RESUMED **[12.30 pm]**

COMMISSIONER: We'll reconvene at 12.30, and welcome from the Australian National University Mr Ken Baldwin. Counsel.

MR JACOBI: The Commission will return to the topic of climate change energy policy both today and in the new year. It is doing so today to address the significance of LCOE calculations, given the release last week of a significant study undertaken by CO2CRC called the Australian Power Generation Technology Report. Today's session will address briefly the results of that report, but more significantly, seek to place LCOE in its appropriate context by exploring its utility and limits as a decision-making tool. These topics have already been canvassed in some detail in earlier evidence, particularly in the evidence of Professor Mark Diesendorf, but also in the evidence of Mr Paul Graham for CSIRO concerning the GALLM model which was in fact used in the CO2CRC study.

These issues will also be discussed today in the context of the necessary timing of carbon abatement strategies, another issue canvassed by a number of witnesses to the Commission, including that of Professor David Karoly, Professor John Quiggin and Professor Tom Wigley. The Commission also proposes to return to the topic of climate change energy policy briefly in the new year to address the outcome of the current COP21 climate talks underway in Paris.

Professor Ken Baldwin is the director of the Energy Change Institute of the Australian National University, where he is also deputy director of the Research School of Physics and Engineering. The Energy Change Institute provides leadership in energy change research and education in a number of fields ranging from science and engineering of energy generation and energy efficiency to energy regulation, economic, sociology and policy. Since 2011, Professor Baldwin is a member of the Project Steering Committee for the Australian Energy Technology Assessment, AETA, produced by the Bureau of Resources and Energy Economics, BREE.

In 2015, he was appointed as a member of the Socio-Economic Modelling Advisory Committee to the South Australian Nuclear Fuel Cycle Royal Commission. Professor Baldwin is an inaugural ANU Public Policy Fellow, and in 2004 was the winner of the Australian government Eureka Prize for Promoting Understanding of Science for his role in initiating Science Meets Parliament, a program aimed at helping scientists to better communicate their science to the media, policy makers and parliamentarians, and the Commission calls Professor Ken Baldwin.

PROFESSOR BALDWIN: Thank you.

COMMISSIONER: Professor Baldwin, thanks for joining us. Can I start with exploring what is crucial when we determine the viability of electricity generation technology?

PROFESSOR BALDWIN: Okay. So maybe I can just preface my opening statements by saying that the ANU Energy Change Institute is both technology and policy neutral, that is, we don’t favour one particular type of technology over another, or indeed, a particular style of policy over another. We aim to push all our research equally without favour of one particular technology or another. So that sort of underpins everything I have to say today.

When it comes to determining the viability of a technology, there are a number of factors that come into play and quite clearly cost is one of those, and cost can include of course all the capital costs, maintenance costs, operational costs, but it might also include environmental costs of a particular technology through, for example, a carbon price, et cetera. So the cost is clearly one major element. Another important element is geography, where the particular resource for that technology exists, whether it's a wind resource or a wave resource, et cetera.

Thirdly, there is the timing of the generation of that particular technology, whether it's a technology that relies, for example, on the sun at particular times of day or on the wind at particular times of day or year, et cetera, or whether it's a technology which is independent of time; it can be operated any time. And then fourthly, there are externalities to the sort of usual economic discussion about cost and matching of demand, and these externalities can include environmental factors, for example.

COMMISSIONER: Can we move on, talking about the levelised costs of electricity and how far does that go in assessing the cost competitiveness of a particular form of generate?

PROFESSOR BALDWIN: LCOE is one measure of cost, and indeed, it's a useful measure for comparing different technologies in a situation where we can describe this is plug-and-play. So in other words, you simply remove one technology and replace it with another technology at a particular location. So the advantage of LCOE is that it takes into account not just the fuel and operating costs and the maintenance costs of a particular form of technology; it also takes into account the capital cost amortised, if you like, over the lifetime of the facility in order to give an average for that particular type of technology over the long term, and so in that sense, being an average cost, it's useful occasionally to compare averages and this, I think, is the advantage of LCOE in that it allows us a fairly level way of comparing different types of technology.

But on the other hand, as I mentioned in my opening statement, you have to take into account other factors when evaluating different forms of technology. So, for example, the levelised cost of electricity doesn't take into account necessarily the geographic location. So it assumes, for example, that you remove on particular source of energy and you replace it with another at the same location, but of course if this new form of energy - let's already it's a renewable - doesn't have a resource value at that location but does at a more distant location, you then have to take into account the cost of transmission from the distant location where the resource exists to the location where it's used. So that's an example of where LCOE has to have a more nuanced perspective when it comes to establishing the viability of a particular technology.

Likewise with the timing, the LCOE doesn't take into account necessarily the timing of generation of a particular technology. What it does take into account is the capacity factor, that is, the time as a percentage of the total available time for which that particular source is available, but it doesn't actually specify what time that is and that can be crucial when you're looking at meeting demand which peaks and varies at different times.

MR JACOBI: So it doesn't take account of the value of the electricity that's generated, which is that if electricity is highly sought at a particular point in time it won't necessarily weigh that as part of the exercise.

PROFESSOR BALDWIN: Indeed. It's taking an average perspective which is based on the capacity factor, that is, the amount of time for which that source generates electricity. So typically, let's say, for example, wind power has in most wind farms a viable capacity factor of around 40%, which means that 40% of the time it's generating power, 60% of the time it's not, but it doesn't specify the actual time which that power is being generated, and if that doesn't coincide with market demand then value of that power being generated is much less compared to if it was at the peak.

COMMISSIONER: Last week I think we saw some LCOE figures generated by the CO2CRC?

PROFESSOR BALDWIN: That's correct, yes.

COMMISSIONER: I wonder if we could just walk through what that actually delivered, and I think, from my memory, it's certainly the first one I've seen in 2015.

PROFESSOR BALDWIN: That's right, yes. So I think it's always important to have constant updates of LCOE calculations, and the reason for that is that things are constantly changing. The technology is changing, particularly for new technologies which have what is called a rapid learning rate where science and innovation means that the cost of those technologies is being driven down through new discovery, but also because just through simple volume economies of scale the cost of a technology decreases over time, and for new technologies this decrease in cost is much more rapid than for mature technologies which more or less plateau out over time. So it's very important that LCOEs are constantly revised and evaluated.

So I think that this is very timely, this CO2CRC report. It is two years after the last Australian Energy Technology Assessment was released in 2013, which was done by the Bureau of Resource Energy Economics and the Department of Energy, as it was then, and I would just say that the most recent report by the CO2CRC involved a stakeholder reference group, as did the former AETA, Australian Energy Technology Assessment, but this was a closed stakeholder reference group. So in other words, it wasn't open to public scrutiny, so no one has had very much time to evaluate it and discuss it and provide a robust response to the report as yet.

COMMISSIONER: Are we using the same basic information that has been conducted at another LCOE activities?

PROFESSOR BALDWIN: I think that report that was released last week certainly referenced the Australian Energy Technology assessment but it also referenced other LCOE calculations and that’s appropriate. It would be a very useful, I think to have an open discussion about the assumptions and the new information that is presented in the CO2 CRC report and I think that will happen by and large. But maybe it is not as public as for example the Australian Energy Technology assessment was, where people were brought in to a room around the table and it was argued backwards and forwards as to the merits of particular elements in the technology assessment for particular technologies. So I think this certainly goes a long way to updating us and I think that the numbers in there are defensible and they have been looked at by the internal reference group but we should really have a very close look at them in detail over a period of time.

MR JACOBI: I am just wondering perhaps if we can go to them, and I think we have got some slides that pick out the CO2 CRC study and I think the first deals with levelised costs at 2015 and I am interested particularly to understand, I guess what has gone on in the last couple of years in terms of what levelised cost - - -

PROFESSOR BALDWIN: Sure.

MR JACOBI: - - - is in these, as compared to what it was in the AETA update in 2013?

PROFESSOR BALDWIN: Yes. So I think what we are seeing in the data here is that there have been changes which have arisen as a result of improved knowledge of learning rates for different technologies, so that has been reflected in the – for example lower costs for solar. Solar is moving very rapidly. For every doubling in the production of the number of solar panels, the price goes down by roughly 20 per cent and we notice 20 per cent might be 25 per cent one year or 15 per cent another year. So this is useful new information that is being presented. And indeed, it is informed by other things, so for example the ACT government has held a series of reverse auctions for wind and solar and the prices that have been achieved by the ACT government in those reverse auction processes are, if you like, a benchmark of the LCOE for those technologies. And I might point out, one point that maybe we will come back to later, the ACT government is a small player in the energy market in Australia. Therefore the price that it gets for a particular resource is a very small perturbation if you like, on the total resource available, whether it's wind or solar. So in other words, that is probably closer to being an LCOE if you like, than if you all of a sudden decided as the state of New South Wales might, to buy enough electricity from the various renewable sources, to provide half of its output.

So in that sense, the ACT reverse auction prices are if you like a little bit of an instantaneous snapshot of LCOE. So if we look at wind for example over here on the right hand side of the picture, so wind comes in at about $100 per megawatt hour and it goes down to, on the graph, about 80 and then maybe up to 120. And if we look at the ACT government reverse auction the prices that that achieved were in the range 80 to 90 cents per – well, per kilowatt hour, sorry $80 to $90 per megawatt hour and what that means is that these are 20 year agreements. So if you then net that back with 81 cents let's say in 2035 to 2015 then this comes in at the sort of mid 60 cent per kilowatt hour – sorry, 60 – I'll talk in dollars per megawatt. Mid $60 per megawatt hour - - -

MR JACOBI: In current dollar terms.

PROFESSOR BALDWIN: In current dollar terms.

MR JACOBI: Yes.

PROFESSOR BALDWIN: Okay. So what that tells you is that that is below, if you like, the bottom part of the wind data here. But the actual price bid is actually almost exactly at the bottom part of the wind data that is shown in this graph. So you have to take in to account current knowledge when it comes to these issues. Again, the ACT government is bidding for the cheapest wind resource in the country. So any other bids that might come in subsequently particular if a big player came in to the game and bid for a large fraction of the country's resource in that particular area, this would mean you would be going up the little green bar that you see on the chart, to the higher priced resource available in the country. So benchmarking these LCOE calculations against what is happening in the market is actually quite a useful thing to do and I would say that these calculations aren't far off, given that between 80 and $90 per megawatt hour is what came out of the ACT government reverse auction, which if you net it back to current prices is a little bit less than shown on the chart.

So that shows how things can change, why you need to do this frequently and why it is important to have a robust and contestable process for discussing these LCOE calculations.

MR JACOBI: Can I just pick up, and I am just interested to understand, perhaps by reference to particularly nuclear, with which this Commission is concerned - - -

PROFESSOR BALDWIN: Yes.

MR JACOBI: - - - and compared to where the position stood in, I guess 2013, we understood from some earlier evidence that we were likely to see much higher LCOEs for nuclear than had been calculated at the time of the AETA 2012/2013 numbers.

PROFESSOR BALDWIN: Yes. So just going back to AETA in 2012 and 2013, again the AETA process was robust, contestable and big stakeholder reference group was open to pretty much anyone who had an understanding of energy issues to come along and make their point. And as a result of that very robust, contestable process things changed between 2012 and 2013. So there was an update of the value of particular types of technologies between those two AETA reports. And in particular, it was pointed out that perhaps there had been an underestimation of the cost of nuclear, in particular the capital cost of nuclear between 2012 and 2013. So the 2013, the report reflected that change of understanding and so that is why, as I say it's very important to have this very open contestable process around these issues and the update that we see here for 2015 from the CO2 CRC, again is part of this process and it appears that the number for the LCOE for nuclear in the CO2 CRC report is higher than it was for AETA in 2013. And this is primarily due to a new understanding of the capital cost for nuclear that is around at the present. So at this very point in time, it appears as though the LCOE for nuclear has gone higher than it was in 2013 and this is primarily due to the latest knowledge that we have on the build cost for nuclear power stations.

Now of course this is a moving target. LCOEs change over time and it could be that in a year or two's time, with more new understanding of the build costs of nuclear for example the nuclear power stations that are going to be built in the UAE, the one that is going to be built in Britain, nuclear power stations being built in China that there is a different value in the coming years and that is why LCOEs need to be continually upgraded but the CO2 CRC report reflects the current understanding of the latest build for a nuclear power station and that is higher than it was in 2013.

MR JACOBI: I am just interested to pick up, I think we were on the second slide, the extract of the projections which as I understood them, had applied the GALLM model to give a 2013 prediction of LCOE costs as the situation then stood. I am just wondering whether you could offer us any insight in to that.

PROFESSOR BALDWIN: So this is – so this is for 2030.

MR JACOBI: This is for 2030.

PROFESSOR BALDWIN: Yes, that is right. So this is the chart that is being shown at the moment and indeed, the model is looking forward at the way that things might appear in later years, utilising an understanding or a modelling of the learning rate for particular technologies and of the understanding for how economies of scale might develop over time or not, as the case may be. And so the predicted cost that we see here, in particular, show solar being more competitive with wind in 2030 which is what you might expect because the learning rate for solar, as I said, is very rapid, wind is a more mature technology, so the learning rate is shallower. And so wind is shown in 2030 to be rapidly being caught up by solar in terms of LCOE. Nuclear on the other hand, is still more expensive and this again is a projection, so it is an estimate of what might happen in the future. But as I emphasised when we looked at the value for 2015, this constantly has to be updated in light of new evidence and new understanding for nuclear build costs around the world and indeed, it has to take in to account the economies of scale that might arise were let’s say post the Paris climate change agreement this year, were nuclear to become a major way of addressing climate change around the world, and that can significantly changed the outlook for the nuclear capital expenditure economy of scale. So it's a projection, as it is for solar, for wind and all the other technologies, so we need to bear in mind that these are informed by projected learning rates and projected economies of scale, but nonetheless the indications are that nuclear is more expensive than the other renewables on this basis.

MR JACOBI: I just wanted to pick up I think the particular reference to capital cost, chapter 16 of the report contains a particular chart that picks out the capital cost of the various technologies which I understand underpin those LCOEs - perhaps we can bring that up. I just wonder whether you could offer us any insight, I think you spoke of learning rates, is that what we're seeing there with respect to the projections out to the future?

PROFESSOR BALDWIN: That's correct. So what you see is, for example, if we look at the renewables and we look at large scale PV you can see there that the curve for large scale PV - and this is also true for other technologies, seems to flatten out over time. Okay. So this flattening out of time indicates that the technology is becoming more mature and hence the cost is not driven down nearly as rapidly, even though over time there is a greater unit volume production. Now, to some degree this is informed guesswork. We don't know, for example, in the R&D space what breakthroughs might happen in the future.

So let me give you an example. At the moment with current solar panel technology we are looking at technology that has, you know, been improved over the years to the point where the balance of plant costs are starting to become the larger component of solar rather than the actual solar cells themselves. As the cost of solar cells is driven down through the learning rate, they become a smaller and smaller fraction of the total cost of a panel and what that means is, if you can double the efficiency of your solar cells, you can halve the costs of the energy from the panel, if the solar cell cost is zero and the balance of system cost is the rest of it.

So new technological advances can make a huge difference in that circumstance. It can, you know, as I say, if you double the efficiency you halve the cost effectively. So these are looking forward without being able to guess in some sense where this breakthrough might happen, but these are projections based on current understanding, so they should be taken with, to some degree, a pinch of sale.

MR JACOBI: I think that picking up the next is that based upon those particular capital costs there's been a projection of the relative shares that would be shared on a costs basis alone in Australia of the particular generation technology. So I am just interested whether you could explain the transitions that are picked up there.

PROFESSOR BALDWIN: Okay. So what we have moving from the last slide to this slide is a new model. So the model takes the understanding of the levelised cost of our electricity projected into the future and then it puts into a model of the energy system and allows it to evolve over time effectively. What you see here in this chart is a picture of the different sources of energy evolving over time and quite clearly this is dependent upon the input factors into the model which include the cost of electricity and indeed the cost of things like carbon capture and storage.

So what we see on the model, for example, is coal gradually decreasing. This assumes a certain price on carbon, but because carbon capture and storage technology is included in here at a particular price, we see that taking over down the track and enabling coal to be used with carbon capture and similarly with other forms of fossil fuel. Notably, the renewables play an important role so rooftop PV continues to grow and become a large fraction of the total, as does utility scale solar, utility scale wind, and indeed solar thermal because there's a prospect of providing some degree of storage with solar thermal and this helps address the baseload issue that comes with reducing the amount, for example, of coal.

Gas is continuing to be a part of the mix and then, you know, of course, you can always introduce nuclear at some particular point in time, and this has been done in this particular graph almost instantaneously in 2015 whereas, in fact, I think what we would suggest is that this couldn't happen before 2025 at a minimum and probably more like 2030, but nonetheless it's interesting to see the role that's being played there.

MR JACOBI: I am just interested, the Commission has had in submissions that it's received LCOE analyses presented on the basis that there's a particular levelised cost for a particular generation technology compared with a levelised cost for another particular generation technology at a point in time, and the argument is advanced, well, the LCOE for this technology is lower than the other technology, thus this technology will prevail and become the winner. I am just interested in your view with respect to that?

PROFESSOR BALDWIN: Okay. So this is a fairly simple model because it used LCOE as the chief proxy for deciding on whether a technology is viable or not. Okay. As I said at the beginning, there are other factors that come into deciding whether or not a particular type of technology is going to be employed in the energy system. LCOE does not include the geographic distribution of the energy technology, in other words particularly the resource for renewables, it does not include the fact that there needs to be a capacity over build, if you don't a guaranteed dispatchable source of supply as, for example, occurs with renewables, and - - -

MR JACOBI: That's the so-called spinning reserves.

PROFESSOR BALDWIN: So this means that if you look at the synchronicity of sources, let's say it's solar, then of course, you know, different parts of the country have cloud at different times, et cetera, et cetera, that's fine, but maybe there's a big front passes over the country so you get a band of cloud moving across and you can, if you like, forecast what's that going to be and then, of course, overlaid on that is the fact that, you know, we have day and night, so clearly there's some synchronisation between the different solar sources in the same way there is synchronisation between wind because we have, you know, different wind patters around the country and sometimes they can be synchronised as a big front moves through, at other times it might be a different set of patterns.

With the different levels of correlation between the outputs of these renewables, you end up with a need to have overbuild of capacity in order to guarantee the delivery of a certain amount of power at a certain amount of time, and so the Australian energy market operator, for example, when it did its study back in 2013 included this additional capacity in its calculations of whether indeed you could achieve 100 per cent renewables generation for Australia. So you need to take into account the geography, you need to take into account the timing, and you need to also take into account other extraneous environmental factors that influence the introduction of particular technologies, including a carbon price.

MR JACOBI: I want to come to the AEMO report in a minute, but I just want to come back to the Commission has received submissions which have flatly said, "Look, the LCOE for nuclear is this. It's better than it is for solar or worse than it is for solar at this point in time, thus nuclear should be or should not be implemented." I am just interested in your view as to whether that's a sufficient basis or a sufficient way to think about the problem.

PROFESSOR BALDWIN: The very short answer is no. The reason that it's not the only parameter is simply because the LCOE is an average, it's an average over the technology, it's an average over the geography, it's an average over time. You have to look specifically at the location and the timing and indeed the capacity of that technology to deliver energy at a time when the demand is required, and so LCOE is, as I said at the very beginning, a bit like plug and play. You're assuming that you pull out one form of power, you put another one, and that's the comparison, whereas the actual situation on the ground is very different, you have to take into account these other factors.

So the simplistic argument that LCOE tells you everything is not a valid argument. You do need to take into account all the other external factors and in a full model of the energy system as opposed to plugging in one particular technology at a particular point and particular time, you have to allow for the change in the LCOE due to these system-based factors, and that changes the landscape completely.

MR JACOBI: I just want to pick up on the AEMO model because as I understand it, it makes an attempt at conducting such a system based analysis for a particular set of scenarios associated with high penetration renewables. And I am just interested to understand, I think we have got a slide that picks up from a number of scenarios of the sorts of projections of costs and I am just interested in perhaps whether you can offer us some interpretation of thinking about what the added implication is of adding in those system aspects?

PROFESSOR BALDWIN: yes. So this particular table is taken from the AEMO 2013 100 per cent renewable study and shows the cost for the capital investment in a number of different technologies, roof top PV, larger scale generation, the cost of connection of this larger scale generation and the cost of new transmission corridors. So when it adds all those costs up, it ends up with a number at the bottom that shows you the investment that is needed in the new build and this takes in to account the fact that you have to build a certain amount of over capacity in the particular technology, in this case photovoltaics in order to overcome this problem that they are all in some sense correlated because of the availability of the resource at similar times. And so in order to fill the gaps at other times, and in order to fill the gaps with other technologies which are similarly time dependent, you have to over build the capacity.

And even though Australia has a wonderful advantage in that the NEM is one of the geographically extensive in the world, it’s got 4,000 kilometres of generation across a very large geographic area, even then the averaging that that geographic spread gives you, isn’t enough to prevent the requirement for additional capacity in order to cope with generation where there are lulls in particular time periods. Then this is factored in to the cost of the wholesale price of electricity by simply amortising that investment in additional capacity over the whole system.

MR JACOBI: Reading the study, it went on to take those particular scenarios and calculate some conceptual whole sale prices that were associated with them and I am just interested perhaps whether you can offer some explanation, insight, in to what the effect is of adding in those particular transmission and other costs based on that sort of analysis?

PROFESSOR BALDWIN: Yes. So when it comes to the geography issue, this is the first nuance to the LCOE, the location of the resource at a distant location means the development of transmission lines and transmission corridors, purchase of land et cetera. These costs are – when factored in to the AEMA study, indicated that they added between six and $10 per megawatt hour to the LCOE for these 100 per cent renewable scenarios which is of the order of let's say for $100 a megawatt hour of the order of 10 per cent. Now that number of 10 per cent appears again in the CO2 CRC study. They also have a rough estimate in there and I believe that they came up with very similar figures that in order to access resource at a distant location, you would have to add in transmission costs of that order if you looked at it sort of system wide. But they haven't gone in to the study in the same way that AEMA have, I think they simply just make a statement along those lines somewhere in the report. So when it comes to the capacity contribution to the price, this adds quite a large factor. Indeed it – according to the AEMA study it more or less doubles the wholesale price of electricity. That of course makes 100 per cent renewables scenario much more expensive than it would otherwise be but nonetheless that is a price that is reflected in the calculations and indeed I guess the argument is, is that the price we need to pay in order to have a zero carbon energy based system. So that is really why the AEMA report was developed, was to see whether it was feasible, what was the price, the additional cost and then the question could be asked whether that cost is worth the investment.

MR JACOBI: I just wanted to – just interested in the extent to which studies similar to the AEMA study which modelled whole system costs on, again, I accepted based on conceptualised scenario of what the future might look like, have been done in Australia and the extent to which they might be planned to be done in the future?

PROFESSOR BALDWIN: So the AEMA study was unique in that it was the first time this had really been done on a system wide basis and since then there have been examination of particular aspects of particular technologies in particular locations and what the additional costs would be in a system sense for those specific examples. But there hasn't been an over arching model published that goes in to this in the same full systems based approach that AEMA has undertaken. But I understand that in the future, Grids Forum that issues like this were canvassed and that there were specific things studied but I don't believe that it was taken to the same extent as the AEMA report from 2013.

MR JACOBI: I just want to pick up with respect to transmission itself, the Commission has heard evidence that in general terms - - -

PROFESSOR BALDWIN: Mm.

MR JACOBI: - - - that connection to the grid or transmission to the grid from a new generator is met – the cost is met by the new generator and save for a new transmission becoming a regulated asset, it will otherwise be met by a new generator. And I am just interested, are there competing views with respect to who ought bear the transmission costs or are there competing arguments?

PROFESSOR BALDWIN: Indeed there are. So in a practical sense, you might find that a generator might be willing to bid in to the market and undertake the connection costs from the site of the resource some short distance to a major transmission line, and this indeed has happened in South Australia on occasion when new wind resources have been brought online there has been the connection cost has been included in the generator's cost. But if we have a resource that is a large distance from a transmission line that would require a large investment, then clearly this would be a significant increase in the cost that a generator would have to bear and there is an argument that says that this perhaps could be socialised to the extent that the social benefit from bringing on a resource which is low carbon, has a positive externality for society and therefore should be borne by the customers who would then buy this low carbon or carbon free form of electricity. So there is an argument to say that the transmission network should be the provider of the connection to the generator site, that this should then be passed on to the customer and that that way you socialise the cost of bringing on a new, for example renewable resource in order to have positive environmental externalities.

MR JACOBI: Just want to come back to LCOEs just briefly and the Commission has received a significant number of submissions which in addition to the argument that I have referred to before, advanced LCOEs from other jurisdictions, not only that but also prices that were struck within other jurisdictions for the supply - - -

PROFESSOR BALDWIN: Mm'hm.

MR JACOBI: - - - of energy. And I am just interested to the extent to which it is correct to apply a US or a European LCOE to the Australian scenario?

PROFESSOR BALDWIN: Clearly there are different cost structures in different countries and clearly there are different resource capabilities in different countries. I am referring in particular here to renewable resources which obviously have a very specific geographic distribution. So applying an LCOE from the US or Europe or Africa or anywhere else in the world to an Australian situation is fraught with problems to start with; if only for the fact that the resource value changes from location to location, even within a country. More broadly, there are differences in costs associated with labour costs, with transportation costs, with sourcing of particular pieces of the technology for the build cost. And these have to be assessed in the jurisdiction that is constructing the generation technology and they also in some circumstances, and this is done in the energy technology assessment back in 2013 and 2012, it has to even be assessed in the state in which the build is taking place because there are variations in these costs around Australia. So an LCOE that is simply transported from another location and put in to a particular location needs to be looked at very, very carefully to make sure these costs adjustments have been made properly.

MR JACOBI: The Commission has heard a lot about the likely impact of storage technologies with respect to what we are looking at and I notice in fact it's not actually included in the LCOE's - - -

PROFESSOR BALDWIN: Correct.

MR JACOBI: - - - that are and I am just interested in the extent to which storage might be thought to have on the sorts of issues that we're contemplating, particularly with respect to how it might work to resolve intermittency, not at a technical level but certainly at an economic level.

PROFESSOR BALDWIN: Yes. So you're correct that storage isn't included here in the calculation of LCOE, and this again comes back to the issue of timing that I raised at the very beginning. The time at which the energy is generated is crucial, not only in terms of meeting a market price, but also in terms of satisfying demand, and so what we see in some jurisdictions, for example, in California where there is significant penetration of renewable resource in the market, that at times when the solar output is very high or the wind output is very high that the increase in the renewable generation actually eats into the ability of the baseload generators to help meet that demand.

And so unless you completely shed the renewable load in some way, what happens is you then request that the other supplies decrease their supply and they can't do that instantaneously necessarily, and so you chew into the baseload profile of these other generators and that decreases their capacity factor and hence their profitability. So this is a significant issue where you get a large degree of renewable penetration. Now, storage is a solution to that. You can then store the renewable energy, which might be very high at particular times and very low at other times, and then reuse it at a time when you have a high demand, and this smooths out the profile of the renewable resource, it retains the more or less constant capacity of the baseload systems making them again back to a profitable situation, and it can be a win-win for, if you like, all technologies, because you have a way of adjusting the system that meets the capacity factor requirements of all generators providing you haven't over-built the system in the first place.

COMMISSIONER: Is there a time constraint on the storage?

PROFESSOR BALDWIN: It depends on the type of storage. So there are storage systems like the molten salt storage systems in concentrated solar thermal which can retain heat for in the order of 15 hours, which is terrific if you're concerned about the diurnal changes in solar radiation. So you can go overnight and still provide output from that stored molten salt heat. When it comes to batteries, again you've got a fair amount of flexibility then, because unless you completely drain the battery systems you have flexibility in the output, but there's no time constraint like the molten salt heat which will last roughly in the order of, let's say, 15 hours.

When it comes to pumped hydro, again there's no real constraint, unless of course you again drain the resource. So we're talking here for pumped hydro about a small reservoir at the bottom of a hill, a large reservoir at the top of a hill, maybe 400 metres or more above, connected by a pipe and a hydro generator at the bottom that allows you to pump water up and down, and then of course retrieve the stored energy at the top of hill at times when there is a high demand for that energy. So in those terms, there's again, like batteries, no real constraint on the time frame which you can extract that stored energy on, compared to, for example, molten salt.

MR JACOBI: Just come back to storage, and perhaps we can come back to the fourth slide. That makes a relevant prediction of the future about the share of particular technologies and, as I understand, it doesn't take account of storage. I'm interested to understand what sort of uncertainty the potential for storage throws into these sorts of predictions.

PROFESSOR BALDWIN: Certainly. Well, one of the reasons that you might expect, for example, that solar thermal plays a greater role is through this storage capability. So if that were taken into account, you might expect to see the percentage of concentrated solar thermal increase, and indeed, this is relied on to a large extent in the AEMO study as a way of getting around the intermittency issue with renewables. So that could play a significant role. Pumped hydro and batteries could play a significant role no matter what the form of energy generation is. So again, that would encourage intermittent sources into the system. Again, however, you do have to remember you have to factor in the cost of the storage, the fact that it's not a hundred per cent efficient, et cetera, et cetera, when it comes to working out the value for the resource at a particular time.

So just a side comment on this. It often is the case that, for example, with wind, that wind is generated at night and wind is significantly stronger at night, which means that it's generated at a time when the price is low, normally speaking. So consequently, the LCOE will often over-estimate the value of wind in some geographies. And similarly, with the cost of solar, often when there is a summer peaking in demand, solar can help lop the top of the summer peaking because when it's hot and sunny people have their air conditioners on and that's when the demand is high. So the solar can sometimes in fact have a higher value in the market because of that.

With storage, you can, if you like, even out the contributions of the renewables so that they can be switched on and off at times in the market when it makes the most sense to bring them on line. To give you a microcosmic example, there is a company in the ACT which is looking at technology which takes the energy you store in your battery in your home which is charged by your solar PV on your roof and it bids back into the market to supply electricity at a time when it's most needed, and this way you can optimise your own home solar installation with battery storage to enable you to extract as much value from the electricity you generate from your roof as possible in a market that allows that particular form of operation.

Now, not all markets allow that form of operation and this is another externality that needs to be taken into account when we have these discussions, because market reform is going to be crucial when it comes to, for example, lopping the top off peak demand, making the demand structure more uniform, enabling supply to come on line which can more readily meet that more uniform demand profile, and indeed, with storage, this makes the whole exercise a completely different story, because with such micro-bidding systems you can then pick your time at which you sell to the market and that makes a huge difference to the mismatch between the intermittent supply and demand of renewables in particular.

MR JACOBI: I just want to come to timing and I just want to pick up, given what we've been talking about in terms of solar PV and storage about what the challenge is that faces any new low-carbon technology that might enter the market in terms of timing, how one really has to think about that particular challenge.

PROFESSOR BALDWIN: Yes. So again, you could go back to an LCOE and look at the LCOE of, let's say, two technologies, and you might find that at one point in time a particular technology has a cheaper LCOE than another technology and that over time though these two learning rates cross at some point, and at that the point at which they cross you could argue that the LCOE then says that both of them are equal players in the market and then as they cross, the one with the cheapest cost will become the winner. Okay. So that's a simplistic argument in the same way that an LCOE is a simplistic estimate of the value of a particular technology.

But let's stick with the simplistic argument for the moment. So one can say, for example, that nuclear might, for example, be a sensible form of energy generation at a particular time because of its cost, but in the long term, because of the rapid learning rate of solar, at some stage solar is going to beat nuclear in terms of its LCOE value, and that says to an investor, "Well, okay. Let's say I built a plant in year X, and then I know from the learning rates that the best estimate for the point at which the curves of solar and nuclear cross is maybe X plus 10. That means that ten years after my initial investment, everyone will switch to solar and my nuclear plant won't be worth nearly as much as I thought." So that's a simplistic argument. So let's now nuance that simplistic argument.

First of all, as I said, LCOE is not the be-all and end-all warning sign. Okay? LCOE has to be taken with a pinch of salt, understanding its limitations and remembering the fact that timing, geography and externalities play a big role in determining whether a particular technology is useful or not in the marketplace at any given time. So with those caveats, you might then look at whether the expected lifetime of this nuclear window of opportunity could be something other than 10 years because it satisfied a number of criteria. First of all it produced power at a point, at a geographical place where it was needed and could deliver at that point at a time that was required for the particular demand profile that it was meeting. And even though the LCOE for solar might be lower, the fact that solar is located at a different place and produces electricity at a different time might indicate then that the nuclear power plant would be viable even allowing for a lower solar LCOE because it met the demand that it was built for.

So that is one argument. Another argument is that it depends on the way in which these agreements are reached. So in other words, is this spot market competition or is this a power purchase agreement over an extended period of time for which the authority requests that a particular technology delivers electricity under a contract and for example, we have PPA agreements, I mean if you like the ACT government reverse auction as a form of PPA agreement, the purchase of power for desal plants and for aluminium smelters, although we are seeing fewer aluminium smelters in this country, done under power purchase agreements as well. So it is a matter of the type of contractual arrangement that the generator has with the energy system that in some cases will determine the viability of that particular source over time. So simply identifying a window determined by LCOE for which a particular technology might be ahead of the competition, doesn’t tell you the full story. It does depend on a whole range of other factors.

MR JACOBI: I am just interested to understand if a government is faced with a task of (indistinct) by economists of welfare maximising - - -

PROFESSOR BALDWIN: Mm.

MR JACOBI: - - - or optimising welfare what sort of studies need to be undertaken in order to be able to form a view about whether your electricity system is in fact going to deliver that maximum welfare or optimise welfare?

PROFESSOR BALDWIN: So I think the answer to that is you have to take an entire systems based approach to understanding the needs of the particular network over a long period of time. Looking at the LCOE is one element that goes in to that but it is by no means the totality of things that are required. So as systems based approach where you look at the marginal return from a particular generating source, let's say a small part of the grid, like in the ACT government reverse auction process, this makes a small perturbation to the system as a whole and consequently you might think that the LCOE is a good proxy for how that affects the system. But when it comes to a large-scale contributor to the electricity supply in the grid, that is a large perturbation to the system. You can no longer use a simplistic value like the LCOE to map out how this could develop and so you need a system based approach which take sin to account a whole range of externalities, it takes in to account the over capacity build, the transmission line build and indeed the typology of a network that allows you to access resources in different parts of the country.

A system-based approach like this is something that needs to be done, particularly if we are going to see, after the Paris conference this week, a significant shift in the world and the Australian scene in regards to reducing our carbon emissions. And you can only do this with a systems based approach and so it makes eminently good sense to post Paris 2015, for Australia to start an energy policy analysis based on a systems based approach to our electricity generation. Which, after all, is almost a third of our greenhouse gas emissions intensity when it comes to the national budget.

COMMISSIONER: Can I just pick up on that? Can you run us through the likely sequence of events following Paris in terms of the Australian policy making regime? We have already committed to 26 to 28 per cent.

PROFESSOR BALDWIN: That's correct.

COMMISSIONER: What is the timing for the policy of decisions around that? And how do you – do you have a view about how long it will take to develop those policies? Assuming that that is what comes out of Paris?

PROFESSOR BALDWIN: Yes. So I think what you need to look at is the outcome from Paris in terms of our global and our national commitment - - -

COMMISSIONER: Mm'hm.

PROFESSOR BALDWIN: - - - to greenhouse gas reductions. There is an argument that says that polluters in the developed world have already delivered most of the CO2 which they are allowed to deliver in to the atmosphere and that developing countries will continue to deliver CO2 in the atmosphere until such time as they catch up with the developed world in terms of their technology. So there is a burden sharing arrangement that needs to be developed that will achieve the ultimate goal of keeping the world's temperature below two degree increase by 2050 which is by and large the agreed target. You then have to apportion the change in your greenhouse gas emissions over time between developed and developing countries in such a way that you achieve this worldwide target. And let's say that this means that by 2050 we need to be net carbon zero and so that that tells us is that you have to then develop trajectories for each country so that they reach that point given the burden sharing arrangements.

So post Paris, if there is an agreement, and there is a broad consensus as to how the burden sharing should work, then this will provide, if you like, the overarching parameters set for the Australian government to work within. If we indeed are to be a good citizen and have the moral high ground and contribute in the way that we should to reducing global emissions. And it is important that we should. Australia is a major producer of energy for the world. If you look at the amount of energy that is created in one form of another in Australia every year, a very large fraction of that goes overseas. So we are a major energy supplier, so we have a moral obligation to do the right thing in Australia ourselves. And this is also a result of the fact that we are highly carbon intensive, 75 per cent of our electricity comes from coal, another 15 per cent from gas, 90 per cent from fossil fuels and indeed our transport system is highly carbonised compared to many developed countries.

So we have two moral obligations both as a major exporter of energy and as a major carbon intensive country that has already put a lot of CO2 in to the atmosphere, to have a strong trajectory in to 2050. Now that trajectory can be either rapid or shallow and then rapid at the very end and that makes a big difference when it comes to the cost. In terms of environmental cost, all reports show the Stern report and others, that the more rapidly you decarbonise, the less the cost to the environment and to the economy in the long run. However, you can still achieve the same goal if you move rapidly at the beginning and then taper off at the end, or if you do nothing for a while and then rapidly do something. Then you can still achieve the same goal, it's just that the cost will be different. So the Australian government will have to determine what type of trajectory it goes down and if we go on a trajectory of 26 to 28 per cent by 2030 that is telling us that is doing only a little bit at the beginning which means towards the end we are going to have to do a lot more in order to reach the same goal.

So we can change that trajectory, it is within the government's control to do that and when that trajectory is determined, that determines the closure rate for coal fired power stations; it determined how the mix of gas and other forms of fossil fuel flows during this time to reach the net carbon budget. It determines how many renewables we need and at what rate we need them. It determines in fact whether we should be looking at nuclear as a possibility given this window of opportunity argument that I talked about before. And when it comes to greenhouse gas emission reductions, the window of opportunity argument is an important one. So let’s say that we decide that we are going to do this completely with renewables, it will take us a while to get all the renewables on board, it might take a while for some of them to get cheaper. Okay. So there is a waiting process during this time when we try to get to net zero emissions by 2050. During that waiting period, we are emitting carbon, okay. We are putting carbon in to the atmosphere, so if there is an opportunity to bring on another technology during this period, while we’re trying to ramp up the renewables as much as we can, ie if there is an opportunity to bring on nuclear, then this produced a positive benefit because it takes advantage of this window of opportunity for nuclear and uses that to pull emissions out of the atmosphere that would have otherwise gone in.

Now, whether that window is small or large, whether it's economically viable or not, is a question that relates again to this curved crossing argument we used before for the LCOE. If it's 10 years, if it's five years, if there's PPAs, if there's not PPAs, all these go into determining whether there's a window for nuclear or not, and that at the moment is an open question because we don't know exactly what the trajectory for all the competing technologies is going to be, we haven't modelled a national systems based approach to determine which renewables we're going to bring in, in which part of the country, and at which time, and indeed we don't have an overarching energy policy in which this all sits which includes, for example, a price on carbon, it includes incentives like the renewable energy target and direct action, and it includes the third lever after price on carbon incentives which is a regulatory regime such as introduced by Barack Obama, which determines the emissions thresholds and the emissions performance standards of energy generators and energy users around the country.

MR JACOBI: Does it need to include as a comparator the cost of doing nothing?

PROFESSOR BALDWIN: Absolutely it needs to include the cost of doing nothing, because the cost of doing nothing tells you the opportunity costs for delaying action well and truly down the track to the point where you really have to do something very rapidly to meet the net zero by 2050 goal.

COMMISSIONER: Professor Baldwin, thank you very much for the preparation of your evidence and your ongoing work.

PROFESSOR BALDWIN: Thank you very much for the opportunity.

COMMISSIONER: Pleasure. We'll adjourn until tomorrow morning at 0800.

MATTER ADJOURNED AT 1.32 PM UNTIL THURSDAY, 3 DECEMBER 2015