RESUMED **[11.30 am]**

COMMISSIONER: Welcome back. We return to topic one "Climate Change and Energy Policy" and I welcome from the University of New South Wales, Professor John Fletcher. Professor, thank you very much for joining us this morning. Counsel.

MR JACOBI: Professor John Fletcher is a professor in power and energy assistance at the School of Electrical Engineering and Telecommunications at the University of New South Wales. He is currently the coordinator of the Nuclear Engineering masters programme. Professor Fletcher obtained a Bachelor of Engineering and a PhD in elect iconic engineering at the Heriot Watt University in the UK. Prior to joining the University of New South Wales in 2010, Professor Fletcher was a senior lecturer at the University of Strathclyde in Glasgow and a lecturer at the Heriot Watt University in Edinburgh. His areas of research expertise include power electronics, electrical vehicle traction propulsion and renewable power and energy systems and the Commission calls Professor John Fletcher.

COMMISSIONER: Firstly, there is a lot of discussion, useful discussion at the moment about ways of generating power and particularly with a focus on power free of greenhouse gas emissions. Given that you have a good understanding of the power needs in Australia, what are the challenges within the electricity system, presented by increasing the proportions of solar PV, wind and thermal sources?

PROFESSOR FLETCHER: I think one of the main challenges Commissioner, is that these renewable sources are intermittent and variable and that places challenges on the network and how we maintain a balance between supply and demand which is critical for the operation of the network. There are a number of technical challenges associated with integrating renewables and I have listed some of these - - -

COMMISSIONER: Could we just go through those technical challenges with a brief description of each if you wouldn't mind?

PROFESSOR FLETCHER: So technical challenges such as voltage control and that is maintaining the levels of voltage on the network because it is legislation that defines what those levels should be and by introducing renewables we change the levels of voltages at parts of the network and can potentially push them above the upper thresholds.

COMMISSIONER: The implications of that would be?

PROFESSOR FLETCHER: The implications are that the local network operators have to do something about that problem because they are the ones that are supposed to regulate the voltage levels on the network. So that is a challenge – one of the challenges that renewables places on particularly the low voltage distribution network. That doesn't really matte whether or not it is wind or solar, the kind of fundamental laws that define how networks work is if you want to push power on to a network, you have got to raise the voltage at the point where you are introducing it. So a natural consequence of introducing the renewables in the distribution network is that you get voltage rise.

COMMISSIONER: Yes.

PROFESSOR FLETCHER: And if you integrate too much, that voltage rise goes beyond the limits.

COMMISSIONER: And the implication when it goes beyond the limits?

PROFESSOR FLETCHER: You have to introduce some technical mitigation to reduce the voltage again.

COMMISSIONER: Okay. And that technical mitigation might be?

PROFESSOR FLETCHER: It might be recabling that local part of the network to reduce - - -

COMMISSIONER: Right.

PROFESSOR FLETCHER: - - - the voltage rise. It might be changing the settings of the transformers at the local substation. There are a range of potential technical solutions but they all cost and you have to – you really have to assess each particular challenge in each location on its merits.

COMMISSIONER: Right, okay.

PROFESSOR FLETCHER: So it can be quite involved.

MR JACOBI: What you are talking about here is end of grid renewable generation which is a rooftop solar PV and those sorts of sources, is that?

PROFESSOR FLETCHER: It's still a challenge at the medium voltage network, so if you want to connect a large scale wind farm to the medium voltage network you have got to push the voltage up to get the power on to the network, so it is – and that then has ramifications with the network downstream of that point of connection as well. So in fact the technical challenges associated with that are greater because it has an effect for a larger part of the network.

COMMISSIONER: Okay. So that is voltage. What are the others?

PROFESSOR FLETCHER: The other one is matching up generation profiles with demand profiles. So you get – particularly with solar, you obviously get lots of energy during daylight but virtually nothing at night. And you want to – that doesn't really correlate very well with peak demand in particular, so you are generation is occurring at the wrong time of day, so you have to still match your supply with demand, including this local generation that is reducing your local demand during the day but not doing anything for your peak demand in the early evening.

MR JACOBI: In terms of technical solutions to that, I think the Commission understands that that can either be via a demand control which ultimately matches demand to when the power is being generated. Are there well-known and accepted costs associated with deploying those sorts of systems, or what other sorts of modifications that might need to be made and would achieve those sorts of outcomes?

PROFESSOR FLETCHER: I think the costs are uncertain. There is very little prior in that area to really look at and get a really confident idea of what the costs are. So I think the costs we really don't know what those are for those types of systems. And sorry, your other question?

MR JACOBI: Well, I think the other potential is to mitigate intermittency by having peaking generation which otherwise matches it and I think we will probably come to that later. So I am just wondering perhaps if we can come back to the other issues. You spoke of the issue of correlation (indistinct) spoke of inertia?

PROFESSOR FLETCHER: Inertia. Yes, so the system on a short term relies on inertia and when I say inertia, I mean in the large steam driven generators of your system, they have lots of mechanical inertia, so they act as short term energy stores - - -

MR JACOBI: Right.

PROFESSOR FLETCHER: - - - that fill in the gaps between supply and demand. So when you get an event on the network, for example you lose some supply because a generator or a line trips, for the short time it takes you to bring up some reserve, the inertia fills in the gap for you. You will see a slowly decreasing frequency as you slow down all the generators as they supply the surplus energy. With the renewable energy system you generally don't have an inertia response. So they don't provide that natural response that you get from a large-scale thermal generator. So that is another challenge that's introduced and as you decrease the level of inertia you have in your system, you can potentially get to a point where the system may not remain stable when you see an event occurring on the network.

MR JACOBI: In terms of technical solutions for managing that, are there technical solutions other than actually having thermal sources in the system that have that sort of inertia built in to them?

PROFESSOR FLETCHER: Yes. You can use energy storage which could potentially fill in the gap. Some renewable systems you can persuade them to offer some level of inertia response, particularly wind turbines where you have – you do have a mass, it's rotating so you do have some stored energy there that you can tap in to. But these are really the leading edge of research rather than the leading edge of deployment.

MR JACOBI: I might ask then from that, again in terms of costs, are those costs known or in terms of what it would cost to implement those sorts of systems in to a system, other than the sort of system we have got at present?

PROFESSOR FLETCHER: I think the cost of energy storage is probably reasonably well known. There are things like providing an actual response from wind turbines, potentially only requires a kind of minor change to the control algorithm that the wind turbine uses but that needs to be assessed in the context of how the overall power system reacts dynamically to these changes in the characteristics of the turbine. So you are making the wind turbine then look slightly different to what it used to look like and you then need to assess what happens with that overall system once you have made that change.

MR JACOBI: Perhaps we can pick up the next.

PROFESSOR FLETCHER: Houses and protection challenges, so introducing renewables on low voltage distribution systems changes what happens when you get a fault on the network. So the types of faults we are thinking about are branches falling on lines, getting short circuits between lines and earth and you need a protection method that protects your system, particularly from fire.

Now when you introduce renewables in the distribution network, you change the way the power flows in that network and quite often you have to reconfigure your protection systems to account for that change in the power flow that you get when you have a fault.

MR JACOBI: By power flow are these the flows that we are talking about because we have got generation at the end of the system? We have got power working its way back up through the voltage network?

PROFESSOR FLETCHER: Well, that's another problem. The protection problem is more to do with the flow of fault current that you require in order that the protection system detects as a fault and isolates that system. So it's a critical part of the network. And when you introduce generation in a network at a different point in the network it will change the flow of fault current when you see faults on the network. So you have to access those changes and potentially change the settings and the protection mechanisms that you use in the network.

MR JACOBI: I think I've stumbled across reverse power flow, I suspect, by the question I just asked, in terms of power working its way back up from the low voltage network up through the high voltage network?

PROFESSOR FLETCHER: Yes. So a standard example of that is you've got a distribution feeder that that's feeding a lot of residential properties, many of which might have rooftop solar. During the day a lot of people are at work. There's very little demand within that residential area, but there's lot of solar power producing a significant amount of power and that power then has to flow back up the network because there's nowhere locally that’s actually using everything that's being produced. So again, that is also encapsulated to an extent by the voltage control issue because they're kind of related. If you're getting power flowing back up the network, you've got to have a voltage rise occurring on that network.

MR JACOBI: The Commission is interested in the extent to which the evidence it receives is thought to be accepted broadly within the areas of expertise in which it studied. Are there any generally accepted rules of thumb about the extent to which you can introduce particularly the technologies we were just talking about before we begin to experience these sorts of issues?

PROFESSOR FLETCHER: I think there's a generally held view that up to 20 per cent is relatively easy to integrate and then beyond that, you start seeing some of these challenges and companies and network operators having to provide some technical mitigation for the challenges that are produced by introducing higher penetrations of renewables.

COMMISSIONER: In South Australia we're certainly above that level. So these challenges that you're talking about now are challenges that we're having to deal with with the current network?

PROFESSOR FLETCHER: Yes, I would agree. Yes.

MR JACOBI: What we're dealing with is a network that has, as I understand, as has been explained in earlier evidence, been designed around centralised generation, and I'm interested in the extent to which the sort of problems we're dealing with here are a product of the fact that we're fitting newer intermittent technologies onto a network that was designed around thermal technologies.

PROFESSOR FLETCHER: Yes, and we're trying to transition to something that is much more lower carbon in terms of the generation sources. So there is a big challenge associated with doing that because we're going from a centralised to a much more distributed model where we have very little control over what actually happens with distributed generation because there are things like rooftop systems where network operators don't actually have any foresight or any control over what they're actually doing. So that itself creates an issue for the distributors.

MR JACOBI: We picked up the technical aspects the sorts of challenges that are involved. With respect to one or two, we've addressed the issue of the economics, and I'm interested to understand whether you have a view about the extent to which the economics of managing those particular challenges and installing the sorts of mitigation issues you've talked about has been the subject of study or analysis in terms of us understanding in broad terms what its costs might be.

PROFESSOR FLETCHER: I think there's very little agreement on the costs associated with these technical mitigations because there's not a lot of examples. So, for instance, things like battery energy storage are often quoted as being a mechanism by which we can help solar PV, but when you look around the world there are very few examples of where the economics of linking battery energy storage with PV have really stacked up to the point where people have done it. So there's really very little evidence on the costs of some of the technical mitigations required to transition from where we are now to a much lower carbon generation system that's powered by renewables.

COMMISSIONER: I recall seeing in an AEMO report some cost estimates of integrating further renewables into the network. Based upon what you've said, you don't have a lot of confidence in those numbers?

PROFESSOR FLETCHER: I would say with AEMO report many of the technical mitigations were bypassed by using a fair amount of what we call baseload capability. So that’s one way in which you can avoid many of the technical solutions that are required for 100 per cent renewables, so things like geothermal, biomass, those types of generation systems that kind of look like conventional fossil fuel systems in terms of how they interact with the network.

COMMISSIONER: Okay. There is a significant amount of discussion about 100 per cent renewables and the sorts of time frames, very little comment on the financial viability of those particular processes. What is your view of the sorts of time frames to resolve some of these technical issues if we were to significantly down the path of generating a sizable portion of demand through what are called wind and solar sources?

PROFESSOR FLETCHER: Are we thinking more about what types of studies are required?

COMMISSIONER: Yes, studies and time. I mean, there have been some estimates and we could march down this path quite quickly. I'm interested in your view of the maturity of thinking in what you see in terms of pathways to significant proportion of wind and solar generation.

PROFESSOR FLETCHER: I guess my concern is we're wanting to move from here, the system we've got now, to a system of the future, but along the way we may have to take a number of steps where we invest in assets and infrastructure that then becomes stranded, and that's a concern. So, for example, in the AEMO report - a report that I enjoyed reading and thought was good because it put a marker down in the sand and said, "Look, this is possible, but these are potential costs." What they didn't address is how we actually moved from where we are now to what their proposed vision was in that report.

So actually costing the steps is really quite challenging if you haven't worked out what steps you're going to take to get there. That's not a criticism of the report. That's just my thoughts on how we move from where we are now, which is a very centralised view of the network, to something which is potentially much more distributed.

COMMISSIONER: Is it your view that the market mechanism that we have at the moment is capable of making those decisions and those investments were we to, through climate change, be forced to take more and more renewable energy into the system?

PROFESSOR FLETCHER: I guess it depends on how we cost carbon, because at the moment we have a market and that market results in an electricity system which is 80 per cent coal and that's what the market has achieved, and if we want to change the network we have we have to incentivise the new technologies in some way. So we have to change the way the market operates to incentivise those new generate techniques, and the challenge there is when we change the market conditions there may be a number of unintended consequences that we have not modelled and thought about.

So I think really when you look at all this discussion there are technical solutions to these challenges. We don't know whether those technical solutions would be economic, but for me, the biggest challenge is how do we create a market that will actually work with the network that we want to have at the end of the transition.

COMMISSIONER: And it may well be a very different network than the one we've got at the moment.

PROFESSOR FLETCHER: Absolutely, yes.

MR JACOBI: I just want to pick up, in terms of your view about where you think that the likely pathways in terms of economics are likely to go, in terms of new renewable capacity coming on to the system in Australia. Do you have a view about where wind and solar PV and perhaps for example commercial solar PV which we have heard something about, are likely to go in terms of being connected to the network?

PROFESSOR FLETCHER: Yes. So my view is that wind will largely be connected to the medium voltage network and will be large-scale wind farms or a few hundreds of megawatts, that seems to be the most economic way to do wind. There is obviously a lot more potential for rooftop solar in residences and then we have got a lot of - - -

MR JACOBI: Is there a reason for you thinking that rooftop solar PV, there is a particular reason for that proceeding further, aside from the rooftop space and the high solar insulation we’ve heard about?

PROFESSOR FLETCHER: Well, I think in terms of the economics of PV, we reach grid parity with rooftop solar, so that is when you cost the lifetime costs of the energy from a rooftop system, they are in parity with what you pay for retail electricity. So at that point it generally would make sense to invest in rooftop solar. At the utility scale your PV is competing against wholesale prices which are much lower. So at the retail end, PV is competing against 28, 30 cents per kilowatt-hour, at the utility scale it’s competing against four or five cents per kilowatt-hour. So you need another order of magnitude in change of the cost of your large-scale PV system. So rooftop solar, I suggest because it makes economic sense today to do that. Whereas at the utility scale, it doesn’t.

MR JACOBI: If you think that will drive commercial solar PV in the same way that is on large industrial rooftops and large - - -

PROFESSOR FLETCHER: I suspect we've got a lot of roof area on commercial properties, warehouses, distribution centres and that type of thing. That looks like ripe situations and locations for PV. I guess what we have to look at is the economics, what do these commercial users pay for their electricity? Is it at the standard retail rate or is it lower? Because that affects the economic sort of whether or not they actually do it.

MR JACOBI: I want to pick up particularly your background and knowledge with respect to wind, and we have heard some evidence with respect to the ability of wind resources to be correlated or not correlated for the purposes of being able to export energy such that you can manage intermittency through a geographic distribution of wind resources. What is your view with respect to the extent to which geographic distribution can address intermittency?

PROFESSOR FLETCHER: Well, I believe there are many studies that have looked in to this, this idea of aggregation of wind that is distributed geographically and there is consensus says it works. I guess what you have to take in to account is how well set up the network is. So for example in the UK, where you've got a highly meshed system, it's very easy to transmit energy from one part of the country to another. That may not be the case in Australia. You might have a good aggregation of generation but is that supported by the infrastructure that you need to ship that energy around the system?

MR JACOBI: Is this the idea that we have heard a little bit about it in terms of us having a long thin network, does that give rise to an implication that there is going to be a need for more transmission in order to achieve those sort of geographic aggregation effects?

PROFESSOR FLETCHER: I would think so, yes. I mean we have a long thin network and we have a number of bottlenecks between states and that causes effectively local markets, so South Australia has a spot price market that's different to New South Wales and partly that's because we can't transmit energy through one state to the other with significant quantities to get a spot price that's the same across the country.

MR JACOBI: To shift from wind to solar, I know you have got some experience and background in that too, I am just interested to the extent to which you think that the pairing off storage and solar PV might be an effective way of managing, again, the intermittency associated with that and it being economic?

PROFESSOR FLETCHER: Okay. So technically it makes sense, you couple PV with storage and you can then shift – effectively shift your generation profile to the point where the market price is highest in the evening. But my view is that it's just not economic yet. You are partnering one expensive generation technology with an expensive storage technology. So economically it just doesn't make sense. And again, that is borne out by the number of – the few number of systems that you can find that are coupling PV with energy storage to do that type of function.

COMMISSIONER: In the residential market, do you have the same view?

PROFESSOR FLETCHER: Yes, I do. Absolutely.

COMMISSIONER: Because I see there are some Tesla batteries just been released on the market?

PROFESSOR FLETCHER: Yes, I take the same view. Yes, so a Tesla battery might cost you $7,000 that's a lot of electricity bills to pay for that. So a solar system creates revenue because it generates energy, an energy storage system just stores that energy, it's not giving you any extra energy, it's allowing you to shift when you use it, which can be useful but it's not actually giving you any additional energy. So I'm sceptical that at current prices, we will see a large-scale adoption of energy storage systems like the Tesla system.

COMMISSIONER: Do you have a view as to what sort of price reduction, leaning curve effects might be necessary before you think that might become effective?

PROFESSOR FLETCHER: I think probably reducing the cost by a factor of five would create a system where for the average rooftop system owner, they could look at that and say yes, this is worth doing.

COMMISSIONER: Okay. Thank you.

MR JACOBI: Do you have a view, we have heard not only from vendors of those systems but we have also had some discussion with those that are developing technologies to store energy at the generation level, that is perhaps co-located with a wind farm or otherwise to store energy within the network itself? Do you have a view about the extent to which you think that that might be commercial deployable and to be economic?

PROFESSOR FLETCHER: I think potentially it could play a part. A lot of the energy storage systems rely in terms of their economics, on the difference between peak energy costs and off-peak energy costs. Now if you imagine introducing a lot of energy storage in to the network, you would almost eliminate those price differences, so the economics then don't stack up because you remove the whole reason to have them in the first place. By introducing so much of it. So it potentially has a part to play but I don't think a big part to play.

COMMISSIONER: In terms of hydro as a storage mechanism, I mean clearly it's important in Tasmania, do you see it being economically feasible in other parts of the country?

PROFESSOR FLETCHER: I think of the large-scale energy storage techniques, pumped hydro is probably one of the best in terms of economics. So it could play a part. I guess there are big environmental challenges with new hydro systems, so that would be an important barrier to the introduction of storage systems. But from a technical perspective if we are imagining large-scale integration of renewables and we have a system that is interconnected well enough, then pumped hydro could play a part in supporting and smoothing out the generation profiles from renewables particularly solar.

MR JACOBI: I think we may have touched upon this earlier but I am just interested the extent to which the introduction of more renewables might be driven or affected by the sort of market signals that exist in the marketplace, in particular have in mind, we have heard evidence from AEMO directed to the fact that the maximum price amount to the minimum amounts are intended as a signal to entrants. That is that when a price reaches a very, very large number, many thousands of dollars, that signals to potential new entrants to – potentially in to the market and I am just interested to your view about the sufficiency or otherwise of those price signals to signal to entrants to come to the market?

PROFESSOR FLETCHER: Yes. It's an interesting area, there have been studies that have shown that particularly in South Australia, as more and more renewables are introduced, effectively they become uneconomic because they – we have got an energy only market and they bid in at the lowest cost. The times where they make the money are when you've got the high spot market prices. So that's the signal. As the market price increases, it means that the renewables can make more revenue.

But we're already in a situation where our maximum cap on spot market prices are really quite high and it's shown that to transition to a 100 per cent renewable state we may have to increase those spot market caps by a factor of five or 10. So that's really a quite significant change in the way the market would operate.

COMMISSIONER: What impact would that have on electricity prices if that was the case?

PROFESSOR FLETCHER: It would probably have a marginal increase in the short term, but the challenge there is that your renewable infrastructure then becomes uneconomic. So you get a spike in the construction of facilities, but then over time they become economic in terms of raising revenue.

MR JACOBI: I just want to come to nuclear. The Commission has received many submissions that have said, "Look, nuclear and renewables are not good partners," and we've had other submissions that have pointed to them being in competition. I'm interested in your view about whether they're in competition or whether they are complimentary in some respects.

PROFESSOR FLETCHER: Well, I guess in the low carbon marketplace they're obviously in competition because they're both low carbon technologies. When you look at how much the world needs to do to reduce its carbon intensity, they're obviously complimentary because they both offer low carbon generation technology. So my view is they're not in competition. They're providing a generation technology that is low carbon and you've got to view that as being a good thing.

MR JACOBI: Within a system itself, within an electricity network, the intermittency of renewables is said to be not well paired to nuclear which is inflexible. I'm interested in the extent to which within an overall network whether that holds or whether there are qualifications or - - -

PROFESSOR FLETCHER: I would say there are qualifications. For example, if we look at the 100 per cent renewables report that AEMO did, when you look at their generation profile there is a significant amount of what you could view as being baseload generation, and the example they gave was geothermal and biomass. And when you look at that profile it's easy to see how nuclear could fit within that scenario, not necessarily a 100 per cent renewable scenario, but a 100 per cent low carbon scenario. So I think, from the point of view of that report, it's obvious that nuclear could play a part within that much more renewables-based system. So they're complimentary in that sense.

MR JACOBI: I understand that in that particular report they had significant amounts of additional interconnection built into that system.

PROFESSOR FLETCHER: It did, although it wasn't really interconnection. It was a transmission network that brought geothermal energy from the Cooper Basin into New South Wales. Now, if you adopted a more nuclear approach which supplanted that geothermal, you then wouldn't have to build those transmission networks. So even from that point of view, it seems to have advantages because it eliminates the need for a thousand kilometres of HVDC transmission network.

MR JACOBI: We've heard in the evidence of particularly Mark Hickson from the UK some of the challenges that are presented by what I might describe as market-level interventions in electricity markets, and you've spoken about there potentially being a need to increase the maximum capped amount. Do you have some views about the extent to which marketing interventions can have consequences in marketplaces?

PROFESSOR FLETCHER: Well, the UK is a good example looking at Hinkley Point C, the new nuclear station where they're attempting to create a deal on the basis of a strike price, which is essentially guaranteeing a dollar or a pound per kilowatt or megawatt hour to the nuclear stations, which is a direct intervention in the market. I mean, it's no longer market. It's a market driven by government policy. Now I do see one of the big challenges in the transition from where we are now to where we want to be is in how we design a market, or indeed, should we have a market, or do you have to adopt a more centralised approach on how we have an energy framework for the country, a more government directed system.

COMMISSIONER: Perhaps a national energy policy might be a grand start.

MR JACOBI: Coming back to nuclear, based on your knowledge of the electricity network in Australia, do you have any views about whether there are any barriers to integrating nuclear within that network?

PROFESSOR FLETCHER: I think there are a few barriers, and most of my barriers that I've mentioned are related to large-scale nuclear reactor. If you want to buy a nuclear power plant today, you'll be buying a large-scale nuclear power plant, not a small modular reactor. So the basis for my comments are on the basis of large-scale nuclear. Some of these aren't relevant to small module reactors. One of the issues is a poor interconnection between states which restricts the amount of energy we can ship between states, and that might be a particular problem for South Australia if we went down the route of installing a large-scale nuclear plant, so when minimum demand occurred in South Australia you would want to ship any additional surplus power through to Victoria, but you may then exceed the limits of the transmission network between the two states. So that's a bit of a barrier, being able to ship large amounts of bulk power around this long, thin network we have.

An obvious challenge for nuclear is the wholesale price of coal and gas, which is much lower than nuclear. So again, you would need some sort of market intervention that meant that effectively a nuclear baseload would always be part of the generation mix. We need to construct nuclear on parts of the network that are capable of integrating the energy they produce. So again, in South Australia there's maybe only one or two parts of the network that are at this stage suitable for integration of large-scale nuclear. The alternative is building them somewhere else but then having to invest in a transmission network to get the energy from the plant to the centres of demand. Those are my main views on the barriers to large-scale nuclear integration within the Australian network.

MR JACOBI: Do you have views - and this doesn't just apply with respect to nuclear concerns in the process of the transition - as to whether we might end up stranding assets within the system in which we make investments?

PROFESSOR FLETCHER: Yes, I do have concerns it might happen. So, for example, the AEMO 100 per cent renewables report didn't consider what assets would be stranded in the transition between where we are now to that particular scenario. So we do have to take care that we don’t strand assets that we already have or we don’t strand assets that we've developed in the meantime.

COMMISSIONER: We're already starting to see that though, aren't we?

PROFESSOR FLETCHER: Yes. South Australia is a good example of that. I mean, again, it maybe points back to having a national energy policy.

MR JACOBI: Does that imply that it would be necessary to cost, in essence, what the loss is associated with such an asset being stranded and not in fact operating across its lifetime?

PROFESSOR FLETCHER: Yes. I mean, that should be a consideration in any sort of study that we do.

COMMISSIONER: Which leads me to the broader question. I've seen a lot of levelised costs of electricity assessments, but have we looked at this challenge nationally in terms of estimating the cost and the way that 100 per cent renewables might developed in a national framework, how that might be carried out?

PROFESSOR FLETCHER: I think the research community is attempting to address some of those questions, although they're very complex, and small changes in, for example, the market can create really big changes in how the system works. So I think there are elements of those technical questions and economic questions that we're trying to answer, but I don’t think we have a firm view of what the realistic costs would be.

COMMISSIONER: But we do, as I understand it from the evidence we received, that the challenge and that some of the coal fired power plants in Victoria have come to the end of their life, perhaps in the middle of the next decade. Noting how long it takes to plan these assets, one would have thought a national body would be looking at how that transition is managed and what replaces that generation capability?

PROFESSOR FLETCHER: Yes. I guess we are kind of leaving that to the market.

COMMISSIONER: Well, that is why I am asking the question.

PROFESSOR FLETCHER: Yes.

COMMISSIONER: Is the market capable of making those decisions?

PROFESSOR FLETCHER: The challenge we have with any market is they tend to be short term.

COMMISSIONER: Yes.

PROFESSOR FLETCHER: Whereas a lot of these investments, whether it be renewables, nuclear, gas, coal, they are long-term investments, some of which don't really make a profit until 25, 30 years after their construction which is the case generally with large-scale nuclear.

COMMISSIONER: So a market is not likely to make that sort of (indistinct)

PROFESSOR FLETCHER: No, and that is why for example in the UK effectively you have got the market intervention, trying to come up with a strike price that makes it viable for the investors to invest the cash in a nuclear plant.

MR JACOBI: In the answer that you gave with respect to the sorts of issues with respect to integrating nuclear, expressed in terms of a large-scale plant, which I understand is around a gigawatt and I am just interested if one was thinking about an SMR, that is plants operating at around about the size of 300 to 600 megawatts, whether you think that those same challenges would apply. I assume that the issue of network connection won't apply to the same force but do you see similar issues in terms of interconnection and wholesale costs?

PROFESSOR FLETCHER: Definitely wholesale costs. The economics of small modular reactors is probably likely to be not as good as large-scale, so that is still – that is a bigger challenge for SMRs. But in terms of points where you can put them in the network, obviously you have got more opportunities to do that.

MR JACOBI: Does the interconnection pose the same issue at that point?

PROFESSOR FLETCHER: Not so much because you can – you have got a finer scale that you can ramp up your generation technologies. So with a large-scale plant, you are maybe going to build 1.6 gigawatts, you know you are going to have a problem when you hit minimum demand in South Australia whereas if you are building small modular reactors or 100 megawatts or 200 megawatts, that type of scale, you can effectively ramp that up rather than just having a large plant. So you can tailor your generation portfolio better to what you need within your state and with what interconnection capability you have.

MR JACOBI: Just want to pick up and just some questions from the Commissioner, (indistinct) have a discussion about the sorts of studies that might – we might want to contemplate if we are thinking about making a transition and I am just interested in your view, the AEMO report picked up, at least on its highest cost scenario of – in fact I think all of its costs were in the range of starting at about 200 billion and making it – working their way through to about 340 billion for 100 per cent renewables outcome. Whether there needs to be an analysis of that against the costs of the market or the value of the market itself?

PROFESSOR FLETCHER: Well the current energy market, wholesale energy market in Australia is worth somewhere between seven and 10 billion dollars and yet the AEMO report - - -

MR JACOBI: A year?

PROFESSOR FLETCHER: A year. And the AEMO report is it's worst case estimate is 350 billion. It's kind of eye watering.

MR JACOBI: Yes. Just want to - - -

COMMISSIONER: Could I ask one question, we have got some evidence about carbon CCS and its relative success overseas and in the AEMO report it has a position at various times in the timeline and yet we have seen in England where the UK it has kind of dropped off - - -

PROFESSOR FLETCHER: Yes.

COMMISSIONER: - - - a billion dollars worth of investment is now not being made because it can't – well, as I understand it they can't make that work. Do you have a view about the future of carbon CCS as a viable clean technology for generating power in Australia in the future?

PROFESSOR FLETCHER: I think I'm fairly negative on carbon capture. Obviously your plant takes a big hit on its efficiency because it takes a lot of energy to compress the carbon in to a form where you can store it and my view is it is not really carbon free, all you are doing is sticking it in the ground and you are still producing the carbon. So I am very sceptical that carbon capture will play a part on a global basis in terms of lowering our carbon emissions. I think the costs are just too high and there really aren't that many locations where you can actually economically use carbon capture.

COMMISSIONER: Biomass and geothermal also take a sizeable portion of the market at various stages as it is modelled. Your views on both of those at this particular time?

PROFESSOR FLETCHER: I would say the development of large-scale geothermal in Australia is probably quite speculative. So if I was looking at risks associated with developing various base load type generation technologies, my own personal view is we would probably want to look at nuclear as a low carbon base load technology rather than speculate on whether or not we can exploit geothermal on the scale that we require according to AEMO's report.

COMMISSIONER: What about gas? Do you think gas has got a big future?

PROFESSOR FLETCHER: I think it probably does. Being less carbon intense than coal, so I think as a transition fuel for the Australian electricity industry it may have a big part to play in the future years. But whether or not we end up with a network that has significant amount of gas in it, as we transit to something that is a goal for a low carbon generation future, I'm not sure whether or not it will play a part. So that might end up being one of the sets of stranded assets that we create as we move from where we are now to where we want to be in terms of our carbon intensity.

COMMISSIONER: The price of gas is clearly critical to that decision and we see a lot of international prices now being introduced to the Australian market. That is – do you see that changing?

PROFESSOR FLETCHER: Gas prices, volatility? It's probably likely to get worse, in terms of its volatile nature. As many more countries become interested in gas as supplying a kind of lower carbon intensity fuel in to their national electricity industries.

COMMISSIONER: Counties that may not have the ability for wind and solar that we have in Australia.

MR JACOBI: Yes. I just want to pick up just with respect to those particular base load technologies and other low carbon technologies. Do you think that there are any obvious scenarios that ought be studied on a systems wide basis in order to make this sort of – they are 100 per cent analysis done by – 100 per cent renewables analysis done by AEMO studied a subset with geothermal and other inputs in it, I am just interested to understand, do you think there are any particular scenarios that ought be the subject of studies in order that we can essentially be informed to make some choices between possible options for a future system?

PROFESSOR FLETCHER: I think one of the challenges is there is almost an infinite number of possible visions for a low carbon network. So I mean I don’t really have an answer but what I would like to see is something that considered not a 100 per cent renewables but a 100 per cent low carbon network. That provided a mechanism for us to look at nuclear as being part of a generation portfolio that is complementary to renewables and helps us get to where we want to be with technologies that we know about. So if there is a technology that we know about, there has been a lot of experience running a nuclear plant, it’s got a base load, it is complementary to renewables, so we should consider it. By considering it, I am not saying we are going to do it but we should look at it seriously.

COMMISSIONER: What does it mean, in your mind, when we say, yes, for instance, we should consider it? If you had to make the decision, how would you consider it? What investments would you think we would need to make to be able to make a more informed decision?

PROFESSOR FLETCHER: I think the first thing is to do a reasonably large-scale study on how nuclear and renewables could be complimentary within the network and what our network infrastructure would have to look like in order to achieve that. So that would really be the first step.

COMMISSIONER: And cost that?

PROFESSOR FLETCHER: Try and cost it. I mean, to a large extent, is it a question of cost or is it a question of the value to the nation? We talk about levelised costs, but realistically, if you want to go out and buy a nuclear power plant part of the discussion is not what it cost to build. It's what its value is to the company or the organisation or the country who's building it, and that differs between whose clients you're talking to.

COMMISSIONER: So we have a study. In that interim period for the study, do we need to build the knowledge base in relation to nuclear? Do we have that knowledge base? Do we need to do some preparatory skilling?

PROFESSOR FLETCHER: Well, if we decide we want to go down the nuclear route - and we definitely need to train a number of different areas up. I mean, there's engineers, there's tradespeople, scientists. We need to create a workforce who can then play a part in this new industry and that takes time, and to do that we need to have credibility. So we need to attract people from overseas who have worked in the nuclear industry. So that's an important part of any training that we do.

COMMISSIONER: I know counsel wants to get into that field. Can I finish with a question which relates to the national decision making for this process, and I think you've answered this question, but the market, from your description, seems an unlikely avenue to develop a national policy. So your view on creating that national policy and perhaps linking it to what we've seen in Paris this week and last week? Do you see an impetus for that sort of national debate?

PROFESSOR FLETCHER: Well, maybe from Paris we will have a national debate on developing a proper national energy policy. I think that's an important part of all these studies and all these potential visions that we have for a low-carbon electricity network, and we can tinker with the market as much as we want, but at some point I believe the nation has got to take a view on where it wants to go, and to do that we need a policy and we need things and tools to drive that change, whether it be renewables or whether it be nuclear.

COMMISSIONER: My final question, and you may not want to answer this, but what are the levers that force this national debate on energy policy? What are the things that have to be created so that we get to a stage where we are discussing a national policy on energy? Is it simply climate change?

PROFESSOR FLETCHER: I think climate change is a good driver.

COMMISSIONER: Are there other things that you think - - -

PROFESSOR FLETCHER: Possibly the national economy and how energy plays a part in that, both in terms of exports and what we have in terms of a vision for our own carbon intensity as a nation.

COMMISSIONER: So opportunities for industry, I think - - -

PROFESSOR FLETCHER: I think, yes, definitely opportunities for growing new industry, making new jobs, creating a workforce that's equipped to deal with the future.

COMMISSIONER: Thank you.

MR JACOBI: Perhaps one last question on electricity. In terms of thinking about questions like cost, is there a particular consequence in terms of not making a decision, and that is that we end up with a particular mix of generation assets that - I have in mind here the idea of achieving an optimal outcome that is a least-cost low-carbon outcome that we might end up by not thinking about it at some different point?

PROFESSOR FLETCHER: I'm not sure what the answer is to that.

COMMISSIONER: That's an answer.

MR JACOBI: Perhaps we can come to the question of skills. You have responsibility with respect to the University of New South Wales masters program for nuclear engineer. I'm interested to understand in broad terms the current capable of that course to train nuclear engineers, the number of people who are enrolled and where those students are currently going.

PROFESSOR FLETCHER: Okay. So two years ago we ran the first year of our masters of nuclear engineering at UNSW. We currently have 10 students enrolled on the course; some of those are part-time, some of those are fulltime; some are international, some are domestic. We also have a few staff who have enrolled on the course from ANSTO. So they're trying to get themselves qualified with a degree that says nuclear engineering on it. So that's not something that you can do at an undergraduate level in Australia.

The main reason for coming up with the course and running it was that we could see in Southeast Asia and in China there's a big market for courses, particularly in English, that are in nuclear engineering. So China has currently got plans to build 50 or 60 new nuclear reactors, so there's a large workforce requirement. So we're trying to tap into that market. We're trying to tap into the local ANSTO market, so getting ANSTO people trained up on what makes nuclear engineering different to conventional engineering, and then just providing a source of graduates for the global nuclear engineering market. So there are companies in Australia that do business in nuclear engineering and nuclear energy. Some are trying to provide a pathway by which our engineering students can access those jobs and those markets.

So that's the primary rationale for developing the nuclear engineering masters. It's quite a broad-based course. So we cover the fuel cycle. We cover reactors. We cover safety, security and safeguards, which is a really important part of running a nuclear licenced site, and that's actually an area where Australia bats above its average in terms of how it plays on the world stage because we're seen as being very neutral in terms of nuclear because we don’t have our own national provider nuclear power plant. So we're seen as being very independent in that respect. So that's the broad outline of the taught component, and then students do a research project, quite often which is in collaboration with ANSTO as well.

MR JACOBI: If there needed to be a substantial increase in the skilling of the nuclear engineering lever, do you have a view as to the sorts of models that you would think about in terms of skilling a greater number of nuclear engineers?

PROFESSOR FLETCHER: At university level or across the board?

MR JACOBI: I'm thinking at university level, and then perhaps I'll come to the issue of what I describe as specialty trades in due course.

PROFESSOR FLETCHER: Okay. I think for me, the key element, what we're doing at UNSW, is we can do all this in collaboration with ANSTO, which is just 25 kilometres down the road from us. So our students can have access to facilities and training in a nuclear environment that many other students can access easily, and I think that's a key element of what we do, is providing students with experience of a nuclear site. Okay, it's not a power plant, but it is a research reactor and it is nuclear. So that's one of the key elements of what we're doing.

In terms of creating a workforce, I think again having that ability to access nuclear sites and how they operate and function is a really important part of training nuclear engineers and creating a workforce that really understands things like the quality assurance that's required at a nuclear power plant, safety, all those elements that are really important in the nuclear area.

MR JACOBI: If one was thinking about expanding the number of graduates from such a course, perhaps to support a construction program or an operation and a regulator, do you have views about the sorts of models that Australia might need to think about in terms of delivering?

PROFESSOR FLETCHER: We definitely need more than one masters course. We need a number of undergraduate programmes because we want – we don’t just want master’s level engineers, we want engineers who have done a bachelor’s, who understand the differences between nuclear and standard engineering. We need the master’s level students who have more of a research side to them, developed during the masters but then we also need PhD graduates, we need a research programme that is properly funded by the government, by the ARC or something similar. So that there is a range of measures we would need to create a workforce that could deliver all the elements that we need to support a build and operate programme within Australia.

MR JACOBI: Do you think there would be anything that would be necessary in terms of ensuring that graduates would want to undertake such a course or programme?

PROFESSOR FLETCHER: Well, I think the primary driver is having a job market. And a lot of the inquiries I get from domestic students are, look I'm really interested in learning more about nuclear engineering, what are the job opportunities afterwards? And there are a number of job opportunities in government, ARPANSA, ANSTO, some of the medical sciences use nuclear engineers. So there are opportunities but if we had a nuclear build that would obviously provide an impetus for many more students to actually want to come to university and learn about being a nuclear engineer, or a nuclear scientist.

MR JACOBI: In terms of increasing capability, do you have a view about the ability for Australia to make linkages with foreign universities?

PROFESSOR FLETCHER: I think we are excellent at doing that because that is quite often what we do in other engineering areas, so I mean I have great links with universities in China and in the UK, so with the masters in nuclear engineering, we are already collaborating well with Imperial College in London, the nuclear engineering centre. So we already have established a really good working relationship with their nuclear engineering centre. So staff come from Imperial College to UNSW and teach intensive mode courses to our students. So we are already doing that, tapping in to kind of international expertise in this area. And taking their advice on how we can access new markets and do things in a better way.

COMMISSIONER: And the ability, I presume, exists to do that within Australia as well? In terms of if there were specific universities with specific specialisations?

PROFESSOR FLETCHER: Absolutely, yes.

COMMISSIONER: Rather than try and develop it in one university?

PROFESSOR FLETCHER: That is right. Yes. So I could imagine that for example ANU offer a nuclear science masters. They have a slightly different flavour of the treatment of nuclear and that is important in that context as well. So it's not just about UNSW, there are centres of expertise who can offer expertise and experience in a particular area of nuclear engineering or nuclear science.

COMMISSIONER: And those formal linkages you are doing research in any case?

PROFESSOR FLETCHER: We do that already, yes.

COMMISSIONER: Yes. Okay. I think that concludes all our questions.

Professor Fletcher, thank you very much for flying in from New South Wales today. The evidence has been very important as we consider the terms of reference we have. We will now adjourn until this afternoon, 2 o'clock with Mr David Knox.

ADJOURNED **[12.33 pm]**