RESUMED **[12.01 pm]**

COMMISSIONER: We reconvene at 12.00, and I welcome Ms Tania Constable and Prof Peter Cook. Mr Jacobi?

MR JACOBI: Tania Constable is the CEO of CO2CRC and a senior fellow of the University of Melbourne. Tania has had an extensive career in the Australian Public Service, most recently with the Commonwealth treasury, and prior to that - prior to her time at the treasury, she worked in the field of resources and energy over the last 17 years. Most recently Tania was the head of resources where she had responsibility for policy and legislative advice to the Minister for Resources and Energy on oil and gas regulation, exploration and development, mining activities for coal, minerals, and uranium.

In 2013 Tania was recognised with an Australia Day meritorious award, public service medal for outstanding public service in the development of Australia's liquefied natural gas, and other resources in the energy industries. Professor Cook is one of Australia's foremost scientists and technology leaders in the areas of energy, greenhouse technology, and sustainability. He is a professorial fellow at the University of Melbourne, a company director, consultant, senior adviser and author. He was an IPCC coordinating lead author, and in this role was a co-recipient of the Nobel Peace Prize for 2007.

He has been a consultant adviser on resource and energy issues in Australia, Finland, Greece and other countries. He's been a consultant to NASA and various national governments and a range of companies and other boards. He's occupied a number of senior executive positions during his career. In 2003, following five years as the executive director of the Petroleum Cooperative Research Centre, he initiated the Cooperative Research Centre for Greenhouse Gas Technology, CO2CRC, and served as its chief executive until 2011, and continues with CO2CRC as a principle adviser. The Commission calls Ms Constable and Prof Cook.

COMMISSIONER: Professor, if I might start with you in the broad, we've been hearing evidence over the last couple of weeks about climate change. I'm interested in your view about how we're doing globally, and then to bring that back to Australia. I'm particularly interested in your view about that, the achieveability of 450 parts per million. Then we'll move across to the subject that we've asked you to talk about, which is carbon capture and storage.

PROF COOK: Well, first of all let me say I'm not a climate scientist. It's one of the things that I've been interested in, that I'm published on, but I am not an expert in climate science. So I generally go on what I read, if you like, from people who I regard highly. The issue very often boils down to, well, is the jury out or is it in? Do we believe it?

Well, my view is that you never get 100 per cent certainty on anything in science, so if people are saying, "Well, there's just a slight uncertainty," that's not the basis for taking no action, in my view. I think that the cautionary principle does apply, and I think it's appropriate to take action. Are we going to get to 450? Not the way we're going we're not. I don't think there's quite the sense of urgency at the moment.

People pay lip service to these things, but if we take carbon capture and storage, and Tania will talk about this much more than I will, we're not actually seeing the action that's needed by industry and so on if we're going to actually get where we want to get to. So I think it is achievable. Is it achievable with what we're doing at the moment? Probably not.

Should we be achieving it? Yes, we probably should aim at that. Are we certain that its going to - 450 will cool two degrees? No, we're not. You know, there's some leeway there, and there is more science to be done, but that's no basis for saying, "Let's do nothing until we know for sure."

MS CONSTABLE: Am I able to add to that, Commissioner?

COMMISSIONER: Certainly.

MS CONSTABLE: So the 450 parts per million, which is equivalent to a two degree scenario, and that work has been viewed quite extensively in various reports by the intergovernmental panel on climate change by governments around the world, by the IEA who look at it quite - in similar terms, the IEA are 450 parts per million, the IPCC talks about the two degree scenario. Peter said it's difficult, but that's the scenario that we need to work with in a portfolio approach where carbon - technology such as carbon capture and storage is going to be needed, otherwise the costs are going to be so much higher.

The two degree scenario, governments have already started to talk about, well, is it appropriate to talk about 450 parts per million, two degrees. Is a reality more likely to be four degrees, or even six degrees? If we start to move down that track and have those sorts of discussions, then based on what the climate scientists are already saying, that's very difficult for us.

So no matter what, it doesn't matter whether it's four degrees or whether it's two degrees, we need to do as much as we possibly can in a global situation with all of the economies at the table, which is what Paris brings with the climate change negotiations, to actually make sure that the commitments are in place across the world to actually achieve significant cuts in omissions. Australia is well placed to do that. Well, we put commitments on the table out

to 2020. The government of the day has already made a commitment that they will look at what the commitments might be post that 2020 period.

PROF COOK: Perhaps I can just add to that, in saying that I don't think we're on track to reach the 450, I'm talking globally. I'm not talking about in Australia. I'm talking globally.

COMMISSIONER: Well, let's talk about Australia.

MS CONSTABLE: Well, Australia has put forward commitments out to 2020, based on to a 2005 position. Certainly we're on track to meet those commitments out to 2020. I think the real problem starts to occur, the real challenge rather than problem, is what does that look like after that? It is going to take not just one government, but governments across Australia to come to the table and agree what those post 2020 targets might look like, and how we're going to achieve those in the economy across all of the different economic sectors.

So it's not just a matter of the power sector. It will involve all industrial sectors. So this is an issue for all governments, industry, and research communities to work together to make sure that we are able to achieve significant cuts in de-carbonising the economy across all of those sectors. I think that what we're doing places us well to participate in that debate.

COMMISSIONER: I think that's probably the right time for us to get into your sector. I mean, we are looking at all the technologies that might be applicable, and clearly nuclear is one. Carbon capture and storage is another. If I go to the IPCC special report, and the summary of the policy makers, which I think you participated in, Prof Cook.

PROF COOK: That's right.

COMMISSIONER: I read one of the conclusions, and I'd like to understand the basis for the conclusions. It was, "Carbon dioxide capture and storage technologies could reduce lifecycle greenhouse gas emissions for fossil fuel power plants," and then the bit that interests me is, "Medium evidence, medium agreement".

PROF COOK: Sorry, "medium" - - -

COMMISSIONER: I know it was a long time - - -

PROF COOK: Yes, that's right. Where are we now? "Medium evidence, medium agreement," that's - - -

COMMISSIONER: Am I reading too much into that?

PROF COOK: It's just the very formalised process of the IPCC which - - -

COMMISSIONER: Could you explain to me that part of it and your view of it, more importantly.

PROF COOK: I think that this is the most recent one. I was involved - I don't think this is the special report, is it?

MS CONSTABLE: Yes, it is.

COMMISSIONER: It is.

PROF COOK: This is the most recent one, isn't it?

COMMISSIONER: Yes.

PROF COOK: That's right. I was involved in the previous one, not in this one. So in terms of the precise words that are here, I'm not responsible for them. What they mean, I mean basically "limited evidence", they were not able to get a lot of peer reviewed literature because they don't try and collect new information, they go on peer reviewed literature totally. So what they're saying is they need more evidence. Medium agreement is what it says. There was not universal agreement on this. There was obviously enough agreement to say the weight of evidence would suggest this, but they're not saying here that everybody agreed with that. So that's to do with (indistinct)

COMMISSIONER: In that case let's step back a bit and just talk about the technology itself and where we are, and particularly to perhaps start it on your point in terms of power generation and that being the biggest greenhouse gas emission pollutant to date. I think you've got your second slide which talks about world energy consumption (indistinct) for that. Perhaps you can walk us through this particular slide.

MS CONSTABLE: I included this particular slide because really what it sets here is the scene for a whole range of challenges we have at a global level around energy. So the story here is that this is really an Asian story. So where are we going to see energy consumption at a global level going forward? Most of that is going to occur in the Asian region. So China is currently putting in one coal-fired power station every 10 days. India, between 2015 and 2018, is putting in 178 new coal-fired power stations. The Asian region in terms of LNG is consuming a considerable amount of LNG during this period. So where are we going to see the increase in energy over that period? It will be in the non-OECD areas and in that Asian region.

So the coal capacity in 2015 - just to give you an indication - we're seeing 867 gigawatts in China, 246 gigawatts in India. How does that compare to Australia? 37 gigawatts. By 2040 alone, India will be expected to add about 342 gigawatts of coal capacity. So it's a huge amount of energy demand coming forward. What does that mean for Australia? As a commodity producer, a big fossil fuels producer, and a supplier to that Asian region, it's in our interest, given that in 2014 alone our exports on fossil fuels were $68 billion. Now, that's a huge amount for Australia. We can't afford not to be in this debate, not to take it seriously and not to have the likes of carbon capture and storage as part of a portfolio of solutions on technologies, Commissioner, because that would be (1) irresponsible, but (2) I want to make this very clear and it's one of the key messages I actually would like to leave the Commission with, this is not a competition. In terms of looking at this whole issue of emissions reduction and energy security, those two – that nexus, in the longer term, we need to make sure that we have a portfolio of technology options available around that 2030 to 2040 period, to be able to really meet those two particular goals at the same time. Which is not going to be easy to do, I must say.

COMMISSIONER: Not based upon those projections - - -

MS CONSTABLE: That is exactly right.

COMMISSIONER: - - - requirements.

MS CONSTABLE: Yes.

COMMISSIONER: Because if we understand some of the technical literature they are looking to be CHC free by 2050 – within the two degree limit that have been established. So that is going to take a number of technologies to be able to do that.

MS CONSTABLE: Exactly. And I think that from the perspective of the use of fossil fuels over that time, it is unrealistic given the numbers that I have just talked about and what is going in to China, what is going in to India, for that to – for anyone to say to some of those economies, you are not going to draw coal out of the ground, you are not going to draw LNG out of the ground. It's unrealistic and it's not something that is going to be possible. So we need to make sure that those portfolio of options are there to be able to address the needs that the world economy has.

COMMISSIONER: When we look at the global emissions reduction effort to date and get a sense of what is being achieved and what is likely to be achieved?

MS CONSTABLE: So we thought it was important to put this up and just talk about the global effort on energy. This is the second goal that needs to be considered in the reduction over all of those global emissions. And this looks out of course at who is contributing what at a period – we're looking out to 2030, 2040, 2050. Most notably of course, the renewables is playing a big part in terms of contributing to that global emissions reduction ethic. We have seen an incredible increase in the use of renewables which is a great thing. We are also seeing some emissions reductions through fuel switching. Importantly for us, and we are talking about carbon capture and storage of course, is that 17 per cent of the overall global emissions effort, when you are talking about the scenarios we started off with in the climate debate, 17 per cent of that global emissions reduction will need to come from carbon capture and storage to achieve that overall goal. Now we are on track. Even though it is viewed that carbon capture and storage is moving slowly, at a global level, we have got to remember that we are talking very big capital investments, much bigger than we have got on some of the renewables technology. So it is going to move more slowly because of the different aspects of carbon capture and storage but we do see a lot of that effort starting.

We have got first of a kind starting to occur across a range of industrial processes, not least of all in Australia very shortly with Gorgon which talk about that later on. And we have had Boundary Dam in Canada, around brown coal and we will also talk about that. But around that 2030 period we will see more and more projects coming on line at that global level. There is 55 projects at various stages of planning and these are figures that the Global Carbon Capture and Storage Institute, which is located in Australia in Melbourne, they have a very good understanding at that global level of projects around carbon capture and storage. So from the development stage right through to the execution stage, there is 55 projects in various industrial areas that are in the planning stages.

MR JACOBI: Could I just bring us – perhaps take us a step back and go to the currently mature technologies with respect to carbon capture and storage, and perhaps we will come later to the concept in development. I am just wondering whether you could offer a brief explanation of the broad concepts of the technologies that are involved and I think we have got a slide for this, and it might be slide 6.

MS CONSTABLE: So we will go through some of those technologies. I am going to get Peter to take you through the expert around, from a technical perspective, around the carbon capture technologies, pre-combustion technologies, post-combustion and what that means, oxy-fuel, all of which we have been working on in Australia and then the storage, which is quite exciting. I have done a lot of work on site characterisation around Australia

and specifically for the CO2, CRC we have the Otway site which is near – in Victoria and we want to talk about that, if that is all right. Get Peter to take you through the various capture technologies if that's okay.

PROF COOK: If we turn over the page and look at six, the three main options, the pre-combustion, post-combustion, oxy-fuel capture and this is all about producing as pure a stream of CO2 as you can get. The reason you are doing that is because you don't want to be putting lots of oxygen in the ground or lots of nitrogen in the ground. So what you are trying to do is get something that is fairly pure and it ranges up to, from fairly pure to very pure. Pre-combustion capture is all about separating out the carbon and the hydrogen from coal in the first instance. And so you end up there, essentially with hydrogen as your fuel and carbon dioxide, quite a pure carbon dioxide. And it's a process called integrated gasification combined cycle. What that is about is a chemical process essentially. You are then able to use the hydrogen as a fuel, or you are able to directly – for electricity generation, or you are able to use the hydrogen for vehicles or whatever else you want to do with it. There are people looking at this on a large scale. Is this possible at a large scale? It's being done on a small scale and it's being done commercially but primarily for chemical plants and the like. So it's a tried and true process but it's not tried and true in terms of massive scale you need to do it at for power generation, at the moment. But it is being looked at. There is a company doing it in the United States, place called Campbell County which is in the southern United States and I think we might have something on that there.

Post-combustion capture is the more normal process that applies. You are burning a coal, you end up with a blue which has about maybe 10 per cent CO2, sometimes less, a little bit more, depends on the efficiency of the plant. You have then got to get that up to about 90 per cent, so you are able to do that by putting it through various solvents and (indistinct) membranes. There is a variety of ways you can do this, so what you are doing is you are stripping out this relatively dilute stream of CO2 and making it in to a concentrated stream of CO2. That costs money to do that because you're using solvents and you have to heat those solvents and get the CO2 out of it and so on. I am happy to go in to the detail of how you do that but I am just trying to give you the big picture at the moment.

COMMISSIONER: Big picture would be good.

PROF COOK: The other one is oxy-fuel combustion and that is where you are actually burning the fuel, not the air and of course air is 80 per cent nitrogen and that has no – you are not burning nitrogen or anything else, it just goes through your flu stream and just a darn nuisance. So what you are doing, you are actually getting pure CO2 in the first instance which you are getting out of the air and that costs you money. But then you are burning your coal in

a pure stream of CO2 which means you – sorry, a pure stream of oxygen and you then get a pure CO2 out the other end, plus your power. Now that has been tried very successfully in Australia through what is called the Callide Project and they got a very pure stream of CO2 out of – essentially no problems with that. The problem is always cost with these things. You know these things do cost money but in terms of knowing how to do it, all three of these processes have been done at a variety of scales and so we know they work. It's a matter of making them work economically.

MR JACOBI: Could I just come to the issue of cost? At the time that the 2005 report was written, I notice that there is a reference to hope that the cost of capture, which I understand is the most expensive part of CCS technology, that is the capturing of the CO2, could be reduced by 20 to 30 per cent. That was a view that was expressed in 2005 over the next decade. I am just interested to understand whether or not advances have been made in making it more economic since that time?

PROF COOK: Yes. But not to the extent that we anticipated in 2005 and the reason for that is that it hasn't been undertaken at the – with the number of projects that we anticipated in 2005. It has come on more slowly. We believe doing this, we are actually getting on and doing it, it's an essential part of bringing down the cost. If you look at the Canadian example, the Boundary Dam where they've actually done it, their view is that when they do it next time, because they have all the costs of doing first of a kind and so on, they are confident the next time there will be able to do it at 30 per cent less than they have done it this time. So we have indicators that we will get that cost down quite significantly.

MS CONSTABLE: And of course the technologies are there and being – and already being implemented, so some companies around the world already have capture technologies that are now off the shelf and being used in projects. Boundary Dam is a good example of that where the capture technologies that they are using are technologies now that can be bought off the shelf and companies are not looking to put tests – untested technologies in to their commercial plants, as you would expect. So we will see some movement because we are still dealing with first of kind. So as we see more and more of these projects coming on line, the costs of course will come down. That statement of 30 per cent is really critical because we have seen the first brown coal power plant now. As that is rolled out and we see more and more, we will see the costs further reduced. Again, I just want to restate, we are talking about large capital investments, we are not talking about small capital investments here.

On the oxy-fuel, if I can just talk a little bit more about the oxy-fuel. That was an important project for Australia. The CS Energy and its consortium that

involved some Japanese companies and there was a significant investment made by the Australian government, so 350 million dollar investment by Australia in the oxy-fuel capture process that now even though it has the whole demonstration has finished at the end of 2014, those learnings have been taken back in to Japan and the Japanese part of the consortium will consider next steps. So there are proponents now around the world that are looking very closely at oxy-fuel as a real option for carbon capture and storage. So we have finished the demonstration, we have done what we needed to do in Australia and now the next steps are being taken in terms of consideration of commercialisation.

MR JACOBI: Was that demonstration within the electricity sector, or is that demonstration at the chemical plant end?

MS CONSTABLE: No, it was at the electricity sector – at electricity sector, so at CS Energy, at the Callide Project in Queensland.

PROF COOK: They refurbished a (indistinct) that was already (indistinct) used for electricity production so it was – it is an example (indistinct)

MS CONSTABLE: We took it a step further because we took a small amount of the CO2, this is where we started to integrate what we were doing in Australia, even though it's very small and not joined up, it is still integrated to the point where we capture the CO2 and then stored about 100 tonnes of the CO2. It was taken by truck down to our Otway site and we injected that in to the (indistinct) so in that way carbon capture and storage is starting to become reality in making sure that we have got an integrated approach. So the oxy-fuel project from capture through to storage has helped demonstrate that in Australia.

MR JACOBI: Again, coming back to the summary for policy makers from 2005, it referred to the challenge of retrofitting existing plants with CO2 capture and the sorts of costs that are likely to be involved. I am just interested in your view about what you think the prospects are of retrofitting coal-fired power stations in Australia with carbon capture and storage?

MS CONSTABLE: So this comes down to the costs, and the costs - I was talking a little bit more about the study we're doing on levelised cost of electricity and we have in that considered the costs of a whole range of technologies, not just carbon capture and storage, but we go to the heart of renewables. We look at retrofitting in Australia and the costs around that. I'm not able to talk about what the final costs might be, because I don't want to give the Commission inappropriate information, particular because we're going through a stage of examining the preliminary data.

Of course it is possible to do that in Australia as it's occurring around the world already, but it does come down to cost and the best fit of a power station in Australia, and then where you might actually store that CO2. So that comes down to the transport and storage costs associated with the capture of the CO2. So the retrofitting is possible, but it becomes a matter of cost. We're likely to see that more so occurring internationally, with Australia being a fast follower down the track, and we're looking at what we might do from an Australian perspective out somewhere around that 2030 period as opposed to it being something that's considered right now.

There is no-one right at the moment that is considering retrofitting a power station at a commercial stage in 2015, and it's a cost - it's an economic situation. But this is a global effort and we're looking at the international effort and what we might do in Australia to help bring those costs down.

PROF COOK: I mean, it's worthwhile mentioning that CO2CRC has retro-fitted a small scale post combustion capture plant to the Hazelwood power station for example. So it's certainly possible and some of the earlier work by CO2CRC indicated conclusively that you could actually retrofit more cheaply than you could new build, which you'd think, "Well, that doesn't make sense."

But the reason for that is because an existing plant has all the approvals that it needs, you've got the land there and so on, you've got the exporting power systems all available there. So when you add all those up together, that actually amounts to more than the additional cost of the new build. Now, having said that, there's no way you're going to put a retrofit on a 50 year old plant. So it does depend on the age of the plant as well. But certainly retrofit is feasible, it depends on the circumstance, including as Tania says the distance to the storage site and so on.

MR JACOBI: Yes, can I just pick you up on two parts of the answer? I think first I want to deal with the experience that you had with respect to the Hazelwood plant, and I think we've got a slide that deals with (indistinct), and I think it might be the next slide.

MS CONSTABLE: Yes.

MR JACOBI: I'm just wondering if you can explain the nature of the retrofit that you considered there and the extent to which you might have had success or otherwise with respect to carbon capture with respect to that plant.

PROF COOK: Yes, it's building on a process called the Benfield Process which has been used for a long time, and there it uses potassium carbonate to strip out the carbon dioxide from the flu gasses, and it's a process that's been

used for a long time. It's used in South Australia for instance in the Cooper Basin, used by Santos there for pulling the CO2 out of gasses. But it has high costs associated with it.

So it's a good example actually of innovation, in that the question was that these - previously we've used liquid potassium carbonate (indistinct) solution. If we look at it as a slurry, can that decrease the costs, and it turns out that the costs can be decreased very significantly because you have much lower costs of stripping out your CO2 from the potassium carbonate. So that's what this is - you know, simplistically, it's all about dealing with potassium carbonate, a tried and true way of getting rid of CO2, but using it in a new sort of way as a slurry, and that's really what's happening here.

So it lowers the cost, it lowers the energy use. Potassium carbonate has low volatility, as it says there, which is different to many of the other solvents such as amines which are widely used. So it has a number of very positive features to it and the company which has really split off from CO2CRC, which is - I think it's called UNO Pty Ltd or something like that - is now pursuing this and talking to a number of potential partners and so on.

MS CONSTABLE: So it's pretty exciting because we developed a set of patents from this particular technology. It has been handed over to company and the inventors, some of whom sit in various universities, University of Melbourne, Monash University to name a couple of them. So seven inventors are sharing in this particular technology and are seeking now to commercialise it.

It didn't fit with where the CO2CRC was going in terms of our being a research provider, we're not there to commercialise these technologies. We're there to help get them off the ground and assist the industry to do that. But the UNO MK 3 certainly it does have potential in taking that next step as a very useful solvent technology for the purposes of capture.

MR JACOBI: Now, I noticed on the slide this reference to valuable by-products, and I'm just interested in understanding the extent to which the ability to use the CO2 in some way - I think we've had some evidence earlier in the week that the CO2 has been used in enhanced oil production, and that's underpinned some of the developments overseas. But the extent to which that there might be some economic outcome associated with carbon capture and storage might be necessary to drive its economics.

MS CONSTABLE: So that is happening more around the world. We have now an example in Australia where there's a value add, Air Liquide partnering with AGL in South Australia to utilise CO2, to use capture the AGL plant, capturing CO2 and using the by-product to produce carbonated water. So that's

the first example in Australia where there is a by-product and a value add. That's happening elsewhere in the world, and there are now quite a few projects, enhanced oil recovery being the most common in terms of the utilisation of the CO2, and Boundary Dam is another good example of that.

So that's the most common value add. Although it's a little bit more under wraps, a huge project in China, the GreenGen project, is also exploring the use of CO2 with a valuable by-product, again around carbonated water. There's a number of interested parties from around the world, governments; UK, United states; that are contributing to that in terms of making sure that there is a value add with the CO2, the extraction of the CO2, and putting a value on the carbon basically.

PROF COOK: The only thing I'd add to that is that the 2005 report estimated the total world use of CO2 was probably of the order of 200 million tonnes a year. So in other words, it's quite small compared to the total amount of CO2 that's emitted. That doesn't mean that's in no way to diminish it's relevance, because it is relevant and you do it where you can. It's not going to save the planet, but in certain circumstances it's a really good thing to do because you're making money out of it and you're decreasing the amount of CO2 going into the atmosphere.

MR JACOBI: I just want to pick up the other part of an answer you just gave earlier with respect to the distinction you drew between old coal fired power plants and newer ones, and I'm just wondering whether newer plants, and perhaps some of those that you referred to earlier when we started, are being designed in a way that more easily lends themselves to carbon capture and storage being fitted to them.

MS CONSTABLE: So I think this is an area that focussed people's attention at a multilateral level, and I can think of a couple of fora where this has received a lot of attention, the Carbon Sequestration Leadership Forum is one of those fora that has considered making sure that plants are capture ready around the world, and by capture ready that they're putting in technology that allows the retrofitting to occur when it becomes economical. So, you know, we're seeing different standards of technologies and governments ensuring that plants - that investors are putting into place new plants that are either capture ready or getting ready to be capture ready as part of their investments.

MR JACOBI: I was interested to understand what you think is going to be needed in terms of investment to get us to the point - again coming back to the 2014 summary for policymakers, it makes the observation that it hasn't yet been applied at scale to a large operational commercial fossil-fuel power plant, and I am just interested to understand what you think the steps are in terms of investment to get us to that particular point.

MS CONSTABLE: I don't think that's the case any more. I think that came into play before Boundary Dam got off the ground, and that occurred in October 2014. So that's no longer the case. It's not just a matter of being ready at the power plant capture stage. A lot of the work has to be done before that stage. You start with site characterisation. The work that we've done in Australia, you know, that's occurred over at least the last 11 years, so since CO2CRC has been in place and the research effort at, you know, those early 2000 years, enormous effort in making sure that site characterisation was the first stage, and that continues to be the case in Australia and around the world.

Unless you have got the right characterisation occurring in specific sites, because they are all going to be different around the world, you don't necessarily have exactly the right structures in the right places matched up with your sources of CO2 or whatever the industrial process might be, and the ability to store that CO2 close by. I do have a slide later on that talks about that.

So that's really the first stage that needs to be taken into account before you get anywhere near the capture. I really need to make sure that the Commission understand that and, of course, there's parallels that you could draw directly, Commissioner, with the nuclear power sector. Unless you have done all that work and you put your effort into, well, where would we be looking to store the leftover resources from nuclear energy, then you're not going to have the social licence to operate that particular plant or that particular sector.

So that's one of the stages that is critical, making sure that you've got all of the approvals in place, (1) it's legal, that you have got the right regulatory approaches in place, that you have looked at like any sort of investment in technologies that you have gone through. Now, if the financial processes - have you consulted well enough with the community, and that's going to be critical to any CCS and any technology being successful, and that at the end of the day all of those things need to come together as a suite of activities and actions to make the project successful and the sector successful.

Starting with carbon capture and storage, I think it's a technology we still haven't done enough work in making sure that the community understand. When you ask people what do they know about carbon capture and storage the answer is usually, "No, not very much," so we have to get better in communicating what we're all about and what carbon capture and storage can actually do in terms of mitigation of carbon dioxide.

PROF COOK: There's probably something else that - something I'd like to expand on and it's not - there's some additional things which are really important that are going to make CCS go ahead, and one is to have the right

policy settings, of course, and Tania can certainly talk about that more than I can. That can include regulations to limit emissions and so on. At the moment the situation is why would anybody do it.

The power that you produce is cleaner and so on, but you don't get a cent more in terms of the electricity that you sell. So why would anybody do it at the present time, and the answer is, well, they don't, because they can't make money from it. There's nothing like the renewable energy targets or anything like that to say, you know, "Well, let's use CCS because that produces cleaner carbon." I don't know if you want to say anything about that, Tania.

MS CONSTABLE: I think policies are the domain of the Australian government and state governments around Australia. What I will say is that there are three types of regulatory approaches - or three types of approaches we see around the world. One is the regulatory approach, another is putting a price on carbon, and the third is a direct action approach. I think there's three examples around the world. So the US is largely looking at a regulatory approach and we have started to see projects coming, you know, on the ground because of that regulatory approach. I will say that the Gorgon project has become a reality because of that regulatory approach that we had in Australia in a requirement in Western Australia for the project to put carbon capture and storage into place before the approvals were given.

The EU, of course, has been going down the putting a price on carbon, but they have got a very low price on carbon, so there's not enough there at the moment for any fuel switching to occur and a reversal of the merit order of the projects. So until you see a price on carbon come up where that fuel switching starts to occur, it's a little bit harder but, of course, it is there and that's what a market mechanism does do.

Then, of course, there is the direct action approach that we have currently in Australia that you're seeing, you know, subsidies being given for various technologies and we are seeing small demonstration of projects, so pilot projects, demonstration of projects, and that's really very important for us to have in Australia because it's a complementary approach. We'll see what happens with Australia in terms of policy position that might be put forward by the new government in the future. So they're the three approaches that, you know, we see different reactions from investors around the world.

COMMISSIONER: Do you have a view about which is the most effective or is it too early to say?

MS CONSTABLE: Well, you know, I always think that a market-based approach is the best approach. If you put the right sort of frameworks in place and you have the right incentives there, so it could be a range of incentives,

because there are market failures to many of these technologies, they have their limitations, so with a technology like carbon capture and storage, you need to have probably some additional incentives, as we've seen with renewables, to see these technologies rolled out.

I personally would like to see a market neutral approach on policy, and I think that the LRET, the renewable energy target approach, has been a good one in bringing forward the renewable energy technologies. I would like to see that rolled out to be more market neutral and allow all low emissions technologies to be considered as part of a portfolio approach for Australia. I think that that would make a difference to what we see in Australia, and I want to stress this is not a competition, this is about the market actually making a decision about what is the best technologies for the area that we have in Australia. But we're seeing that elsewhere in the world and I think that that's quite an effective approach.

So competitive neutrality around technologies, we see that put forward in the latest energy white paper, a neutral approach to all of the technologies, but there's been no specific policy change in allowing for other technologies within the equivalent of a renewable energy target. So I hedged a little bit, Commissioner. I know that.

COMMISSIONER: You hedged less than others.

PROF COOK: Is it worthwhile mentioning the - perhaps what they're doing in the UK with contract difference systems. What they're doing, they're investing 2 billion pounds into CCS projects. The problem that they could see is that there was no support (indistinct) management, and so they've implemented what we call contract difference system, which means - it's the difference between how much it costs you to produce the electricity, and how much people are prepared to pay. I mean, that's basically what it is.

That's really all you need in order to sell cleaner electricity into the system. The market is just not there at the moment if it's left to its own devices. The difficulty with putting the price on carbon is to put a price on carbon at the moment to get a CCS project going, and just relying on that, would cost, you know - it might even be $100 a tonne or something like that, which is just going to be so difficult to implement that it's just not going to happen. It would have a distorting impact right the way through the economy.

So that's why just a price on carbon alone is just not going to do it. So it will be interesting to see how the UK system works out. They're going through a tender process at the moment, and there's a couple of projects that are shortlist for that. So that will be an important learning experience.

MS CONSTABLE: So the two projects that have been shortlist in the UK is the Peterhead project and the White Rose project. Interestingly I've just actually come back from the UK, I was over there for a few days a couple of weeks ago. They made a very interesting statement at the conference that I was at. They have - they're in this tender process, and a decision will be made in March 2016. The statement was made it was, "Well, we'll either have two projects that will be successful, we'll have one project, or we'll have no projects."

I thought that was an interesting statement, because why would you say that unless it's not going to be zero, or it's not going to be two? It could be one, for instance, and in the last couple of days there's been a suggestion that some of the proponents within the White Rose project may not stay within that project. So it's an investment issue for the individual project, but it does indicate to me that there could be some - that, you know, it may end up being just one project out of the two that are in the competition.

But it's an interesting position that the UK do have, in that they've been very supportive of carbon capture and storage. That was very evident. It reminded me of where Australia was at around about 2007, 2008 stage in carbon capture and storage being very prominent in their thinking. So it was good to see.

MR JACOBI: There's a number of things I want to pick up. The first is you made reference to the Gorgon development. I'm just interested to understand the nature of the regulations that were necessary to produce that outcome, and the nature of the technique that's been used there, and your view about its success or otherwise.

MS CONSTABLE: So this is again very exciting for Australia. The Gorgon project is due to come online in 2016, an LNG gas processing facility with carbon capture and storage attached to it, with the storage of the CO2 occurring very close to Barrow Island in the Dupuy Formation. This project is going to capture three to four million tonnes per annum of CO2, and store it in that structure. In order to put this into place a few things happened.

A signal by the Australian government that this project was supported in terms of the investment occurring in Australia, and it made a very small commitment financially, but a lot of effort was put into the support - vocal support from the government. I think the Western Australia government can be congratulated for its position also. So the Australian government gave the project $60 million. When you think back, it's not very much money given that it's a $60 billion project, and two billion of that is related to the storage of carbon dioxide.

So for that project to proceed through to being put into place next year is quite

exciting, because it will be the largest CO2 carbon capture and storage project in the world coming online. So we have that in Australia, and again first of a kind, and very - that will, I think, send a signal to the world that Australia does have its first commercial sized plant injecting CO2 in Australia. So to actually achieve that, a couple of things occurred. The Western Australian government had to put into place the Barrow Island Act.

It sent a signal to say, "Yes, we'll approve your project, but you need to store the CO2." To facilitate that, the Barrow Island Act was put together, and it was specifically put together for that project. Now, there has been various views in Australia on what is appropriate. Should we have project-specific regulation? Should we have state regulation? Should we have a whole national approach? It's pretty hard to achieve on legislation in Australia.

But we've got a good approach offshore, just to just segue to something broader than that, where the Australian government has the Petroleum Greenhouse Gas Storage Act 2006 which was approved on 21 November 2008. That looks at all offshore areas. Now, that doesn't include the Gorgon Project, which sits in Western Australian waters. But the Gorgon Project is covered with other legislation that's required to report under the Environmental Protection and Biodiversity Conservation Act for environment issues. There are a few other Commonwealth pieces of legislation that are promised. But in terms of the storage, it's the Barrow Island Act that applies. It's very longwinded, I know.

MR JACOBI: I'm just interested also to address you - you referred in an answer to the need to characterise areas for the purposes of storage, and I think we've got a slight - I'll pick it up. It's number 9. We dealt extensively earlier with the issue of capture, and I just wanted to pick up in terms of storage the sorts of analysis that you think need to be undertaken.

MS CONSTABLE: I'd like to highlight - so when work - a considerable amount of work was done on carbon capture and storage roadmap by industry, government, and researchers around Australia. In 2009, a part of that work involved the - a carbon taskforce being put together that looked at the transport and storage of sites around Australia. What we've just done very recently is do an update of that work. It will be ready at the end of October with the levelised costs for electricity works. So I have a portfolio of work that will be done within that. This particular slide refers to some of that work.

So the University of New South Wales, CO2CRC has been working with a range of proponents around Australia to bring this work up-to-date. What it shows is basically the blue bars that you have, that you see there, and there are two - the first half of the slide demonstrates Western Australia and the other - the right-hand side of the slide demonstrates the east coast of Australia. The

blue bars indicate the source hubs, so where you would have various sources of CO2 around Australia, and the size of those bars demonstrates the size of the emissions profile in each of those areas.

Then the red arrows show you where you would store that CO2, the different formations that have already been tested to various degrees. So some of it has been - the characterisation of the sites has been done very, very well, or some of it has been done in a preliminary sense. Then the lines that are matching that are the pipelines, the (indistinct) transport routes. So most of what we would need to do in Australia is going to involve pipelines, so that's an investment in itself. Pipelines to actually get it from the sources of CO2 to the sinks.

It doesn't necessarily match up that you have got the best sources - your sources of CO2 matched to your best sites. So you have got a variety of things that you need to consider, and there is another slide on the next page that shows you - this is just an example, but we do pick this up in a lot of detail in this particular study that looks at the various case studies. Short distances with high injectivity rates in terms of you can actually store large amounts of CO2, and that's where your costs are going to be lower, where you might have short distances and right out to poor injectivity, or you might have long distances where you're seeing that down the bottom, but you might have - long distances with high injectivity to long distances with low injectivity.

The costs of all of those are demonstrated in this particular graph. So this is work that was done in 2009 that we're updating right now in terms of what would that mean and how much per tonne of CO2 would it take, and then you, of course, then match that up with the whole picture in terms of carbon capture and storage as an economic possibility for Australia. So this work is essential to understand the big picture.

MR JACOBI: Am I right in thinking that there needs to be more characterisation done of other regions in order to reduce costs of installing infrastructure such as pipelines?

MS CONSTABLE: Yes. So what we have in Australia is we have already an infrastructure in place for power for electricity transmission and that's been in place, we have got a very mature grid compared to other parts of the world. If I think about China as an example, you know, they have a grid, a baby grid, but they have a grid Ours is quite mature, but what we don't have is the infrastructure, the pipeline infrastructure to support CCS as a reality in the future. So that's got to be given consideration. We know the routes that would need to be taken, but the infrastructure and the investment that is required. If you're thinking about the pathways forward and what it would take to actually get CCS off the ground and a reality in Australia, we need to think much more

- you know, much differently than we have.

So this applies to any technology, not just CCS. We should be thinking about the system of energy in Australia as opposed to the private sector that just looks at it on a project by project basis. The governments of Australia industry should be looking at what does the system need to look like on energy in Australia, and one of those aspects is what would it take for these particular technologies to get off the ground and for CCS significant infrastructure around pipelines.

MR JACOBI: Just picking up that issue of systems, has there been an analysis done of the sorts of total system costs that would be associated with a world where fossil fuels were burned and carbon dioxide was emitted with CCS and the sort of system that one might have - we've heard from ClimateWorks where we might have a more decarbonised world using a wider range of renewable and other technologies.

MS CONSTABLE: So that word "decarbonise" is an interesting word because, you know, it's been captured by the renewable sector in some areas, but fossil fuels is decarbonising right now. I have just talked about Gorgon and the $2 billion investment that is being made in Australia. The coal industry is investing hundred and hundreds of billions of dollars around the decarbonisation of its industry, so all of the technologies that are in play are adding their bit to making sure that we get to a low emissions future. So the decarbonisation of our economy is essential, but all of the industry sectors are playing their part to make that happen.

MR JACOBI: I think we've got one last slide that shows a sedimentary basin, so I'm interested if you could explain the significance of that in terms of CCS.

MS CONSTABLE: Peter, I'll hand back to you on sediment.

PROF COOK: Maybe it's worthwhile just to set the scene going back to slide E which shows you the options for storage. In other words, there's not one geological model. There's a number of ways that you can store CO2 and that's shown here. The largest single opportunity is storing CO2 in deep saline acquifers which are sedimentary layers that can run or that can underlie thousands and thousands of square kilometres. So they're seen as having the largest volumetric opportunity.

Some of the easier opportunities are to put CO2 into depleted gas fields, not to get more oil out or anything like that but just because essentially you have created space. One of the important things to stress - and it's one of the misconceptions that lots of people have, not here I'm sure - is that you're putting CO2 into caves and voids and so on, you're not, of course, you're

putting it into the pour space that's in the rocks that's presently occupied by saline water for the most part.

So what you're doing is you're looking for those opportunities and you're looking for it in sedimentary basins, and that brings us back to diagram 11 which is an assessment by CO2CRC about the potential opportunities that lie in some basins, and so you can see that some of these basins are highly suitable for storage and, for instance, the Cooper Basin in South Australia would be one of those basins which is seen as suitable. The Gippsland Basin down there in the south-east is another one, and that's the basin for the proposed CarbonNet Project which you might have seen some information on, and also the Otway Basin which is there on the South Australian and Victorian border which is also seen as a potentially good place for putting CO2 and that's where the Otway Project is and has been for a number of years.

Then you get to some basins which are more marginal and some that are perhaps unlikely. In some cases you're also balancing not only the rocks but also the potential opportunities for actually having a source seam match, because that's one of the important things, you know, it's all very well to have a source, but if you have got nowhere to put it into a sink then that's not going to work, if you have got a sink and there's no obvious source. I mean, for instance the Amadeus Basin there in the southern part of the Northern Territory or the Officer Basin in the northern part of South Australia have rocks that are suitable but, you know, there's no source, there's no significant source there. So you get to the stage where you're not going to run a pipeline 3000 kilometres, it's just not viable to do that.

So that's the basis of this diagram. It's a very coarse look at what the opportunities are, but it's a very good building block and, in fact, you know, there has been more detailed assessment of those various areas done by the storage task force three or four years ago. But CO2CRC started this about, I don't know, 12 years ago, something like that, maybe more than that, and that's been a building block that's been very useful in terms of assessing which areas might and might not be suitable.

MS CONSTABLE: The challenge for us is some of the industries and the areas that - so LNG gas, and it's fair to say that there are some fields that have high CO2 content particularly set up in the north-west of Australia. It's critical we find solutions to extracting that CO2, that high content CO2 out to ensure that (1), you know, they're economically viable but are able to reduce emissions, it's again those dual goals that we need to meet. So that's an area of focus for carbon capture and storage in Australia and the research organisations such as the CO2, CRC to be able to assist with that, the work we are doing at the Otway.

PROF COOK: Interestingly there, the area where you have got some of the highest CO2 gas wells in Australia is actually in the Cooper Basin, in the northern part of South Australia, some of the south-east part of Queensland. There you have got up to 50 per cent CO2 in the gas wells. Santos spent a lot of money separating out the CO2 from that gas, probably about two million tonnes a year, one to two million tonnes a year but that is vented at the moment. They don't reinject that or anything else because that adds to the cost and so that is just vented to the atmosphere.

MR JACOBI: I think the last thing to pick up on is I understand you are having LCOE done and for your purposes, I think there are a number of slides that show LCOE as it relates to CCS. We had seen earlier ones and during the evidence of Mr Stock earlier in the week, I am just wondering whether you could take us through the implications of these?

MS CONSTABLE: So this is work that was done by the Global Carbon Capture and Storage Institute and so this is a global level but – so I have used this to give you an indication of what we will be doing at an Australian level. That work that we are doing in an Australian level will be ready at the end of October. So that will be a comparison of the technologies from 2015 looking at what could occur if a project proponent came forward now in the next couple of years and wanted to put a technology in to place, what would be the cost in today's dollars, 2015 through to 2030. We are not willing to look too far beyond that because the world might change again. So we are looking at 38 different technologies, but technologies that we know of, or just coming over the horizon such as energy storage is certainly in there. A whole range of technologies and we have got a stakeholder reference group that is made up of 41 organisations. We put out a press release, so this is a partnership made up of those 41 organisations. It is being driven by CO2, CRC, CSIRO, ANLEC R&D Arena and it is being peer reviewed by a whole range of groups including the Resource Energy Economics Bureau within the Australian government.

Why I am mentioning this is because what we will have is a common set of data. The building blocks which you might make assessments across a whole range of technologies around Australia. I would caution that it can be used for inappropriate purposes in making a direct comparison straight away of the costs of technologies. You have got to take other things in to account in how would this be rolled out if it was put on to the national grid. What this study does is just form the building blocks, gives you a common set of data. So the Resource Energy Economics Bureau will pick this up in their Australian energy technology assessment and it will become the common set of data for Australia. So very appropriate to talk about in the context of what you might – you are doing with the nuclear Commission. The transport and storage will add to that. We are looking at what it might take at a regional level, so what does this mean in New South Wales, what does this mean in Queensland?

What does it mean in Western Australia in terms of the technologies? And then specifically looking at technologies.

The other component of what we have in this package is CSIRO are drawing out their energy futures, so scenarios – what do the scenarios of these technologies – the projections of these technologies look like out to 2030. So it is not one organisation looking at this, it's a whole group of energy technology users, research providers, industry proponents, participating in this study. The base of which is being conducted by EPRI, out of the United States but on the ground in Australia. Or where there isn't examples of new projects, for example right at the moment carbon capture and storage, then international examples are used, Boundary Dam is a base case in terms of carbon capture and storage. So the work that you have here demonstrates - 5.2 demonstrates the levelised cost of electricity and the different costs of those technologies that you would see and down at one end of course, you have hydro power and at the other end solar thermal in terms of the costs overall. So what this demonstrates is the ranges of these technologies with the base cases being a conventional coal-fired plant and conventional natural gas-fired plant as those base cases.

I would say that this cannot be used in the Australian context because we are seeing some of the learnings change and from an Australian perspective, using real projects on the ground, some of the examples of what we are seeing here, perhaps will change. In the main, the ranges, the costs, the cost ranges are slightly different because we have got different exchange rates in Australia. We have got different productivity rates. Our private productivity is lower than the United States and that then varies across states. I will be getting the Productivity Commission to have a look at the work that we are doing to ensure that those productivity rates are examined very closely to determine whether the appropriateness of them. So the work in here is US based and based on what we are seeing on particular projects in the United States. The Gulf of Mexico is always used as the most efficient plants available and that tends to be a bit lower than you would want – than you would see in Australia. We are not the worst in terms of the costs and particularly productivity rates. I think Canada exceeds – well, is worse than us in terms of an assessment by others on productivity. But from an Australian point of view, that – our productivity levels are different and lower than what we would see in the US but that is – I don't think that will be a surprise to the Commission.

MR JACOBI: Perhaps if we can come just lastly to the chart that shows cost of abatement, which I think is chart 16. I am just interested to understand, with the work that is being done, is there going to be work done as a result of the analysis that you have just spoken about, in terms of cost of abatement of the technologies as well?

MS CONSTABLE: There is. We had a lot of discussion in the reference

group about how we would look at the avoided cost of CO2 and the price on carbon and we have decided that we will include the price of carbon, even though there is not a price on carbon in Australia. The reason for that, so we will look at three scenarios. A low price on carbon, something down at below the $10 level, a mid-case, what would it take to change the merit order of what is already occurring in 2015, and then a high case that would allow for other technologies to come on and that would start to effect the conventional plants that we have in Australia. So those three cases are quite important in understanding what it would take to change the merit order. So that is the context of why we have included it and why it is included in this US study.

COMMISSIONER: I think that wraps it up. Thank you very much Professor Cook and Ms Constable for your evidence. We will adjourn until 7.00 tomorrow morning.

MATTER ADJOURNED AT 1.19 PM UNTIL
FRIDAY, 2 OCTOBER 2015