



Energy and Climate Change Committee

Oral evidence: [Carbon Capture and Storage](#), HC 742

Thursday 23 January 2014

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Written evidence from witnesses:

- [Energy Technologies Institute](#)
- [Rodney John Allam](#)
- [Chris Hodrien](#)
- [Bbf Biochar Cic](#)
- [David Reiner](#)
- [The Geological Society](#)
- [Jon Gibbins and Hannah Chalmers](#)

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Members present: Mr Tim Yeo (Chair); Sir Robert Smith; Graham Stringer

Questions 63–102

Witnesses: **Professor Jon Gibbins**, University of Edinburgh, **Dr David Reiner**, University of Cambridge, and **Dr Jerome Neufeld**, University of Cambridge, **Dr David Clarke**, Energy Technologies Institute, **Rodney John Allam**, NET Power, **Chris Hodrien**, Claverton Energy Group, and **Darren Hopkins**, British Biochar Foundation, gave evidence.

Examination of Witnesses

Witnesses: **Professor Jon Gibbins**, University of Edinburgh, **Dr David Reiner**, University of Cambridge, and **Dr Jerome Neufeld**, University of Cambridge, gave evidence.

Chair: Good afternoon and welcome. This is possibly the first time the Energy and Climate Change Committee has met in Sheffield. We are delighted to be here, as we are enthusiasts for having oral evidence sessions away from Westminster from time to time. We thank the

university for their hospitality and the welcome we have received. I am advised there are planned fire drills this afternoon, so if an alarm sounds you may wish to exit the building.

Could our witnesses introduce themselves very briefly one by one?

Professor Gibbins: Jon Gibbins, Professor of Power Plant Engineering and Carbon Capture at the University of Edinburgh, and Director of the UKCCS Research Centre.

Dr Reiner: I am David Reiner. I am Senior Lecturer in Technology Policy at Judge Business School at Cambridge University. I am also the Research Lead for the Cross-cutting Issues Research Group within the UKCCS Research Centre.

Dr Neufeld: Jon Neufeld. I am a university lecturer at the University of Cambridge in fluid dynamics, particularly of CO₂ sequestration. I am in the Maths Department and also Earth Sciences, so I come at that angle.

Q63 Chair: Thank you. Perhaps I could start with you, Professor Gibbins. The Grantham Research Institute at LSE told us that, overall, CCS is expected to meet between 12% and 37% of total electricity demand in 2050. What role do you envisage CCS playing by the middle of the century?

Professor Gibbins: I think by the middle of the century I would not concentrate so much on what fraction of electricity is being supplied, which is important, but also what fraction of fossil fuel that is being used is being captured and stored. As far as the climate is concerned, that is the more important metric. You need to consider what role fossil fuels will be playing in the middle of the century before you can answer that.

In that situation you should very seriously consider whether or not we have any global consensus on how to tackle climate change. That will be a big determining factor. Clearly if there is no agreement that we are going to tackle climate change, I do not think people will be spending a lot of money of carbon capture and storage or on any low-carbon initiative. However, if we are tackling climate change—bearing in mind that that we probably have in known reserves, according to IEA greenhouse gas figures, about three times more fossil fuel than we can safely use by 2050—we now have a system where we have a surplus supply and the IEA greenhouse gas in the 2012 World Energy Outlook predicted falling fossil fuel prices. In that situation, provided it can be undertaken with carbon capture and storage, we might see more fossil fuel consumption than some models that assume rising energy prices have predicted.

I am not answering your question directly, Chair, because we have this big contingency: will the world actually tackle climate change? If it will, then—perhaps perversely—you might see both more CCS and more use of fossil fuels because we can now do it and they are cost-effective.

Q64 Chair: Clearly, if we do have CCS, it will become safer to use more of our fossil fuels, but at the moment someone who takes a mildly questioning view might say, “The only serious work on CCS is how do you receive public subsidy in various ways in various parts of the world? If this was a technology which was nearly commercial you would expect to see some of the very big energy companies investing much more heavily in research from their

own resources.” Do you think there is a risk that, even if the world wants to go on consuming fossil fuels, we may not have economically viable CCS soon enough?

Professor Gibbins: I think we have economically viable CCS as of now. There certainly very few low-carbon energy supplies being rolled out in large quantities that do not need significant subsidy as against market price. We have seen an example where nuclear appears to be taking some form of subsidy; that has been referred to state aid rules, presumably on that basis. We see significant subsidies for renewables. I would say that, at the very limit, you could argue that a carbon price is also an implied subsidy; it is certainly over there because of Government intervention. Apart from the use of CO₂ for enhanced oil recovery, as far as I am aware there is no way that it could become commercial. Equally, there is no way that any technology that generates electricity at higher than the market price can be deemed commercial, yet we see many technologies generating electricity at higher than market prices being sold in significant quantities. Thereby, they are deemed commercial, but I do not think that they are commercial in the sense that you were using the term.

I think carbon capture and storage would deliver low-carbon energy at a lower cost than a number of technologies that are receiving subsidies and being sold in commercial quantities.

Q65 Chair: Without digressing too far, I can see the point you make about those technologies that receive a direct subsidy, either from consumers or from taxpayers. If it is generated by a cap-and-trade system, the carbon price could be argued to be one that does have a direct benefit to carbon capture and storage in that it raises the cost of emissions from plants that could deploy CCS. That is a bit more technology-neutral in a way, isn't it?

Professor Gibbins: It is technology-neutral if it is allowed to be technology-neutral, because despite having a carbon price, we have technology-specific subsidies as well. I will perhaps defer to my colleague here, but the theory behind providing a subsidy is that carbon price probably would work quite well in a steady state, but when you are in a transition phase it is not so good. Just taking carbon capture and storage as the example, you would expect to start out with the carbon price being low and rising, whereas the cost of carbon capture and storage, because of learning, starts out high and falls. Just left with that situation, nothing would happen until the price was crossed over or until a little while after the price had crossed over.

What you want to do is to do a little bit of carbon capture and storage, get some learning, then do a bit more and a bit more and a bit more, and the only way you can do that is if you find some way of passing out the cost of that to people. You do not want to do it by putting a carbon price up to whatever the first plant would need—say, £80 a tonne, because that is what the very first of the kind needs—and then dropping the carbon price as you learn by doing it. It just would not work, not least because, if you did get a carbon price of £80 a tonne, you would not get the one or two first plants you wanted; you would get everybody doing it. You do not want that; you want a gradual, ordered process. So, great, once you reach steady state, but for the transition, carbon price is perhaps not the appropriate mechanism.

Dr Reiner: Just to come in there on this, the biggest challenge I think is one of the credibility of Government policy. The study you refer to is one of many studies that will

presume our accomplishing our 80% commitment by 2050. I think what you see in the investment decisions not just on CCS but on any other low-carbon technology is that that is not perceived by the market—it is not perceived by the major energy companies operating with the UK as credible.

Even closer to home, we have a £70 a tonne carbon price-floor that is meant to be in place by 2030. I would argue that if you look at the investment decisions being made, that also does not treat what is a very significant potential carbon price as credible. The market, investors, have not quite believed that that 2030 commitment will be delivered. What you wind up having is what has unfortunately been a short-term emissions-trading system, which operates across Europe, which gives you quite a volatile price signal. As we have seen over the first transitional period, 2005 to 2008 and then 2008 to 2013, you see the price bubbling along at €20 a tonne and then collapsing. That does not do very much for investor confidence in technologies such as CCS that require an investment time horizon that is at least a decade and probably longer.

Professor Gibbins: In terms of incentives and technology-neutral incentives, you are probably aware of the mechanism that has been proposed by Chris Davies in his submission to the European Parliament. He has suggested that the climate imperative, which is to increase the fraction of fossil carbon captured, is matched by an incentive whereby, if you import or sell fossil fuels into the EU, you will be obliged to produce certificates corresponding to a rising fraction of CO₂ captured.

It is interesting that that has some elements of being technology-specific towards CCS—in other words addressing the actual problem of the fossil fuel—but also, by analogy with carbon pricing, it makes fossil fuel more expensive so other technologies then compete on more of a level playing field. I think that is an interesting combination of the two things and perhaps it gets over this problem of how you manage your transition in one area. The eventual transition might be that if you have to capture 100% of the CO₂ when you use fossil fuel, you do not use fossil fuels at all; you use an alternative technology and that is fine. It manages the transition and also gives you a reasonable measure of technology neutrality, but it does also directly address the problem of fossil fuels, which is fossil carbon going into the atmosphere. It promotes the only way you can stop that, which is by capturing some of it. It is a halfway house but may be effective.

Dr Neufeld: It is also important to think about how targeted the investment is in terms of research and pushing forward carbon sequestration. In contrast, if you think about transport of CO₂ from where you capture it to where you might store it, research on that has been going on for 30 years, and intensively for enhanced oil recovery where there is quite a price signal to do that research. The key questions that seem to remain are things like: can you reduce the cost of capture on particular kinds of facilities and can you reduce the risk or the perceived risk of storage over longer terms? Those are the kinds of questions that I would have said require the more targeted societal funding.

Q66 Chair: The Tyndall Centre question whether CCS will be deployed in time to make any meaningful contribution to keeping total emissions within the limit we now think is necessary to avoid a temperature increase of above 2 degrees. What do you think about that?

Professor Gibbins: The critical factor here is: what will trigger the global agreement? I do not think any country will deploy significant amounts of carbon capture and storage,

which is expenditure very effectively towards mitigating emissions that, apart from a bit of enhanced oil recovery, gives you no benefits, certainly in the quantities we are talking about. I do not think any country will do that in significant quantity before there is a global agreement.

What will trigger global agreement? Basically there are two options. One is people think that the prospects are so bad that they will do it without being frightened into doing it. The other one is that we have something like the example I have heard called “a Pearl Harbour moment”, where something happens that is so bad that the politics becomes fairly easy. Unfortunately, at that point the climate mitigation becomes very, very difficult, because, as you know, if you have seen serious climate events, even if you were to stop all emissions the next day, things will carry on getting worse for a number of decades. In that situation you would deploy carbon capture and storage, but I think you would also deploy direct solar radiation modification to buy you time to do it.

If I might change your question a little bit, it is probably in excess of 90% that we will deploy carbon capture and storage in significant quantities to achieve meaningful reductions in fossil-fuel emissions. It is very debatable—and I would not want to say it is even as high as 50%—that we would deploy carbon capture and storage before a Pearl Harbour moment. I think it is nearly 100% certain that we would deploy carbon capture and storage after a Pearl Harbour moment.

Clearly the critical event in achieving timely mitigation in advance is an agreement between China and the USA. We could assume Europe would follow and at that point the rest of the world would also follow. I am not sure if that is fully appreciated, although that critical bilateral relationship is becoming apparent as being very important globally. We may be able to influence that to some extent in the UK. The biggest problem—and this is speaking without qualification here—is getting an agreement from the USA. I think China is coming closer to seeing that is necessary.

Effectively, when you ask me, “Are we going to see a significant deployment of CCS by when?” I believe you are asking me, “Are we going to see a serious global agreement to tackle climate change, with the big players involved, by when?” I am somewhat uncertain about by when, but I am pretty certain—I am certainly very, very hopeful—that we will see CCS deployment. If we do not see CCS deployment, what it will mean is that we have given up, we have accepted that we are going to get whatever the climate throws at us and take the consequences. That will be very bad for my children and grandchildren if that happens.

Chair: We will not get into the international negotiations particularly, but I just comment that I think it would be possible for the EU and China to collaborate and pull the Americans along in the slipstream, given that the EU does account for a quarter of world GDP at present.

Q67 Sir Robert Smith: I had better remind the Committee of my entry in the Register in of Members’ Interests, in particular, to do with the oil and gas industry and a shareholding in Shell.

This is probably a question for Dr Reiner. What is the public understanding of CCS and the policies that support it?

Dr Reiner: Weak. We have been doing work on this in the UK since 2004. What we have seen between 2004 and 2013 is an increase in public awareness of just the words “carbon capture and storage” and the idea of carbon capture and storage from about 5% to about

20%. By the same token, we have not seen any increase in understanding of what that does, which at a very simple level would be to ask, “Does carbon capture and storage address climate change or water pollution or ozone depletion or toxic waste?” In fact, again between 2004 and 2013, those numbers are still very low. For example, the British public cannot differentiate between whether something called carbon capture and storage addresses climate change or ozone depletion or air pollution, and that knowledge has not increased. In spite of the fact that those of us who pay attention to energy issues, those of us who pay attention to climate issues or might be spending the better part of our lives working on it, will see more and more newspaper stories about this, and this is now the second inquiry—there was one in 2005—by Parliament on CCS. So those of us working on these issues perceive there to be more attention to this, but the general public does not see that at all. By contrast, with something like shale gas, about half of the British public says that they have heard about it or read about it in the past year.

Q68 Sir Robert Smith: Have you analysed their understanding of it?

Dr Reiner: We have looked a little bit at that. By its nature, carbon capture and storage is a little bit more outside people’s comfort zone. I think there is less familiarity with carbon capture and storage.

Q69 Sir Robert Smith: How do you think the understanding might be improved?

Dr Reiner: One of the things that I did was print out the 2005 Science and Technology Committee report in the 2005 inquiry. Recommendation 32 was, “Clear and transparent information about CCS at an early stage will be crucial for securing public acceptance. The Government must therefore adopt a proactive approach to communication”. And 33, “The Government has done little so far to engage the public in a dialogue about CCS technology. We accept that it is early days for the technology but previous experience has emphasised the value of early engagement”. Here we are almost nine years later and I do not think those two very legitimate recommendations have been taken on board. I do not think there have been efforts to engage the public, to design simple educational materials. It is very difficult to reach a diffuse public—for example, inserting materials into the educational system, finding ways in the course of debate to bring and develop those sorts of materials, I think it has been a bit of a lost decade in that respect.

Q70 Sir Robert Smith: It has also possibly been a bit of a lost decade in developing the policy itself. Would that not be part of it—that public perception of a theoretical idea is much more difficult to achieve than public perception of something that is actually happening? You say shale gas has a higher profile, but then there have been some drilling rigs.

Dr Reiner: Yes, the nature of things moving from being a virtual concept—we have not asked about this. At some level it might be indistinguishable from nuclear fusion: “It is something that scientists are working on that we do not quite understand that might happen one day.” If it has that sort of impression, then it is understandable why the public would not engage on these issues, whereas if people are going around in Sussex and

Lancashire looking for drilling, then that does make it seem much more real. I grant you that that would have an important element to play.

Q71 Sir Robert Smith: The Tyndall Centre told us that renewable energy supply options are typically preferred and the acceptance of CCS may be conditional on it being introduced as part of a mix of measures rather than as a substitute for a renewable. Does your research get to that?

Dr Reiner: Yes. I think there is a fairly consistent finding across Europe and across all the surveys we have done in the UK that solar is the most preferred energy technology. Wind is still preferred, but there are a number of fairly vocal opponents. Both CCS and nuclear power would be viewed still net favourably but with a significant number of opponents.

I would be somewhat cautious in that when you ask questions to do with costs rather than speaking about technologies in the abstract, you do not find nearly that same level of support. When you ask the question, “How much more would you be willing to pay for renewable energy versus conventional generation?”—this is true in the UK and they have done this in Europe, so it is across the EU—again less than half of the public would say they are willing to pay £1 more on their electricity bill for renewable generation. At one level you find very strong approval ratings for renewable technologies but you do not find that same willingness to pay. When you factor that into the reality of the debate, it is not quite as clear as to what the preferred option would be, factoring in costs.

Professor Gibbins: I very much agree with your suggestion that it is very hard to make people aware of something that does not exist. If we can get some real projects going, then that will increase awareness. Perhaps in terms of what the public would like to see, again it depends how the question is asked. I think if you pose the question, “Do you think fossil fuel suppliers ought to be made to pay to stop fossil carbon going into the atmosphere?” people might say “Yes,” even though it would add to their costs. Whereas if you said, “Do you think we should pay for the cost of electricity to clean up the carbon?”, they might say “No.” It is a lot in how you phrase the question.

Dr Reiner: One thing to say again is that the reality of projects does help. I was speaking with somebody at Statoil who was saying at one point during the mid 2000s that their budget for helicopters transporting the press out to see the Sleipner project was enormous, because every week there was an Australian or a Singaporean or a Chinese television programme that wanted to feature this, essentially, completely unhelpful platform in the middle of the North Sea, as a way of demonstrating that reality.

So the sense of being able to kick the tyres does have an important role, and it probably says a lot that we do not have a single major demonstration project even on the storage side. I think again that erodes the sense of reality.

Q72 Sir Robert Smith: The Tyndall Centre went on to say storage is the element that attracts most concern. Is that something you have managed to get to as well?

Dr Reiner: Yes. We have done work in a number of European countries on this, and it is particularly true that onshore storage creates the most concern. Working with colleagues as part of a Framework Programme 7 project two or three years ago, both in Germany and the Netherlands, onshore storage generated quite a bit of negative reaction and concern

over the associated risks—health risks, safety risks and so on. You find less of that in the context of offshore storage. Countries like Norway or the UK or the Netherlands, which also has its current projects going offshore, do not generate nearly that same degree of concern. There is a notable difference between onshore and offshore storage.

Dr Neufeld: It is probably a good point here at home too, since for the UK most of our storage sites would either be the east Irish Sea or the North Sea. Statoil and the Sleipner project that was run in the North Sea also has the great benefit that, from the point of view of both the platform and imaging the CO₂ in the subsurface, this is one of the most publicly accessible and data-rich projects out there. That is crucial in terms of running a storage project where you can engage the public and show them what happens as you inject. For that, Sleipner has been fantastic—certainly better than some of the comparable projects.

Q73 Sir Robert Smith: Finally, on the perception problem, do you think that oil, gas and coal are seen as dirty, old industries and CCS is seen as something the industries are using to try to make themselves more acceptable, and CCS is therefore seen as tainted by what it is trying to make acceptable?

Dr Reiner: What you are describing I think is definitely true of a number of environmental NGOs, which would be very much concerned about the image of CCS as a fig leaf or potentially a distraction away from what they might deem “real” action, which would involve the sorts of things the Chairman was talking about in terms of renewables. That is a legitimate concern among those who perceive the continued operation of large oil and gas majors as a central concern.

At least in the larger public survey work we have done, we have not seen quite that same level of concern, or at least framed in that way. I think many people are quite happy with, “Where does electricity come from?” “It comes from the wall.”—that view of not needing to know about these things. I do think that there is some element of that, and there is some fraction—albeit a small fraction—that would take that view, but it is not as pervasive.

I would say that there is a difference even within fossil fuels. Coal in particular is viewed least favourably. There tends to be more support for gas-fired generation than there would be support for coal-fired generation. Again, it probably also does not help that we have one coal plant under 40 or 50 years old in this country. The image, the impression, that most people would have of a coal-fired plant would be something that is from their parents’ or their grandparents’ generation.

Professor Gibbins: Also, a slight variation on that, I think people’s approval of gas is because they think gas does not need carbon capture and storage, which is pretty erroneous. A carbon dioxide molecule, no matter where it comes from, does exactly the same damage. Also, low-carbon electricity produced with CCS from gas can be cheaper than low-carbon electricity produced with CCS from coal. It is interesting that even James Hanson, who is revered by a lot of environmentalists in the US, said for a long time, “The problem is coal. We have to stop burning coal and burning coal with CCS. Gas is okay.” Still, I think the acceptance of gas does not include gas with CCS. That is something that the UK is leading the world on in saying that we have to be consistent and we have to do CCS on all fuels.

Q74 Graham Stringer: Can I just go back to your first question, Professor Gibbins? When asked about the case for carbon capture and storage, you said the politicians either have to do it now or wait for a crisis to come along and that will sort it out, when there is an international agreement. That is a bit of a body swerve, isn't it? There is a great deal of public money going into mitigation or renewables just from this country alone. What I would like to hear is you make the case for carbon capture and storage against renewables, if that was a powerful case. We may well have to wait some time for an agreement but while that money is going in I would just like to hear that case.

Professor Gibbins: You are right that a lot of money is going in. I think you would find at the moment that a lot of people in the Government—I would include civil servants as well as politicians—if you said, “Could you even consider spending some money on carbon capture and storage instead of renewables?” would just say, “The legally-binding 2020 renewables obligation. We cannot do anything else.” It is the case we do have a legally binding 2020 renewables obligation. We have tried making the argument and we have had it turned down. I think you have to be a little bit sympathetic, particularly with the Ministries that would be responsible, if, for example, the UK Government was seen to take active steps that would lead to a failure to meet its legally binding 2020 obligation; it would be liable to penalties from the Commission for wilfully failing to meet it.

You are asking me to make the argument for doing it, but I am telling you that I believe there are strong legal reasons why nobody listens.

Q75 Graham Stringer: I think there are very difficult political reasons and legal reasons the way things are set up. But you know politicians; they like to change the law. That is what they like to do.

Professor Gibbins: The basic argument comes in your question, I think, when you said we are spending money on mitigation and we are spending money on renewables. A lot of the money that has been spent on renewables I would say dates back to a period when climate change was not a priority. It dates back to a period when we perceived a shortage of fossil fuels—I can certainly remember that time—and we thought we needed to come up with non-fossil forms of energy just so we could keep our society going. That was a lot of the origin of the renewables spend in the 1980s. It lapsed a bit but then it came back.

I do not think that the idea about how you translate a renewables policy into serious mitigation has been thought through. For example, given that we have an emissions trading scheme, all of the money spent on renewables is of no value whatsoever at all for mitigation, because the emissions from the regulated sector—which is where most of the renewables generation goes—will essentially always reach the set cap. If you generate electricity from wind and thereby you do not need to use coal or gas, those emission allowances are freely available to be either used in the UK or elsewhere in the European system, and there is not a lot of thought that we will not get up to our cap.

Part of the reason that we are not able to make a very good argument is people are not analysing and not prioritising mitigation over and above renewables. If you want me to tell you why we should spend the money on carbon capture and storage, there are a couple of answers to that, but they are all related to: what are we spending this money for? If you think you are spending the money to achieve a result in global climate-change mitigation,

then the amount of CO₂ that we save—which as I say is functionally zero at the moment because of the cap and trade system—even if we did reduce CO₂, would have no particular bearing on the global outcome.

What we need to do is to influence the global outcome, inasmuch as we can. I take the Chair's point of view that perhaps that is influencing an EU-China relationship, although that remains to be seen. But whatever influence we have, if we were to spend money on carbon capture and storage at the margin, and we are perhaps talking about spending only 10% of the total amount spent on low-carbon electricity by 2020, that would give us several plants, which would be a very significant amount of global activity on power generation by that time, perhaps a third or a quarter of power generation, perhaps even 100% of the action on natural gas. That would get noticed. That is a big deal. It is a big deal partly because the technology is novel and partly because there are no other motives for doing carbon capture and storage other than mitigating climate change.

Pretty clearly, if we got the equivalent value in wind and perhaps solar, the influence of that—whether that is even noticed in places like China and the United States—is extremely doubtful. I suggest it would have absolutely no influence whatsoever. We are not going to build a nuclear plant by 2020, but if we were to, again that would have a little bit of notice but very barely in places like China and the USA who are quite able to do nuclear. So there is no guarantee that spending money on CCS will influence global outcomes, but at least you have a chance and you have a plausible mechanism, whereas I suggest that by spending that amount of money on alternative energy forms, which are already being built in fairly large quantities, there is no material way that that can have an influence.

If you want to look at it more directly from our own economic advantage, in terms of real economic advantage, it is global mitigation that will matter in the long run. In the short term the UK potentially has significant economic advantages from carbon capture and storage. That comes from the geology, as we have already heard from Dr Neufeld. We have good storage available. It is offshore and it is not too politically controversial. In the longer run, what is going to matter if we have a carbon-constrained globe is not access to fossil fuels but access to somewhere to put the CO₂ when you use fossil fuels, because you will not be able to put it in the atmosphere. So the UK has a significant economic advantage in that respect and it is one that people cannot take away from us.

For example, you could say that the UK should get advantage over making and selling low-carbon generation technology. Perhaps, but that is a very competitive market and there are larger markets. But stuff that you have from your geography and geology, you have it. I think in the longer term that is likely to be as big an advantage to the UK in the new low-carbon industrial age as the coal was in the first industrial revolution, for industry as well as power.

Q76 Graham Stringer: Thank you. I would like to move now to Dr Neufeld. You started to answer the previous question. What different types of geological storage are there within the United Kingdom and around our shores?

Dr Neufeld: Principally in the UK the storage options are almost exclusively offshore—the east Irish Sea and the North Sea. They fall into three broad categories, which are old natural gas, old oil acreages and saline aquifers. Out of those, the first two have the great advantage that essentially they have already been mapped out because of the cost that you get from extracting the natural resource—the natural gas and the oil. In terms of

characterising both geophysically and geologically, those are the places where we already know a fair amount about storage options. We know that a buoyant fluid, be it natural gas or oil, was trapped for centuries, millennia, in these formations.

The key question, if we want to take advantage of our opportunities and push the technology forward, is to ask: are there places like saline aquifers where we can learn about how to take advantage of a whole range of geological structures? Is it possible to sequester CO₂ in places where you do not have such a clean stratigraphic trap? These are the kinds of questions that some early investment could push forward. There is good reason to think that from the physics standpoint there are mechanisms that would trap the CO₂ there quite permanently, but they do need to be tested.

I think in the immediate term there are places that we could go out and sequester carbon with great confidence right now, based on the knowledge we have already gained from oil and gas. There are also places where we could go out right now and learn a great deal about how to deploy CO₂ in a whole suite of settings. Again, they are principally offshore.

Q77 Graham Stringer: How much capacity is there in those three resources that you have mentioned? I find it very difficult to imagine those in terms of carbon dioxide. This might not be something you can do off the top of your head, but it would be helpful to me. Would it take one part per million of carbon dioxide out of the atmosphere, if we use them all? So how much capacity is there, there?

Dr Neufeld: These estimates have a wide variety of uncertainty principally—and I will say this up front—because you are trying to put CO₂ into the core space of what is essentially a porous sponge, except the detail is that, unlike the kitchen sponge where you know that it is reasonably uniform, this is like driving by a road cutting at the side of the road. If you think about the natural complexity that you see there. That is what you are dealing with.

The estimate currently from the UK storage appraisal project was something like 78 billion tonnes as an upper band. That is including saline aquifers where we have much less well characterised geophysics and geology, in addition to these oil and natural gas sectors.

Professor Gibbins: Putting that in another context, that is over a century of UK emissions, total emissions.

Q78 Graham Stringer: That is a good way of putting it. The Grantham Research Institute—the LSE—said there could be 62.7 billion tonnes just within the saline resources, so that is nearly as much as the total you gave. That is very significant. You also said very clearly that you would have to test for leakage. What is our understanding of the potential for leakage at the present time?

Professor Gibbins: To be honest, I think at the present time all of the major CCS pilot projects that have been run have been run under the understanding that this is a first-off and we had better not leak. They have almost uniformly injected into ideal geology where—to put it very crudely—you had a porous reservoir, you had a very impermeable seal, and in some cases this is hundreds of metres thick in terms of an impermeable rock. So there is basically zero chance of it leaking in these scenarios.

The question of leakage is one that is slightly more nuanced than it should be. Current policy says that you define the containment area where storage is to be held—and that is some area within the subsurface—and that leakage constitutes any escape of CO₂ out of that boundary. This is a very high standard. If your boundary is 2 kilometres down and the CO₂ escapes to 1.5 kilometres down, it is not clear that that is either a clear and present danger to somebody on the surface, nor it is clear that this is going to change in any way, shape or form the carbon budget from sequestration. In some sense, a greater clarity from the policy standpoint on what constitutes leakage in terms of permitting would be very helpful.

Q79 Graham Stringer: Assuming that we are not talking about something a mile down, how would you monitor on the surface to reassure people that carbon dioxide was not leaking?

Professor Gibbins: In many ways you can monitor surface fluxes of CO₂. It is a noisy signal because the carbon cycle on the planet is quite variable and complicated. The question again is not only CO₂ fluxes in the subsurface. Certainly if you are down hundreds of metres you can do that seismically or you can do that geochemically. Seismic is essentially looking at sound waves travelling through the earth; that gives you an image of a sufficient volume of CO₂ leaking. Geochemical sampling is essentially a straw and taking a sample of the core fluid of the water within an aquifer above your CO₂ injection site and sampling it for its chemistry; that is much more sensitive but it has the disadvantage that you only get a point measurement.

These are cutting-edge questions and ones that should be addressed in a very publicly accessible manner. If we are going to talk about possibilities of leakage and risks of leakage—and I think, as David has alluded to, one of the central concerns around storage is the risk of leakage—what we need to do is address that with some very sound research where we test and make hypotheses and go out measure scenarios where it leaks and is it dangerous. Currently the answer is, uniformly in any of the pilot projects, “No, it is not a serious concern.”

Dr Reiner: Just to follow up, I think one of the themes that Jerome refers to is this notion of learning. I think it should come back to what it is exactly that we are demonstrating. It is true with regard to CCS, but arguably it is true as well with regard to other low-carbon technologies and our climate-change policy more generally that we do not really think very carefully about what it is that we are doing with our findings. What we end up seeing is essentially billions in subsidies for deployment and barely millions in subsidies or support for something that would be much more akin to learning, whether that is in terms of learning that would tell us more about the subsurface, or learning that would allow us to drive costs down in terms of capture, or learning what would allow us to build offshore wind turbines in a way that does not require tonnes of concrete. I think we are not necessarily formulating the question in a way that is helpful. It almost guarantees that we end up spending many billions building plain vanilla onshore wind turbines, or building what might be a very large-scale capture plant, when we could have been spending the last decade doing a number of these experiments or projects, on a much smaller scale, that would have significantly contributed to what we are learning.

As John mentioned, an example of this is the issue of gas with CCS. There are a number of important projects going on around the world on coal with CCS, but there is

really quite little going on, in comparative terms, with regard to gas with CCS. In the UK at least we have recognised that. At the EU level, the EU was ranking its projects as to which projects to support. Almost by definition, because coal produces twice as much CO₂ per unit, all of the coal projects went to the top of the list. To me that misses the point of what we are meant to be demonstrating, say, at the EU level.

I am not advocating abandoning deployment subsidies, but I am saying that, given that we are already spending considerable sums on deployment subsidies, if we were to think even a little bit seriously about learning and what benefits we would get then I think we would be a lot better off.

Professor Gibbins: I think the UK is doing quite a good job of learning from the deployment that we are doing. We are not there yet, but we are looking quite seriously at how much we can learn from the projects that are going ahead, partly by linking into the work that the projects are doing and partly by seconding people to the projects. That is still under debate, but if it were to go ahead then I think there would be a fair bit of learning by doing coming in from the UK's projects and from the billions. I hope that is backed up by the money then to address the problems that come up and learn from the unknown unknowns that appear.

I would also say that, through the UKCCS Research Centre, we are able to link into projects overseas for learning by doing. You were in Saskatchewan visiting the Boundary Dam project. We are linked to that and we hope to be learning from what they are doing as well, so we will get some advantage from the billion or so they have spent.

Just backtracking a little bit to your previous point about: how can you tell about leakage? There was a case adjacent to the Boundary Dam programme on the Weyburn project where some local farmers accused the injection of leaking to the surface. It was categorically proven that it was natural CO₂. That was done because there was there was a baseline survey before injection started of isotopic analysis and that did not match what was going on. So there are ways to do that using existing technologies. It is important to go in and do the baseline surveys first. In that case that was an example where the science was able to show, when the bubbles came to the top, it was bacteria not the CO₂ that was being injected.

Dr Neufeld: One other thing I think we should underline is when we say “learning”, it is not just the scientific and technological learning but it is also the public learning, the public understanding. That is a crucial aspect to all of this.

Q80 Graham Stringer: Yes. My guess is that if you did a survey—perhaps it has been done—a considerable number of people would think that carbon dioxide was poisonous, so I am sure you are right.

Just two final questions, Professor Gibbins. You have argued for the UK demonstrating that it is willing to invest in CCS that it is at least as valuable, in terms of the global climate change mitigation process, as actually demonstrating full change CCS technology. I find this a surprising thing to say. If you can show you have something, surely that is more substantial than a commitment to it.

Professor Gibbins: I think you are trying to separate things that cannot be separated. Saying you are committed to doing it—

Graham Stringer: I am just asking you to explain what you said.

Professor Gibbins: All right. Certainly saying that you are prepared to do it does not achieve the benefit that I was alluding to, but doing it does and you can only do it by demonstration. The point I was trying to make there is that, arguably, the countries that you are trying to persuade—and now we are trying to persuade China generally on carbon capture and storage, and the United States specifically on gas CCS, because the law in the USA exempts gas from CCS, whereas it is proposing to make it mandatory on coal—I think both of those markets are perfectly capable of generating the technology themselves. The fact that we have demonstrated it shows that the technology is there and that it can be done, but they know that. What they do not have is a mechanism that pays for it and the commitment that pays for it.

Arguably I think that is still the more innovatory part of the overall process, and that is perhaps where I am coming in and saying showing that you are prepared to pay for it and showing that you are prepared to pay for CCS on gas, even though people think it only emits half the CO₂, as I say, that might still have more effect than just saying it is technically possible, because people do know at the moment that it is technically possible.

Q81 Graham Stringer: My final question is are we in the lead with this technology or are we following? You seem to say that we are in the lead and we cannot rely on anybody else, but Professor Haszeldine has told us that we are now following and we are benefiting from other people's investment in the technology, where we are using the information and knowledge that they have gained. Where are we in that?

Professor Gibbins: I think you have to reflect on the nature of the global power industry, where any power plant is built by a multinational technology provider, using technology from various places, with often—particularly in the case of CCS—some local adjustment.

If we use a very specific example, I do not think it is any secret that the Peterhead project is likely to use the Cansolv technology that has been built at Boundary Dam. Clearly there will be some benefit from learning. It is also obvious that it is being deployed on natural gas and there is an element of innovation. The UK is leading on natural gas CCS, because we are the only one that is doing it. It is not leading on coal, because somebody else has done it.

If we are bringing in oxy-fuel technology that has not been deployed at that scale—as in the case of White Rose—then that technology is leading in the UK. It is being deployed by a multinational company. It is not solely UK technology in any sense or form. It is a mix, but that is the reality of the global economy.

We are clearly not going to be the first CCS project on power. We could be the first CCS project on gas, but even if you are the fourth or fifth CCS project on coal—I guess we are going to be somewhere like that—you are not the very, very first, but that is a pretty significant early project, especially bearing in mind that these are not cookie cutters of each other. They are all quite significant variations on the previous ones. Yes, there will be learning from it. That is what life is about; that is a really good thing. It is inevitable and it is very, very good. You have to reflect that that is the way that everything happens globally now. If I come up with a good idea in my lab in Edinburgh, then I could be emailing somebody in China or the USA about that tomorrow. They might go, “Yes, that is interesting.” That is the way things happen.

Dr Reiner: Could I just follow up? One area that the UK can lead and arguably is leading on is policy design. Some of the projects, like Boundary Dam or Tempura County in the United States or like a number of these Chinese projects, very much benefit from the ability of using CO₂ for enhanced oil recovery. That is something that we do not quite as easily have the ability to do here in the UK. What that means is we have had to think a bit more seriously about a policy design and how a policy would allow a CCS project without the immediate side benefit of CO₂ EOR from being economically viable.

Again, in global terms, the notion of marrying capital support and the variable costs—the CFDs that would underwrite the CCS projects—is a novelty. Arguably there is room to go further than that. For example, we do not allow for these first two projects to run other than on base load. One of the things we could be learning, which policy design might allow us to do, would be to ramp up and ramp down and understand how the capture plant might react to that. There are opportunities in the policy design process to bring in or to allow for learning, but I would argue that—particularly in this globalised context—one of the few areas where the UK does have some ability to say, “We are doing something innovative and different” is in terms of policy design and policy support.

Professor Gibbins: As Jerome was telling you, we are doing a lot of innovation in offshore storage as well.

Q82 Sir Robert Smith: I want to go back to storage with Dr Neufeld. My understanding is that the volume of storage you can achieve is very dependent on consistency of the flow rate going into it and the supply of the CO₂ not being cut off, or conversely not having to go too fast.

Dr Neufeld: It does not depend in detail on the rate or on the steadiness and the continuity of the supply.

Sir Robert Smith: It doesn’t.

Dr Neufeld: It depends to a large extent on the geology that you are—

Sir Robert Smith: You can have an intermittent and interrupted flow?

Dr Neufeld: Yes, and in fact most oil and gas production facilities, and indeed most CO₂ injection facilities, will have periods where they have to shut down for maintenance, periods where they have to shut down to address issues or to add improvements, and all of those are built in. In terms of the underground fluid dynamics, that does not make much of a difference. The huge question is: what is the underground geology and what is the variation of the subsurface? That tells you a lot about how fast you can pump in, at what volumes, how many wells you have to drill and those sorts of costs.

Q83 Sir Robert Smith: What is the danger of leaking to surface? If it happens, what are the consequences?

Dr Neufeld: In general the consequences are fairly mild.

Sir Robert Smith: It is just that you have not been as effective.

Dr Neufeld: In the case of storage in the North Sea the consequences are nearly zero. If you leak to the sea floor, the CO₂ is soluble within the seawater. You acidify a local patch where you have leaked into the sea floor. If you do an experiment where you inject something like a megaton per year of CO₂ into a reservoir—which is what is being done at Sleipner—and make the wild and wholly unscientific assumption that all of it leaks to the sea floor, you create an acidified patch that grows very slowly and is nothing like the acidification of the surface waters due to the increasing concentration of CO₂ in the atmosphere.

In the context of UK storage, leakage offshore is not a particularly big problem. It is an opportunity to learn how fluids might migrate vertically within the subsurface, and that is a place where I think we could take it to advantage, but in terms of the consequences it is not particularly large. Onshore is a different question. I will be interested if Professor Gibbins has another example. In Utah there are older exploration wells for oil that puncture a saline aquifer that is charged with CO₂ because of the magmatic activity that gives us the Yellowstone. There is CO₂ dissolved in that water and, as it passes by this particular exploration well, you get a cold-water geyser just like Old Faithful in Yellowstone. Every eight hours you get an eruption that is like the fizzy water coming out of a Coke bottle. People research these eruptions and can go up to the eruptions, and it has even been said that you can trigger them by removing some of the water from the wellhead. In that case it really depends specifically on how well you mix the CO₂ into the air as it comes out as a geyser. In that case it seems, by all indications, to be fine.

I say that as an extreme-end number because, in practice, if you are injecting at two kilometres under the surface, the route to the surface is so fraught and complicated for the CO₂ it is unlikely to make it that far. I think there are a range of answers there.

Professor Gibbins: At Edinburgh we have done quite a lot of work on natural analogues and there are many, many places where CO₂ is coming to the surface naturally. A number of them are tourist attractions. Occasionally people get killed but the risks are much, much lower than driving a vehicle even in those areas. Just as an example, one of the common ways that people get killed is that occasionally people going out hunting will lie down to take aim in a hollow of CO₂ and that will kill them, but it is extremely rare.

I think you are focusing on something that is certainly not going to happen in the UK. We are not going to be putting CO₂ underground onshore. It will all be offshore. There is a certain risk to do with transport, which is probably less than the risk associated with natural gas transport because the properties are fluid. At an environmental level, it is amazing how people are prepared to take the risk of putting all of the CO₂ into the atmosphere, a guaranteed release, but they get concerned about putting CO₂ underground.

Dr Reiner: I would say, taking all that on board, although I can appreciate that as a scientist, there may be then the danger of a bit too much complacency with regard to the need to engage the public, the need for the public to understand these issues. Some of the signalling is done by environmental NGOs. To their credit, the environmental NGOs, at least in the UK—perhaps not in some other European countries—have been quite good at supporting a number of CCS projects and opposing a few others. I think there is sometimes a danger when we look at risks in a purely analytical way from not appreciating the fact that if it is the first ever CO₂ pipeline and it is passing within a kilometre of your home, you will still object. Even if you could be convinced that it is fine, the fact that you think others might not be willing to buy your property because of a newfangled thing will potentially give rise to opposition.

Particularly for the first few projects, until these projects get off the ground, there is a need to be particularly sensitive. There is a danger of conflation with things like Lake Nyos in the Cameroon and so on, which opponents might bring up. Because it has the word “CO₂”—which as I have alluded to might also be confused with carbon monoxide—there are a number of ways in which the first few projects are particularly susceptible. If at later stages that kills off CCS plant number four, that is much less relevant than the first one or two projects.

Professor Gibbins: I think from what you are saying, if that is the case that people are nervous about the first of a kind, the only way you can get over that is by designing the first of a kind project, so that you do not get that sort of influence on people. It is just knowing those places that are going to affect people in that way. Quite legitimately you may not be able to persuade them that it is not a problem, and the best thing is not to go near them.

Fortunately, because we have offshore storage and coastal power plants, we are in a good position to do that.

Chair: Thank you very much. We have another panel of witnesses we are going to talk to this afternoon. Thank you very much for your time. We have much appreciated it.

Examination of Witnesses

Witnesses: **Dr David Clarke**, Energy Technologies Institute, **Rodney John Allam**, NET Power, **Chris Hodrien**, Claverton Energy Group, and **Darren Hopkins**, British Biochar Foundation, gave evidence.

Chair: Good afternoon and welcome. Can I just ask you to do the same as we did with the previous panel and just very briefly introduce yourselves?

Darren Hopkins: Yes My name is Darren Hopkins. I represent the British Biochar Foundation.

Rodney Allam: My name is Rodney Allam. I am Technical Director of NET Power.

Dr Clarke: David Clarke, Chief Executive of the Energy Technologies Institute, ETI.

Chris Hodrien: Chris Hodrien. I am a past owner and technical expert and salesperson for Timmons’ advanced CCS pre-capture proposals.

Q84 Chair: I think some of you are working on new carbon capture technologies. Would you like to tell us why you think they may be better than existing ones?

Chris Hodrien: I am a chemical engineer from the gas industry. Anybody who is a chemical engineer looks at carbon capture in a completely different way from all the people at the Government and the power industry and everything else.

The gas industry and the chemical industry have been using—what you call—carbon capture under a different name on a global scale ever since at least 1910. I started a

chemical company and we were capturing vast quantities of CO₂ in the Billingham chemical works, making chemicals and coal, long ago. So we regard the capture element as completely proven.

If you work in the gas industry, a gas is a gas is a gas. All natural gas contains CO₂. We are very familiar with it. So we regard CO₂ transport as a non-problem and future storage as a non-problem because we have been storing vast quantities of natural gas underground—which is far more hazardous than CO₂—on a global scale for 40 years, putting it down, taking it out again, putting it down again. It is our national gas storage, so we regard all of these as non-problems.

What we are most interested in is looking at how to optimise the CO₂ process. The two big problems with CCS are energy consumption and cost. The cost arises from two things: there is cost of building the CCS plant, but also, because it has a parasitic energy consumption, which absorbs a large part of the energy its host plant is producing, you have to build a much larger plant to produce the same amount of energy at the backend. That is about at least as big a cost again as the direct cost of the capture plant. So the critical thing we need to do is to get this capture energy down.

Any first-year chemical engineering student would know that from the physical fundamentals of developing a good capture process, what you need is the maximum possible pressure of CO₂ and the maximum possible carbon dioxide concentration and freedom from other contaminants. Those are conditions that you find in the petrochemical industry, in natural gas processing and areas like that, oil refining.

The exact opposite occurs if you try to capture CO₂ from the backend of a coal power plant. You have virtually zero driving force because the CO₂ is so dilute you have to stand on your head, using extremely active solvents, to persuade it to dissolve. These solvents then capture the CO₂ very strongly, so they now need a lot of heat. You have to virtually boil the solution up to get the CO₂ out again, so using large amounts of energy.

The plant is physically very large because the gas flows are enormous. The gas flows are enormous because most of what comes out of the back of coal-fired power plant or a gas-fired power plant is nitrogen from the air. The stream is basically nitrogen with a small amount of CO₂, so your plant has to process about 50 volumes of nitrogen for every volume of CO₂ you are trying to remove. On the other hand, if you decide to target your capture technology on processes that do not dilute the gas with nitrogen, automatically the plant is much smaller. So we need to focus on doing CO₂ capture where it respects the physics.

You are all familiar with a can of Coke. If I pull the ring pull on a can of Coke you get a fizz. The fizz is CO₂. The CO₂ was dissolved in the water at a very modest pressure, the pressure of the can, and all you had to do to release it was to pull the ring pull. No heat required at all.

These technologies—they are called “physical solvents”—have been proven in the petrochemical and natural gas industry for over 30 years. I can go out tomorrow and I can buy about four competing solvents with a commercial guarantee, and they use a tiny fraction of the energy of capture on a power plant of either type, gas or coal.

It is a matter of what you want to do. There are two issues about carbon capture. If you are forming policy one issue is the tonnage of CO₂ you are trying to remove and the other is the cost. Virtually all the policy focus for the last decade and more has been on how to remove the maximum tonnage, and it is quite true that the maximum tonnage is coming out of power stations. But we now seem to be finally waking up and realising that what we ought to be focusing on much more is cost. If you want minimum cost, the

smaller quantities of CO₂ that are available from these processing industries, where high-pressure equipment is used and carbon capture is fully proven—you can go out and buy capture technology tomorrow with no research—the carbon capture costs there are a fraction of what they are for a power plant. So we perhaps need to do both but we need to focus much more strongly on the industrial sector. If you look at what the IEA say—

Chair: If you can be bit a bit more succinct, if possible.

Chris Hodrien: Sure. The IEA 2050 blue map scenario is that CCS captures nearly as much CO₂ in total as all the renewables, including large hydro, and they expect half of that CCS capture to come from industry.

Q85 Chair: Does anyone else want to try to answer this question a little bit more briefly?

Darren Hopkins: Yes, I would like to talk about biochar briefly. The recognition of biochar being a carbon capture and storage technology is very outdated now because of the potential use—it is called the cascade effect—of using biochar several times before the product goes into the soil for the sequestration value. It is the added net reduction in emissions from the cascade use of biochar that gives it a head start in the CCS arena, because not only do we capture CO₂ but we can give an exponential reduction in carbon generated and environment benefit to boot.

Rodney Allam: The problem with CCS capture and storage is that it is too expensive. It costs 50% to 80% more to generate electricity when you capture carbon dioxide using the existing methods that are available to us, which are amine, oxy-fuel and IGCC. They can be applied basically to natural gas and coal.

The motivation for the work I did—which is now incorporated in the NET Power cycle—is to recognise that the process of power generation has to be totally different. The obvious choice of working fluid in that system is to use CO₂ itself. If you burn a fuel in pure oxygen, the products are basically CO₂ and water. If you drive your turbines with CO₂ rather than steam or, in the case of a gas turbine, using air, you will have a system that will naturally produce, once the water is condensed, pure CO₂ as a product that must be emitted by the system for it to remain in mass balance.

When you develop such a system, you can produce a system that has a lower cost of electricity than any existing fossil-fuel-based power system and at the same time simultaneously remove all the CO₂. I know it sounds like magic, but this thing has been properly designed and verified both in the US and here, in the US by NETL, here by the Royal Academy of Engineering. It has also been verified by the DOE and it has been verified by our partners, Toshiba, CBI and Exelon. So we have the partnership that we need to develop this system. We have a major turbine manufacturer. We have a major EPC organisation with very extensive knowledge of building massive power stations, and we have a very large operating company that has thoroughly evaluated this and believes it is the system of the future.

We want to develop this system because we believe it is the only way in which significant reductions in CO₂ emissions on a worldwide basis are possible. It is ideal for very large power stations. The modular size that we will introduce, as the first market introduction, will be a basic system of 300 MW expandable to 700 MW for a single-train operation.

We hope to build the pilot plant on Teesside, although we have another alternative site that is near Houston in the US. In the US the advantage is that the CO₂ can be used immediately for EOR, as previous speakers have said. In this country we would emit the CO₂. Although one of the advantages of this system is that we have options to produce all of the CO₂ as a liquid rather than a gas in a pipeline, so that we can ship the CO₂ anywhere in the North Sea using existing designed tankers that are available for hire right now for taking large quantities of LPG. These things are very easily adaptable for shipping CO₂.

The reason we can operate in that way is that the pressure ratio in our system is so high. We use a pressure of 300 bars for the combustion. We use a turbine with an outlet pressure of 30 bars, so the system operates over those pressures. We can take CO₂ off at any pressure, either pipeline gas at 150 or as a fluid at 300 where its internal energy is so high that the additional cost of liquefaction and the additional power is very small. This thing is ready to be deployed now and the challenge is to get it into the marketplace as quickly as possible.

Dr Clarke: I will comment from the point of view of the Energy Technologies Institute. We invest in technology development and technology demonstration, so logically you would probably expect me to say, “Here are a range of different technologies that we should be using for CCS”. My view is slightly different, which is that right now we have a range of technologies that are available, that have been demonstrated in the market at various scales, but none have been demonstrated as a full system demonstration at full power plant or full industrial plant scale.

The real challenge we have right now is not one of technology, it is about investor confidence in the market. That is the critical issue we have to address: it is to sustain confidence. In many ways that means we should not be going into a wide spread of technologies but should be focusing on a few that show very real promise. We have some of those that are on stocks right now and there are some clearly coming through into the market at the moment.

From the point of view of my organisation, we are right now investing over £50 million into carbon capture and storage products generally. They cover a whole range of areas across capture technologies, improvements, transport technologies, transport design tools for the infrastructure investors, and storage projects in particular. Dr Neufeld referenced the UK storage proposal project earlier on, which was financed by my group.

I would stress from our perspective that all of that needs to be focused on sustaining investor confidence and sustaining a single direction around UK policy, which will also help sustain investor confidence in this as an industry for the UK.

Q86 Chair: Do you think that CCS can be applied to flexible generation plants of the sort we need to balance the grid?

Dr Clarke: From the perspective of the work we have done around systems analysis, the answer is most definitely yes. The real prize with CCS is to apply it to more than just power generation, which I think several of the witnesses have already referenced.

In a UK context, we tend to look more at the UK system cost for energy rather than cost of electricity coming out of generation plants. When we look at the UK system, what we are seeing is that the opportunity in implementing CCS—not just on power plants but

on industrial sites as well and in other applications that we can get on to potentially—the prize there is to reduce the cost of the overall energy system in the UK by over 1% of GDP, recognising that at the moment we spend about 9% of UK GDP on energy and the energy system of the UK. Implementing CCS in the future gives you the opportunity, assuming you are going to hit the UK emissions targets as they stand at the moment. To hit those emission targets we have the opportunity to save over 1% of GDP, compared to alternatives. But to do that requires implementing the system on not just power generation but on other applications, particularly industrial sites as well. The current technologies that are being developed today, not just for the future but that are already here, are suitable for application in those environments as well.

Q87 Chair: Professor Gibbins suggested that the UK probably cannot rely on others to develop power sector technologies. Do you agree with that?

Dr Clarke: I think that is largely true. Clearly this is going to be a global market in terms of the technology. At the end of the day, the scale of the plants that we are talking about, in terms of the infrastructure, whether it is pipelines, whether it is the storage solutions and the equipment that goes with that in terms of injection, or whether it is separation plant on power plants or industrial sites, that plant will inevitably come from major global suppliers and they will wish to service that and deliver that into global markets rather than just the UK. I think there is an important distinction, which is the technology and the infrastructure that we in the UK might implement for CCS, we must be sensible and say it is likely to come from multiple companies, multiple countries around the world. In terms of the underpinning IP and knowledge base, there is a real opportunity for the UK to create both the financial lead but also a strategic investment lead by investing in the IP development and the knowledge development that goes to then be transferred into industry and then implemented in real applications.

Why do we have such a big advantage? Exactly the issues that were raised by Professor Gibbins and the other witnesses earlier, which is we have a real opportunity in the UK around storage capacity and the intellectual infrastructure to put those ideas into reality.

Chris Hodrien: Could I comment on that last point? We went and lost the global race to lead on wind power and solar power 20 years ago. We were early players and we chose not to proceed. There was not sufficient drive. CCS is a new and very immature field. I would suggest it is one of the very few fields left that is immature enough that the UK can have a serious crack at. I would not say a lead play, a major player.

Fortunately we have a reservoir in the UK of thousands of engineers who grew up with the fossil-fuel industry and the chemical processing industry and the gas industry, with a lot of the right kind of academic and industrial expertise that can develop a significant IP position in the way David suggests.

Q88 Sir Robert Smith: Just going back to NET Power, is there any public policy barrier to deployment?

Rodney Allam: No, none at all. In fact, it is not really a carbon capture and storage system. It is a power system that happens to have CO₂ as a by-product. There is no specific

equipment there to separate CO₂. It naturally occurs. You have to think of it as a new method of using fossil fuels.

The other thing to think about is that when you look at carbon emissions, you have to recognise the transportation sector emits almost as much as the power sector. For example, if you are dealing with coal, one of the advantages of a coal-based system is that if you gasify the coal before you burn the heat value of the coal you have the opportunity to remove hydrogen, which can be used as a transportation fuel in fuel-cell vehicles in the future. You have to think of the whole structure in the future for both power systems and transportation systems.

Q89 Sir Robert Smith: So you do not have an ask from the Government?

Rodney Allam: We hope that the Government will support us, because we believe that there are ideal opportunities in this country to develop this technology. Major parts of the system we can manufacture here already in the UK. We can do the engineering and procurement. We can do the heat exchanger. We have an opportunity for the turbines in the future. All the rest of the system—the air separation systems and the gas compressors—are available commercially in the marketplace, so there is no showstopper and there certainly is no limitation on building the first stations now.

The important point is to demonstrate the cycle, because it is so radical. It has never been used for a fossil fuel power system of this sort in the world. Secondly to demonstrate the turbine, which is an extremely important thing. It incorporates the combustor in the turbine just as in a gas turbine. The combustor has been fully tested up to its full operating pressure at a scale of about 30% of the size of the one we will use in the first plant. These things have to be demonstrated for the industry. It is such a new thing that it needs industrial confidence, which can only come from at least a one-year demonstration run, virtually a continuous output, on a particular plant. We hope to do that and we are scheduling to finish that by the end of 2017. Our start-up at the moment is projected to be 2016 and we are hoping to start work on the detail and design within the next few weeks.

Dr Clarke: Can I add one comment, not specifically about NET Power but in the context of groups such as the organisations you have sitting here and the concept of what is needed from Government? There is one thing that is needed, not just for NET Power but for other organisations in a similar position, which is that if NET Power were planning—as has been described—to put a unit at Teesside, they need somewhere to send the CO₂ to make it a viable business model. In that context the work that we did recently, which was published in *Optimising the Location of CCS in the UK* around UK strategy for infrastructure siting, I think there is a key piece in the pipeline infrastructure and thinking now about how we would finance the infrastructure that would support these kinds of plants, recognising that the reality is that there need to be relatively few hooks for CO₂ transport and offshore pumping around the UK.

I think we need to be clear early on where the optimum sites would be—we have highlighted where we believe they should be—and then how we would link in major development, such as any sites on Teesside, for instance, or Humberside, how we link those with the network at an early stage and ensure that the business models that have been developed support that kind of infrastructure.

Q90 Sir Robert Smith: Putting aside that we are interested in carbon capture and storage, you are saying that NET Power could put it there and discharge the CO₂ to the atmosphere and it would be more cost effective than other forms of generation.

Rodney Allam: Yes. You are not dependent on value of the CO₂ and you are not dependent on subsidy, because the cost of the electricity is lower than current generation methods without any carbon capture. It is the system of choice in the future. Using CO₂ as a working fluid in power systems is a very new idea. It was used in the nuclear systems that we build in this country: the Magnox reactors, the advanced gas-cooled reactors, used CO₂ as their working fluid. That is really the only application in power systems. Using fossil fuel, you substitute an oxy-fuel burner with the heat that comes in from a nuclear station. The other thing is that, because you are operating at such very high pressures, the CO₂ is available to you at high pressure. Secondly, the size of the plant is very tiny for a full-size 300 MW plant. The turbine has outlet blades that are only about so high. It is a very small system. It would go into the room here. It is going to cost much less to build. For example, it can be built in a factory rather than on a site with a lot of site construction work.

Q91 Sir Robert Smith: On the biochar, in your evidence, you talked about a potential to abate the 3.5 with 22 million metric tonnes CO₂ equivalent. How is that calculated? It is quite a wide range.

Darren Hopkins: I could sit here and spend a little time answering this, but I have a pre-prepared answer for you by Dr Simon Shackley, who wrote the piece of paper himself. To give a brief explanation, the assessment itself is based on modelling. It assumes that there are three different categories: one where no waste would be used to produce biochar, which is the lowest category and then going up. It effectively takes the total available biomass that could be used for biochar production and then, using a pyramid system, would then gradually work down to the total and viable amount of potential biomass available. It then goes on to some rather complex figures. I do apologise, I am not an academic but I do have the paperwork here.

Q92 Sir Robert Smith: Could you give that to us afterwards?

Darren Hopkins: Yes, of course, certainly.

Q93 Sir Robert Smith: Then do you know roughly what barriers there are in terms of public policy?

Darren Hopkins: This is where it gets interesting. Matt Davis from the Environment Agency is just about to finalise a position statement that will put the UK as the first EU member state to carbon sink a portion of its waste footprint. We are the first country in Europe that will mandate waste to biochar. Scotland have already done it. I have managed to convert them already. The Environment Agency are finishing off a draft position statement that they have released at a conference in June. The legislation context is that we are moving forward at a rapid pace.

As to Government support, funding research in regards to biochar is desperately needed and not from its sequestration value. We know and understand the sequestration

value, but it is the exponential added value of its use before it is put into the ground and sequestrated that is the most significant and important breakthrough for the biochar arena.

To add a bit of perspective from the biochar arena. In the last 18 months it has been shown in vitro that if you add 1% biochar as a cattle feed supplement to cattle feed, it could reduce methane by up to 50%. It has an increase in production of milk, increase in general health conditions and an increase in growth. Then when that carbon comes out the other end, it is ready for sequestration and applied to soils. The research funding is paramount to moving forwards. That way we get the perfect exponential benefit of biochar rather than just taking an organic matter, turning it into charcoal and sticking it in the ground.

The cascade benefit if you were to put charcoal into silage, there is a carbon emissions reduction from doing so because you are not using the carbon alternative. You then feed that silage to the cattle. There is a huge reduction in methane and increased milk production. There is an accumulative reduction in emissions from that. You then take the manure that is inoculated with microbial life and nutrients, apply that to the soil and then you have the added value of the carbon reduction from that and then the sequestration value of the carbon going into the soil. There is a great deal of research that needs to be done and not just about charcoal for the ground.

Health implications are breathtaking. Everybody saw the charcoal biscuits. At the moment, these are considered to be a bit of a hippy herbal digestive remedy that you would eat on an occasional basis. The implications of some of the research that we have seen recently is that, if biochar was part of the food chain, not only would we potentially need to eat less food, because we would be getting an increased energy value from the food, but the potential for that charcoal to then start to clean up the sewage systems as it passes through the system—I know it is crazy—and then for that sequestration value to come at the end of it, it is a no-brainer. Just from eating charcoal, we have had an exponential benefit on a huge number of significant polluting systems that are potentially ignored.

Chris Hodrien: I would like to offer the Committee a radical proposition that could be implemented with today's technology. My colleague Anthony Day, who was sitting here, submitted a detailed briefing note in connection with your original consultation in August regarding a radical scheme we have for gasifying a combination of waste and biomass to create carbon-neutral methane to feed the existing gas grid. Because people will pay you to take waste away, for the avoidance of the landfill tax, we can create a fuel mixture of waste, biomass and a little coal, which we need for technical purposes for this specific technology to have a zero fuel cost. As a result, using it with the high-efficiency carbon CCS efficiency technology embedded in the gas production plant—for example, such as Mitin's technology but there are others that would be nearly as good—we can generate carbon neutral or slightly carbon-negative methane at a competitive price with today's natural gas price.

This technology has been running at full scale in Germany for seven years. It came originally out of the British Gas research programme and the Government spent many hundreds of millions developing it, because the whole planned future of the gas industry was not going to be to import LNG. It was going to be to manufacture this synthetic natural gas from British Coal. The technology is proven on coal. The Germans licensed it and used it instead on waste and biomass. It has been operating on a full commercial scale. The only reason you have not heard of it is it makes chemical synthesis gas instead of gas

for the gas grid, but the backend technology to make the gas for the gas grid was already fully proven by British Gas 20 years ago and was a major element of Government policy.

The technology exists. It was proven. It was British-developed, although some of it is now foreign-owned because of lack of interest in the meantime. I would strongly recommend a look at this. The point being we should not just be looking at the power sector. CO₂ is a global problem. It does not matter where you remove a tonne of CO₂. We need to look at where the cheapest CO₂ removal options are. It turns out most of them are outside the power section, particularly the gas grid. You can do this on a very large scale. Believe it or not, there are over 200 million tonnes a year of waste material produced in the UK. Gasifying just a third of that would produce enough gas to power virtually all the Government gas-fired power plants today.

Q94 Graham Stringer: Dr Clarke, you suggested that by 2015 total investment in CCS is going to be around 60 to 80 billion. Where did you get that figure from? How did you arrive at it?

Dr Clarke: The 60 to 80 billion is what we estimate would need to be spent on capture, transport, storage, policy and infrastructure if we were implementing an optimum energy system across the UK. One of the things that the ETI carry out is strategic analysis and applying of the whole UK energy system—power, heat, transport and infrastructure—out to 2050. We do that primarily so we can identify where there is value in us, as a public-private partnership, making investments in technology development and technology demonstration to address key challenges in delivering that system.

The second benefit of carrying out that analysis, though, is so that we can provide recommendations to Government and to industry in the United Kingdom, as to what developments are needed in the future and where the policy areas are where we should be focusing effort. The numbers that you have there, which were in our evidence submission, are taken out of that model. The optimum solution for the UK involves about 30% of electricity generation in the future being fitted with carbon capture and storage, and the vast majority of major industrial sites having carbon capture and storage as part of their implementation. As I say, the model work that we do is focused on cost. We have plant cost and energy cost in there, so that we can provide an estimate of what the infrastructure cost is that goes with this kind of system in the future. That is where that estimate comes from.

Q95 Graham Stringer: You have also commissioned work on the wider economic benefits of CCS. Where are you up to with that work?

Dr Clarke: We have invested in a whole range of projects around technology development in capture technology, in transport systems design, storage technology. Latterly, we recognise that the technology on its own—if I can put it this way—was almost worthless if there was no investor confidence in the industry. We have been working very closely with the finance community working in particular with the Ecofin Research Foundation. Where we have got to with them is a very clear understanding of the financial benefits for the UK, of implementing CCS at a national level in the future. That is this figure of a saving of around about 1% of GDP compared to not implementing CCS across the energy system.

Q96 Graham Stringer: What about [inaudible]?

Dr Clarke: It will be about 35 billion a year in 2050. If you look at the MPV out to 2050, it will be 300 billion MPV. So these are substantial numbers and if you look at the saving of £32 billion you are into the realms of the UK defence budget, obviously; the scale of what we spend. Where we have got to today, as I said, we have published various documentation, various data around the strategy that we see for CCS in the UK in the future, around where we think the optimum location of transport sites will be, pumping sites for CO₂, optimum locations for the associated power and industrial facilities, some of which are out of date for obvious reasons but the assets are there, some of which are on new sites.

That has been very well received by the community. We have had a number of the major investment houses—and even one or two of the pension funds that tend to be ultra-conservative obviously around some of these issues—have been expressing real interest in this now. The critical issue for all of those groups increasingly is not technology but Government policy, as you would probably expect, and sustained support for this as a commitment from the UK.

Q97 Graham Stringer: That was my next question. Often when we are discussing climate change I do include them, but this panel is very optimistic. What can the Government do to provide greater investor confidence?

Dr Clarke: Realistically, there is two things. The first one is to recognise the scale of the numbers I just mentioned and what is involved in actually delivering those. When you look out for the future, in terms of meeting climate change targets for the UK, if you look at the development of the UK energy system—and for simplicity if I talk about power for a second—then in terms of major power generation sites the assets that we have are clearly expiring in terms of life. They will be gone over the next 10 years. We are already in a rebuild programme and that is going to continue over the next 20 years, obviously.

The real take-off in infrastructure investment in terms of the power sector particularly, is from the mid-2020s onwards. That is when it really starts to happen. The implication of that is that whatever the technology and whatever solutions we are going to have in place for 2025 onwards, we have roughly 10 years to prepare them and convince the market that the Government is serious about supporting those from a policy point of view in the future. We believe that for CCS, the cost of that activity is a few billion pounds between now and 2025. That comes mostly in the form of a series of CCS demonstrators. We have one feed study currently committed through DECC for the Drax White Rose partnership activity in South Yorkshire. There is a second one that is hopefully going to make its way through the system in terms of the Peterhead Project in Scotland.

From an investment community viewpoint, the critical issue is that we do not falter—if I can put it that way—around those projects, that we continue with those and we continue with the momentum they will create in industry in terms of delivering those and delivering subsequent projects. The cost for all of that over about 10 years is a few billion to have industry confidence and investor confidence in the UK as a market for CCS. The prize is saving £300 billion over the subsequent 20 to 25 years in terms of roll out of the plan.

The two things for Government I think is to recognise the scale of those numbers. It is basically a few billion now to be prepared to launch a major programme around CCS deployments on a mass scale from 2025-ish onwards. Recognise the numbers. Secondly,

sustain progress around the current demonstrators, such that industry can see that the UK is serious about CCS as an application in the future.

Q98 Graham Stringer: Mr Allam, I have listened carefully to what you were saying. If you are successful with your projects, what will it do to the structure of the energy industry in this country?

Rodney Allam: It would have an absolutely profound effect because, in effect, it would make it possible to re-plan and to use much larger quantities of fossil fuels, because you would have the ability at least to capture the CO₂ at virtually zero extra cost. It would not require subsidy for that large fraction and it would need a real re-planning and a recognition that there would be a much higher proportion of fossil fuel use in the future. It would also allow for the first time places like China and India to realistically consider implementing carbon-free power generation using their own coal assets. They are the people we have to think about if we talk about the global problem of CO₂ emission. If we are implementing this, it will give this country a big share in that tremendously fast-growing market.

There is a tremendous amount of reinvestment required, for example, in this country. If we can deploy this first plant and get to a point where we can start work on the production plant, the commercial plant, and get that in operation—as we hope by about 2020—then we have a mechanism in place for taking a fairly significant share of this new investment that is required in energy generation. It will have an enormous effect, number one in the UK, and number two because of export potential.

There will also be a huge market in parallel in America because I think the two things in the end will move in parallel. Certainly, the first demonstration plant is very favourably located in this country for the reasons that previous speakers have been talking about; the imperative to have a CO₂-free power system, the need to have diversified fuel sources, and the need to have low-cost power. All of the problems that were discussed in the first hour of the presentation were really revolving around issues of subsidy. These issues of subsidy are things that are going to be with us unless we recognise that current methods of carbon capture are just too expensive. They all require very massive subsidies.

I am not here to attack any of the other methods. I am here to say that this method of power generation will just cut the cost of getting rid of CO₂ emissions to a level where it is a natural choice. Even if you do not have anywhere to put the CO₂, it would be the natural choice. I cannot see any way in which this system could not be the system of choice for every major power company in the future, whether they are burning natural gas or coal.

Q99 Graham Stringer: When you go to the Department of Energy and talk to them, do they welcome you with open arms or do they throw you out as a revolutionary that is beyond the pale?

Rodney Allam: I think we have gone well past that point. We have had extremely good support from the Government, particularly from DECC. They have a very professional approach to comparison with existing systems. They have a very business oriented approach and they have given us enormous encouragement. Without them, we would not be anywhere near where we are in terms of considering almost at the decision point to implement this plant; whether it goes to America or whether it goes to this country. I personally have tried to make sure it came over here.

The reasons were purely from a business point of view. It turns out that the site at Teesside is not only ideally suited in terms of pipeline supplies of oxygen, natural gas and services. It is also a place where we can get a lot of pure hydrogen, That is a key to using the first system to produce simulated coal gas. We emit CO₂, so if we have a hydrogen supply with a simple piece of extra equipment we can manufacture simulated coal gas and operate this system on coal gas at the right composition to take all the risk out of implementing it as a coal-based system. We would envisage that the commercial plant was built as a dual-fired system, with the option of installing a coal gasification system so that it could operate on coal, gas, or on natural gas.

There is also the question of being able to handle variations in grid demand. This particular system, because it has a very large thermal capacity in the heat exchangers, it can actually go from 0% to 100% and back down to 0% quicker than a gas turbine system. It can peak shave and capture 100% CO₂ while it peak shaves or moves with the system on demand to take account of irregularities with renewable generation.

Chris Hodrien: Could I comment on this policy question?

Graham Stringer: Yes.

Chris Hodrien: What is important is not what the Government says; it is what the Government does. What both Governments in the UK and EU has been doing is giving a very strong political system that there was a mandatory target for RE—renewable energy—at any cost. Mandatory targets are a much, much stronger signal than some kind of market-based mechanism. CCS was more or less left to fend for itself on the expectation that the European ETS would make the current price high enough that CCS would become viable. Now actually we find it is quite clear that that was just not going to happen.

We have had 10 years of that history where there was a strong mandatory target to decarbonise emissions via RE, and no similarly strong political signal to do advanced CCS which—as we have heard in the evidence—is significantly lower cost. The International Energy Agency say the savings of CCS relative to RE are even bigger than the ones that David said.

The problem is how do you undo that, because industry has got used to the idea that what the Government really wants is renewables? We are now getting a signal in the new Energy Act that you now want to level the playing field, but we still have a situation where we still have a mandatory target for the renewables. We have a very generous published CFD number for offshore wind, but we do not have a published number for the CFD on CCS. It is the CFD that, in the short term, before the carbon price rises much higher, is going to be the only serious driver that will make CCS happen.

I am not sure that simply parity of Government support between CCS and renewables is going to be adequate to undo 10 years of a massive disparity. I think you perhaps need to think about going beyond to persuade industry of this vital industrial confidence that Government really wants CCS. The problem is we are talking about very long-lived plant. Ironically, the type of fossil fuel plant we would put a carbon capture unit on has a much longer operational lifetime than a set of wind turbines that are only tend to last about 15 to 20 years before they run out.

Graham Stringer: Not that long.

Chris Hodrien: They have to make very long-term investment decisions and have the confidence that Government will stick with support, at least until the major capital of the plant has turned off. We need clear signals of continuity of Government support for 20

years. In principle the CFD mechanism provides a bankable method of doing that, but there needs to be a lot more words, not just words but actions that show that CCS is a serious part of the mix.

Q100 Sir Robert Smith: What would you say the rating is of the effectiveness of the Government's support for R&D in carbon capture and storage?

Dr Clarke: That is a tricky question. At the moment I think it is actually quite good. From the perspective of ETI, we have to be clear that the rating of Government support for R&D spreads a very wide range right from R right through to D

Sir Robert Smith: If you could split it into—

Dr Clarke: If you look at it today, clearly, the research councils—and to an extent groups like mine in ETI, but particularly research councils—have put considerable commitment behind the R end of CCS in all aspects of capture, transport and storage right through the space. The Scottish Government and the Scottish councils have put considerable additional commitment behind that as well, in terms of the Northern North Sea and the Mid Central North Sea. Without looking at the detailed qualification of the numbers, I think you would have to say for the R piece there has been a quite considerable level of support and that has been well received and focused well into a few key centres in terms of the UK, UK academia in particular.

The demonstration piece at the other end, we have had long-term commitment around building power fund for a full chain demonstration. We are now getting close to the launch of that; certainly, the feeds for the way for the first one. I think that commitment has clearly been welcomed by industry. It has clearly been delayed along the way for various reasons. I think part of that has been over-optimism as to the reality of how long it takes to set up this kind of high-risk contract in an uncertain environment. But that commitment has certainly been well-received.

It is in the space in between in the development piece, where there has been the biggest gap. That is where ETI has put most of our activity; is in trying to take capability from the research piece into a form that delivers value for the demonstration elements. Perhaps the easiest example to date is the storage appraisal project where we were able to take the outputs from the academic research base, both in Scotland and England, provide funding which allowed those groups to amalgamate around a particular deliverable, which was a storage database in the UK. They took all of their data, and a whole range of new data that we were able to make available through that project from commercial sources, and created the UK storage appraisal. That is now the CO₂ stored database, which currently the States are licensing to groups who are looking to develop sites.

I think that has been a great example of the pull-through of how we can fill this gap in the middle through groups such as myself. We then took the specifics of the storage appraisal project and were able to identify a particular sale on aquifer reservoir as having what looked like the optimum characteristics for first investment in the UK. In discussion with National Grid, they concurred with that through their use of the database. Between ETI and National Grid, we were able to finance the launch of appraisal of that aquifer in the North Sea, which is now going to be the aquifer for the Drax White Rose partnership project.

I think the chain is there, in terms of R through to D, and we need to sustain commitment to it and make sure that capability is pulled through all of those levels. The

focus at the end is the demonstrators, and that is the key piece that we must retain focus on and the commitment.

Darren Hopkins: From the biochar sector, I talked about research needed, but the biochar sector is something that is already happening today. There are retail products on the market that you can buy. This is an industry that is happening, and yet it has had absolutely no funding whatsoever from the research councils, not a penny. Yet this is a carbon capture and storage system that is in place happening today. With the support from the Government and a bit of help to push it forward for research, who knows where it will go.

Rodney Allam: As far as I am concerned, it has been a very, very positive reaction from the Government. We have already had three grants of development money rather than research money and this has pushed our project forward very, very rapidly. It has also pushed forward the opportunity for one of the major suppliers in the Midlands to supply major equipment, which has already been manufactured and delivered for the first demonstration plant, the 50 MW plant. This was due to the fact that DECC was able to very rapidly assess our system in comparison with other systems and come rapidly to the conclusion that we should be supported under a competition that was available to us to enter. I can only say that the way that the policy of supporting demonstration has been implemented in our case, where we are pushing forward very rapidly, has been really very good indeed and we are very pleased about it.

Chris Hodrien: I would like to say we have a disconnect between the CCS demonstration projects and the development. DECC has reasonably generously funded the CCS innovation programme. Unfortunately, the demonstration plants have been subjected to such a high degree of commercial risk—because they were not given any guaranteed access to market for their product, so they had to compete in the open market place—they have had to adopt the lowest risk technology to satisfy the commercial risk criteria. The commercial risk was so high, they could not take technical risks. By definition, the demonstration plants you have are using some of the best proven oldest CCS approaches. At the moment there does not seem to be a mechanism for taking all this wonderful technology that is coming out of the innovation programme, and all the good stuff that ETI is doing, and demonstrating it on a large side stream scale—let us say 5% of the total flow for example—on these well-funded demonstration plants.

There should have been an integrated approach there because you have to get these emerging technologies, which have the potential for very significant cost reduction relative to what the demonstration plant was going to use, and they have to be demonstrated at a significant scale. By “significant scale”, I am talking of 20 MW equivalent at least. That is 10% of the footprint of the plant. Industry are not going to believe the demonstration that stands at the proof of concept scale of 0.5 MW size, which is where most of the developments are occurring at the moment. The demonstration plants provide an ideal platform. I am thinking if we look at the philosophy that has been used in marine energy, where significant Government funding has been put in to create marine energy parks where there is an infrastructure whereby these new technologies can be tested at a relatively important scale relative to that. They are much smaller but at a substantially commercial scale. Some of them are testing full commercial scale devices in a facility that is Government funded, and I cannot see the same on CCS.

Q101 Sir Robert Smith: Do you think that is an opportunity that is too late now because it would disrupt the already held-up projects?

Chris Hodrien: I do not know. Clearly, the projects as planned do not include that facility, so the companies cannot be expected to fund that voluntarily. This extra capability would need to be added on as a fully funded bolt-on.

Dr Clarke: Given at least one consortium is now in its feed study, the only consequence of changing spec during the feed study is if the cost goes up or time goes out, and potentially it stops altogether. I would say once you have started, carry on.

Q102 Chair: We are going to have to wrap up in a moment because we have a train to catch but, just to summarise, do you think the Government is taking the right approach to developing CCS? Some of you have said a bit about that already but are there any additional points you want to make in connection with this?

Darren Hopkins: I had an interesting conversation. Please forgive me. I am new to the CCS arena. I think the most important thing that I have taken on board over the last six to eight weeks is certainly that the use of CO₂ in the States as part of the CCS regime is obviously a major step forward, because capture seems to not be a problem. It is the storage side that seems to be a problem. Surely, using the CO₂ if we can capture it for some systems it is better than just allowing it to go up into the atmosphere anyway. Surely, even if it is only an interim stage, to assist the moving forward of the storage sector the Government could implement perhaps a utilisation system that would assist the pathway into that true storage.

Rodney Allam: I think the Government's roadmap is very sound. The challenge is to make sure that the funding is available promptly, so that the development task can be implemented without major delays at each stage. It is very important to have a continuity so that you can proceed quickly to a point where you have plants in operation. It is a question of speed at the moment. That is the real problem.

Dr Clarke: I think consistency and, in some ways, sustained support for a particular strategy is the most important thing and policy risk is critical for that.

Chris Hodrien: I would like to suggest some substantial changes. I think opportunities have been missed by focusing Government's entire CCS attention on the power sector. As I said earlier in my presentation, it so happens that CCS costs are relatively quite high in the power sector and much cheaper in certain but not all industrial sectors. They are much cheaper in the petrochemical and natural gas processing sector. We already have something like 100 operating carbon capture units in the UK in these sectors. The cheapest CCS plant is the plant you have already built. There is huge opportunities in CCS in the gas industry using this synthetic natural gas production, where you can produce carbon neutral gas at source at a competitive price needing relatively little subsidy—I am not saying none—and then supply this to existing gas-fired power plants.

Given that about 40% of our total electricity is generated from gas-fired power plants, you can decarbonise the fuel supplies then at course cheaper than attempting to put CCS on power plants themselves with no disruption on the power plants, no change to their flexibility or their means of operation. We need to be looking at the big picture.

Chair: Thank you very much for coming in. I am sorry we have to conclude this before we have quite gone through all our issues, but it has been a very useful afternoon for us so we are grateful to you.