty well invisible. Essentially, it was an objection to any development on the rural landscape. That is a major blockage to most large-scale energy projects. I have to mention it, but I have no particular experience or bright ideas.

If we switch to the other obvious area, which is energy regulation, we may need a change in mindset. Ofgem has, in the past, tended to regard storage projects as a user of the system. There was a big debate about whether a storage facility, for instance, should be charged both on input and export from the site: that is, as a consumer and a producer. That has tended to be rationalised so that we avoid double paying, but there is an argument for saying that storage is part of the energy system rather than a commercial user of it. You could imagine a world in which storage assets of whatever sort do not pay transmission and distribution charges at all, and T&D charges are paid by people who inject the energy into the system at first use, essentially, and by consumers who take it out.

There is room for some quite radical thinking on that, but it needs a policy direction, which probably is not there, to push the regulator into it. One of your subsidiary questions was about policy. It is not so much about policy; it is a strategy. We need a national strategy that says, "This is what we think hydrogen is for. Here are the priority uses. Here is what we think might be the volumes". That gives commercial developers the framework to work within when planning things, and the regulator the framework to think about how you achieve potentially radical changes. Regulation tends to be much better at dealing with incremental change than radical change; you have to think differently about transformational change. So I think we probably need to do some thinking about the overall approach.

I want to pick up another point, because Ita has mentioned it. People talk about the use of surplus renewables as a really good way of making

hydrogen. That is absolutely true. It is really irritating to have large quantities of wind generation stuck behind transmission constraints and unable to be used, but the volume that would come from that is not enough. We must not just think of hydrogen manufacture as a way of making use of cheap renewable energy that would otherwise be unused. We need to set up the system so that we can make it in larger scale than that, and have the electrolysers located where they need to be rather than necessarily right next to a wind farm. Those would be my starters.

Ita Kettleborough: I absolutely agree on the planning and permitting. The strategic vision point that you made is also crucial for that planning and permitting. They all fall together. The difference is that a lot of our regulatory systems, given the system that has been operating for the last 30 or 40 years, have reasonably assumed a steady state, but our electricity usage in the UK has been declining, not doubling. It is a radical mindset shift for that system. At the same time, we have a new strategic objective, in the sense of wanting to decarbonise. That is an additional directive. In that context, where we are looking at a system that might need to double in size versus the steady state that has been operating, where we are talking about a fundamental shift of the technologies, the strategic vision is really important.

The only other piece I would add is that the capacity market is important from a storage perspective. We need to make sure that the capacity market can allow all technologies to compete, including demand-side response storage and generation into the capacity market. We also need to make sure that it recognises that some of the long-duration storage options—for instance, pumped hydro, which can play an important role in the middle—have much longer timeframes. At the moment, the capacity market allows for bids to deliver up to four years in advance. That is not going to cut it for pumped hydro. Within that strategic vision, what are the different timeframes that will allow us to have the optimum mix of technologies?

The Chair: That is very helpful. Thank you.

Q42 **Lord Krebs:** I would like to ask the witnesses about possible business models for generating long-duration energy storage because of the large upfront capital investment and the fact that the assets may only be used in certain circumstances, as you have already described. What sort of business models ought the Government to consider, and what factors should they take into account in fulfilling their commitment to provide a business model by the beginning of next year?

Are there examples of successful market arrangements that the Government could learn from? Would a national energy company, as proposed by Labour, be useful? What would it do if it were useful?

David Gray: Can I enlarge on my experience with gas storage in the context of the business model? We spent many years modelling like mad the prospects for a large-scale gas storage plant. That was 10 years ago. It was in a period when gas prices were relatively stable and had been for some years. That continued through to 2019 or thereabouts. There was

not enough revenue from the level of volatility in the market to give you the confidence to go ahead with a very big, very long-term investment. In particular, there was not the evidence to persuade debt providers. Essentially, it became an equity proposition and was much too risky for any likely provider of equity.

As an aside, had we built it, it would have made enough money in the last two years to pay for itself many times over, given the level of volatility we found we had, as opposed to what we could predict and rely on at the time. That makes the point. Commercial models will work over the long term, but they probably will not get built unless you provide some support to give the confidence to go ahead. At the very minimum you need to provide a commercial model that allows the developer to recover enough money to pay debt costs. Then you need an incentivisation, in the form of equity return, to use the asset at its maximum optimum efficiency. So you need to think about it in those terms.

It is not a new problem. We have come across it in various areas. We have a range of ways of getting things done. We have used contracts for difference for renewable generation. We use a cap and floor regime in the electricity and gas interconnectors. We use the capacity market for generation. We do not necessarily need to invent anything new, but we need to think constructively about how to achieve the desired effect for an asset that is very long term and not necessarily used very often. Of the things I have mentioned, the best starting point for a regulatory model to produce a commercial proposition is probably the cap and floor regime, because it absolutely addresses the basic point that you need to pay for the debt. Then it provides a sensible balance of return for the equity holder.

I would do it slightly differently. I would not have an absolute cap. I would have a sliding scale so that the benefit is more and more to the consumer the more the asset gets used. None of these projects will be developed without an explicit or implicit consumer guarantee. Essentially, it is the consumer that pays. Things get built on the basis that they will: either through a RAB model, a contract for difference or whatever. If you are giving a very long-term deal to an unpredictable asset, you need to make sure that the more it is used, the more the benefit goes back to the consumer. A cap and floor regime that protects the debt return and then thinks constructively about incentivising efficient long-term use is probably the right sort of idea.

I will throw in another little special interest. As you said, I am chairman of Mutual Energy in Northern Ireland, which is a mutual company. It owns the interconnectors between Scotland and Northern Ireland, and it owns a chunk of the gas transmission system. It has a very straightforward arrangement. The company can pass through all its costs to the consumers. There is an absolute guarantee from the regulator that that is the case. In return, they expect us to be efficient and, when we make money, to return it to consumers.

That works really well. With that backstop to the consumer, we can raise very cheap long-term debt finance. It has been a very good way of financing the interconnectors to Northern Ireland. I can see potentially quite wide-ranging use of it as a business model in doing long-term assets. It would not remove the need for something like a cap and floor regime, because you have to remunerate the debt providers, but it is a different way of thinking about it that I think would be worth going into.

Lord Krebs: Ita, would you like to add anything?

Ita Kettleborough: Yes. That was incredibly useful. Keeping the system vision in mind when thinking about the cost to the system, as you move towards a renewable-dominated system, what we should be seeing, and are seeing, at the system level for generation is that costs decline. As penetration of wind and solar—now the cheapest form of generation—increases, the costs decline relative to the existing system. All the way up to about 80% penetration levels those costs continue to decline, and the system gets cheaper. Once you hit that 80%, you turn a curve in the cost of delivering the generation, because you are meeting the seasonal and daily storage gaps, which are more expensive. The assets that you need to meet that challenge are themselves expensive. Therefore, you need to use the right mechanisms to make sure that you can pay for them. At a system level, the system as a whole is probably in many cases still cheaper than the alternative—today's system.

When we are talking about that and understanding what we are doing, we are effectively finding mechanisms to have a small number of quite expensive assets balanced by a very large number of cheaper assets. At a system level, we are therefore better off for consumers and for the users of energy. That is a useful context.

David Gray: There was a supplementary about examples of it being done. The gas industry has always been very good at producing storage to support consumer demand. If companies have customers and need to supply them, they do that quite effectively. Where it becomes more difficult is when you have a strategic need, either for security of supply or now for the increasing requirements brought in by decarbonisation. It is hard to think of good business models around the world that already exist for doing that.

The Chair: Do you think it is feasible to have the same business support model to support the predictable seasonal element of the storage as you have for the unpredictable climate-dependent wind/drought, where you do not know whether the strategic storage will be needed or not?

David Gray: It goes back to what I have just said, essentially. The commercial approach to storage will tend to deal with predictable fluctuations in consumer demand, but it will not go beyond that unless—

The Chair: You are saying that the same model will not work for both of those two elements. You will have to think differently about them.

David Gray: Yes. You could bring it all together, but they are two different things, and it may or may not be sensible to do them in the same way.

Ita Kettleborough: With the really unpredictable storage needs, the strategic reserves model is also a model we can look to. As I say, we have done that before, but largely not in a commercial model.

The Chair: You could, of course, have the same facility providing some of both—some of the long-term strategic and responding to the seasonal.

David Gray: Large-scale cavern storage will do both.

The Chair: How do you incentivise two business models on the same asset?

Ita Kettleborough: We have that already. Obviously, we are talking about long duration here, but in the shorter duration market we already have revenue stacking, where the same projects might bid into multiple different markets. We have the capacity markets. We have multiple different markets now and we have the same projects that take their revenue from the merchant market over their project lifetime, potentially some from CfDs and others. We have examples where developers will look at multiple different mechanisms to make the economics of the project add up.

David Gray: The way to do both is to combine commercial arrangements to cover the predictable stuff with some sort of mandated requirement for the strategic element of storage. You see that in the European gas market now. People have worked out that storage needs to be full for the winter, so there are mandated levels of storage in the run-up to winter. You could have something similar applied to otherwise commercial storage sites, dealing with the more predictable variations.

Baroness Neville-Jones: Is deciding on the business model one of the most difficult elements in the whole issue of setting up storage, or do you think it is pretty solvable if people put their minds to it?

David Gray: It was a question about commercial arrangements. The arrangements for storage in that sense are a relatively complex but solvable problem. The blockages at the moment are more about creating a clear, credible long-term strategy and dealing with the time delay problem, particularly planning but also all the stuff you get with big, long-range infrastructure projects.

Q43 **Baroness Neville-Jones:** My question is partially about planning and the use of the national grid. One of the major concerns we have heard from previous witnesses is the long wait times that exist for being connected to the national grid. Are we progressing fast enough? Are we getting grid and electricity infrastructures ready for future demand? What do you think about the policy areas that need focus to reduce the waiting times? That is one set of questions.

The other set concerns planning. Some people say that the connection queue is a long-standing problem and that some proposals are the result of the project's place in the queue rather than when it was actually submitted. Is that a real issue? Generally, do you think that the planning system is a barrier to developing long-duration energy storage and the

necessary supporting infrastructure? From what has just been said, I suspect that the answer is yes. Could you tackle that group of questions?

David Gray: I will take the first one, which is essentially about the queue. That has been a problem for as long as I have been involved in energy regulation—20 years—and it has got longer because we have never introduced a prioritisation system, as it was quite hard to tell which were credible projects and which were not. Once you start interfering with the queue it becomes very contentious. If we are to make the transformational change that we are talking about, we will have to rethink that. Nick Winser produced a report for the Government on the whole question of transmission investment and so on, which I will not bother going into.

One addition to that is that we need a way to prioritise the queue. When I arrived here today there was a very long queue, but I was given a pass that allowed me to go to the front, otherwise I could have been late. We need to introduce some sort of assessment of consumer benefit in projects. When Ofgem receives a proposal for an interconnector project, one of the things it does is a cost-benefit analysis. It looks at both ends of the interconnector. If the numbers add up on an overall consumer benefit scoring system, it tends to give approval for the project. You need a way of fast-tracking high consumer benefit projects through the connection queue. Again, the technology exists. We know how to do the economic analysis. It might be contentious, because people who are in the queue will not want to be overtaken.

One idea I heard was to prioritise in terms of delivery date. That is not the answer. That would simply prioritise short-cycle projects. You need something that says, "This project is really important. It needs a connection on such-and-such a date. It will get it".

Ita Kettleborough: I refer back to the idea that we have been developing around system transformation versus BAU. The grid processing queue was developed in a world where there might be two, three or four major thermal plants a year. Now, the ESO is receiving around 1,600 applications a year. I understand that there are 390 gigawatts of clean power projects currently in the queue. To meet the 2030 targets as set out, we would only actually need 140 of those gigawatts to come through, but they are all still in the queue and the queue is not moving fast enough.

There is potentially a need to look at the queue as it stands today to manage that backlog. I absolutely agree that the idea of queue management is critical. It is a holistic assessment that comes back to having a clear strategic vision of what the system needs as a whole not only in the generation that has been added but, critically, in the storage. As we said, that was not something we were looking at in the past. A key strategic piece that might be part of that is the regional view, looking at projects within a region. Are they important projects from a system balancing perspective? Are they collocated so that we could do something at the same time? Is there a group of projects that could be moved forward together?

That aligns to thinking about networks more broadly and the importance of having a strategic vision for where generation and consumption will be in the future, allowing us to think potentially about a more strategic approach to building transmission and distribution. If we know that we want to connect 20 projects in an area of the sea over the next 15 years, we can build that transmission line in anticipation of those projects, rather than each of those projects having to submit individually to connect back to the grid.

It is a critical issue. It is a barrier to storage projects and generation projects, but the answer will require going back to what we are trying to do and the period of time in which we are trying to do it, and therefore which of the projects meets the priority. We should work with those first.

Baroness Neville-Jones: Do I understand you to be saying that the adequacy of National Grid's capacity is itself related to other questions that need to be solved, and that it is not a question that you can answer in isolation from having decided its relationship to the strategy that we do not have?

David Gray: A strategy or policy statement that actually covered, in a convincing fashion, what the Government see as the requirements would give a context that would make it much easier for National Grid and the regulator to solve the queue problem.

Ita Kettleborough: Related to that, if we are building the renewable system of the future, we need to think of it as a system. Generation is part of it. Transmission and distribution become critically important when you have a renewable-dominated system, because where the wind blows best might not be where the consumption is. You have to move the electrons around more. As we have talked about at length, the storage is critical. Without that storage, the system does not balance.

The power network, storage plans and generation plans need to be planned together holistically. Currently there is a network that is gradually iterated and built upon, there are some generation plans and then there is a storage plan. If you do not design the plan to think across those three, you will not get a system-optimal result. You will not get some of the benefits that the system can bring. It will not be as cheap and it will not be as reliable for consumers and users. The design of that system must be less siloed than it has been in the past.

The Chair: Is it feasible to develop business models for the individual elements that will drive the market to do the right thing to give you an integrated system?

Ita Kettleborough: It is absolutely feasible. We have been doing it on many different elements. The step that we need to take is a clearer strategic vision. For instance, there is a strategic vision at the overall policy level that allows the regulators to take a strategic approach—

The Chair: What is in the strategic vision? You keep saying that there is a strategic vision. What precisely does the strategic vision spell out?

Ita Kettleborough: It would effectively cover how we think the system would optimally evolve to meet generation needs in 10 or 20 years.

The Chair: It would specify what the system is made up of.

Ita Kettleborough: It would specify the types of technologies that we believe we need. It would give us the framework by which further work can be undertaken to understand for instance spatially where that might be. We know we want this much offshore wind and we have said we roughly think this is the right amount for our system. Where are our options? Where do we think we would need to develop? Okay, there are these different sites. The network would then need to be able to connect to those sites. Where would we place storage to optimise the storage uses against those? Effectively, there is a spatial element to the plan that we perhaps do not have at the moment. It would also allow the grid provider to think about anticipatory investments.

At the moment, the grid can think primarily only about what the system needs are now. Even if the system might need double that in a particular location in 10 years, it cannot take that into account in current decision-making on developing an asset. Allowing it to take into account where we think this will go will be a critical part.

David Gray: I have used the word "strategy" here quite deliberately. In my mind, a strategy is very different from a plan. I think what is needed is a strategy. It is a vision. It is what sort of energy system we expect to have by 2040 or 2050, as opposed to a detailed plan for getting there, but it needs to set out the big building blocks that we expect to have: "This is the order of magnitude of renewable generation. We expect it to be located roughly here. We expect to need this much hydrogen storage", et cetera, as opposed to, "Here's a very detailed road map". It is an overarching vision of what the system will need to deliver by 2030, 2040 or 2050, and then a request, please, to get on with it that I do not think we quite have in place.

The Chair: Do we think the future system operator will be able to deliver that? In a way, it is going towards a plan. It says what our system looks like and where it is by 2050.

David Gray: It will help in the context of the electricity system, but what I am talking about is much wider. The question of where we use hydrogen, and whether it is best used in electricity generation, domestic heating or industrial heat, will not be addressed by a future system operator. It will want to think about it, but that is more a political strategy or vision question.

The Chair: But do you think, in the electricity part of it, the future system operator has the right powers and tools to deliver it?

David Gray: To be honest, I have not looked in enough detail at how it has been set up to answer that. The concept is a good one. We need rather more planning in the system operation than we have had, as opposed to day-to-day operation.

The Chair: Ita, do you have any thoughts on that?

Ita Kettleborough: No. Indeed, I have not looked in enough detail at exactly what is being proposed for the overall need for additional management of the system. I will leave it there.

Q44 **Baroness Northover:** This nicely leads on from what you have been saying. You have answered quite a lot of it in looking at the strategy, vision and possible lack of it.

The current Government have a target of a fully decarbonised electricity grid by 2035, and the Opposition have that ambition by 2030. Are developments currently on track in any shape or form to achieve the long-duration energy storage necessary for either of those? If they are not, what would your priorities be to make those goals feasible?

Ita Kettleborough: Overall, I would say that we are not fully on track. If we are to hit those 2035 and 2030 requirements, and if we do it in the lowest-cost way and using the wind and solar resources that we have available in the UK, we are probably not on track to have sufficient storage operational, both short and long term.

Part of that is the planning and permitting queues that we have been talking about. Quite a lot of projects are being discussed, but they are just not getting to connect. On the long-duration side—we have alluded to this—I have spoken about the excess electricity, but beyond the potential for curtailed electricity, we will need wind and solar for green hydrogen production. We are not yet at the pace where we are confident that we will be able to hit the wind and solar needs for direct electricity generation. On the 50 gigawatts, we would need to do eight gigawatts a year in the next three auction rounds in the UK, which is quite an ask, given that the latest auction round had zero. That is only to meet the direct electrification requirements. We would probably need additional wind and solar for the production of green hydrogen that could then be used for long-duration energy storage. So we are not quite on track, although we are making a lot of progress.

In terms of the key policy priorities, we have talked a lot about planning and permitting and the grid. The power market design reforms of the types that we have been discussing will be crucial to providing that long-term business model. There is probably a piece around using hubs and cluster approaches as a potential location to support some of the long-duration energy storage, alongside the other industry users that we have talked about.

David Gray: I agree that we are not completely on track. We are on track to get quite a long way towards those targets, but I do not think that competitive bidding for a date to decarbonise electricity is a particularly good way to think about it. We are already at dates when our ability to deliver the necessary infrastructure, particularly storage, is questionable. We have discussed the things that need to be done for storage. Insisting on targets for decarbonising the electricity network that run ahead of our ability to deliver the necessary storage is probably not very constructive. To get to 90% of the targets is relatively doable, but getting to 100% is much more expensive and might be better done later

with better technology and so on. I would focus on storage and then have the target for decarbonising electricity related to our ability to put in place the flexibility systems generally that are needed to go with that.

Baroness Northover: Do you get any sense that either grouping, as it were—the current Government or possibly a future Government—is coming to the conclusion that you have just indicated?

David Gray: I am sorry, I missed the question.

Baroness Northover: Are you seeing any indication that either the current Government or any future Government realise that they need to be approaching it in that way in order to achieve the long-term goals?

David Gray: I do not think I am close enough to be able to answer as to how the Government are thinking. I think practical constraints bite in the end, and we are facing them.

Baroness Northover: Ita, do you have any view on that? Are you getting any sense that they are seeking to approach it in the way that has just been described?

Ita Kettleborough: There is a sense that, in general, it is being taken seriously. The right discussions are being had. I understand the challenge on the vision and having a date. The other thing about a date is that it sets a clear direction and aligns a lot of disparate actions around it. If you set a date, the question then becomes whether you are willing to understand what is between you and that date. For me, the date is less of a problem, but that is also because the date is largely dictated by what we must do if we are to meet the climate challenge. The power system must run ahead of the other areas of the economy to allow us to decarbonise via electrification.

At the ETC, we really push for having that clarity, but behind the clarity you must have the strategy. What does it look like? What are the different components of the system? How would they need to work together? What do we need to do to overcome the very real barriers that are making the dates very challenging? To the extent that there are discussions on how we think about a future energy system operator or think about more strategic energy system operations, looking at what we might do with planning and permitting and on jobs and skills, there are lots of noises and the right conversations coming out, but we need to continue to move to concrete policy recommendations and actions. Certainly, the discussions are there.

Q45 **Viscount Stansgate:** Apart from the cost—leave that aside—what would you say are the major barriers to a successful scaling up of long-duration energy storage? If I can answer my own question immediately, I think I am right that you will probably refer to the planning process, which you have done already. Are there other issues, apart from that, although emphasise that if you wish, that may arise in relation to the scaling up of long-duration energy storage, apart from the cost element?

David Gray: My answer would not be specific to long-duration storage. It is more a general one about decarbonisation and its resources in terms of

supply chain and people, most obviously engineers. We need to train lots and lots of people to do that. I have never understood why electrical engineering is not seen as a much more attractive option for universities than it is. It is clearly a growth business. Hydrogen engineers—we can go through the whole range of technologies that we have talked about—need expertise.

We will need to think about supply chains for electrolysers. We will need to think about the construction industry, if we are looking at large-scale cavern storage. There are all sorts of things that I could put on your list. The critical ones are planning and the commercial and regulatory arrangements.

Viscount Stansgate: Thank you. You have answered a question I had not yet asked, which was what more you could tell us about the range of skilled individuals needed to be able to deliver this system in the future. You mentioned electrical engineers, and that is obviously one. Where do we need to focus our training and recruitment efforts to get the numbers and the types of people that we will need to make it possible?

David Gray: I have always struggled with how you do that in practice. The idea that we would need—to take a very specific example—more electrical engineers has been obvious for decades. The industry was privatised with quite an old workforce profile. A lot of those people have retired, and the more interesting things have been outside the main electricity system, so they have tended to attract the better graduates. It is hard to come up with a policy that produces the personnel resource, the technically qualified people you need, for this kind of big transformational change. I do not have any bright ideas, I am afraid. I just think it is a real problem.

Viscount Stansgate: Any thoughts?

Ita Kettleborough: I absolutely agree about the engineering challenge that has already been identified. I understand that there are 200 linesmen in the UK, but National Grid estimates that 1,400 will be required by 2030. There is a training time that has to be built in. There is also an infrastructure perspective. I believe there are only two training centres in the UK where they can train. There is a whole practical mapping out of what is needed.

What feels different is the power system, but it is also the larger energy transition. We have a range of areas where we know that we will have locally specific jobs. There is the power system side. There is also the retrofit of residential homes to enable electrification of heating. There is a whole range of jobs where perhaps people do not fully understand the vision and the connection of those roles with meeting the decarbonisation challenge that we face.

Alongside the difficult work of trying to break down exactly which roles and therefore which training absolutely need to be done, there is a piece around linking more clearly for people that some of these roles are critical to delivering net zero. They are the roles of the future. They are the roles that will allow us to meet the climate crisis. That is an exciting and

perhaps a different way of talking about some of those roles than previously. Harnessing that vision can be really helpful.

Viscount Stansgate: You referred to salt mines in Cheshire. If you fill them with hydrogen, what do you think the reaction would be from the people living above them?

Ita Kettleborough: I went to Luleå in northern Sweden, about a year and a half ago, where SSAB built the first pilot hydrogen direct reduction plant to make fossil-free steel five years ago. It is a huge achievement from an R&D perspective. As part of the complex in Luleå, they have also developed rock cavern storage. A salt mine is cheaper, because it already exists and we can just put it in, but for people who do not have them there are rock caverns. Drilling out in rock is probably what people will use.

As part of the R&D they developed a rock cavern to test it. There are a lot of questions around hydrogen storage and hydrogen cavern safety. There are lots of risks. It was very interesting talking to them. One of the biggest pieces of work that they needed to do, for the planning and permitting of that project and that site, was to discuss rock cavern storage and safety, what the risks were, how they were manufacturing it and what specifications they were manufacturing to. They were manufacturing rock cavern storage to very high specifications because of people's concerns about the risks.

Viscount Stansgate: Did it go ahead?

Ita Kettleborough: Yes. It is in production. It is being built.

The Chair: We have a storage specialist coming to give evidence at a subsequent session, so perhaps we can pick this issue up then. I would like to thank both of our witnesses in this session. We have worked you extremely hard and we have very much appreciated the input you have given. If you think of anything else that we would find useful, we would be very pleased to receive it as formal evidence after this event. Thank you very much indeed.