RESUMED **[2.31 pm]**

COMMISSIONER: Reconvene at 14.30 and I welcome Mr Paul Graham from CSIRO Energy flagship. Paul, welcome this afternoon. Mr Jacobi.

MR JACOBI: Mr Paul Graham is a chief economist at the CSIRO Energy Flagship. He is responsible for advice on the global and national economic context, relevant for energy sector settings, setting the strategic direction for economic research and leading major projects and Mr Graham has been with the CSIRO for 15 years and as will become apparent, has been involved in a number of key publications published by the CSIRO in the last five years, being considered by the Commission. Call Mr Paul Graham to the Commission.

COMMISSIONER: Paul, thank you. Today we've been hearing evidence about the various technologies that might be able to generate low carbon energy. We do need to understand what long-term costs for these various technologies might be. And I understand that CSIRO has completed some modelling on various technologies and perhaps you could go through the model and talk about some of the outcomes.

MR GRAHAM: Yes, that is right. CSIRO is sort of naturally interested in the future costs of technologies because we obviously work on some of those technologies ourselves. But a few years ago we came up with a methodology for forecasting the future cost of technologies. We developed a model called GALLM global and local learning model and what that does is it takes into account something which we call learning curve theory and learning curve theory is – I think we've got sort of a picture there - - -

MR JACOBI: We do.

MR GRAHAM: - - - it's the idea that as you develop and deploy technologies you generally observe a fairly constant rate of cost reduction for each doubling of capacity that you deploy. So new technologies might have a – for example might improve their costs by 20 per cent for each doubling, with more mature technologies it might be much less but these are things that you can observe and you can build in to a modelling framework. What - - the framework that you need, needs to take in to account that you need to simultaneously be able to project what's happening to deployment and what's happening to costs. So that is something that is amenable to a mathematical approach and so that was a model, as I said called GALLM which we developed a few years ago and that model over the last three or four years has been involved in most of the cost projection work that – the main cost projection work that you probably may have already seen in Australia. So there was the Australian Energy Technology Assessment in 2012 and there were some further updates over the years. So I think you've got another slide there which just shows an example of the output of GALLM when we take - we sort of take an existing cost that is provided to us in 2012 and then we project forward how that technology cost might evolve.

MR JACOBI: Can I just hold you up there and just spend a little bit of time talking about GALLM. I'm just interested, prior to using a learning curve based model, how were cost projections done for different technologies? What were the different approaches?

MR GRAHAM: Yes, that's right. So there's a process that – for example the IEA does, the International Energy Agency where they essentially write to all the different countries and essentially ask people what – ask experts in each country what they think future costs might be, so that's kind of like a survey, expert elicitation type approach. Other approaches, it's actually very hard to say because a lot of projections that are available will probably characterise them as sort of black box in the sense that there is a projection that's published but there's no explanation of how they arrived at the projection. The most you might see as an explanation is that some observation that these costs – this rate of change was observed in the past, so they've extrapolated it forward. Neither of those two approaches are really suitable for CSIRO because as a science agency we have to be able to trace through a methodology and understand how you got from sort of cause to outcome. That's not to say that an expert doesn't have a valuable opinion, it's just that we got to a position where we felt that we needed to develop our own model just because we couldn't understand – well, we couldn't trace through how people were arriving at their projections.

So GALLM is an approach where you can see exactly what level of deployment we are assuming and you can – and you can see exactly the level of the learning curve function that we assume and the cost outcome is exactly an outcome of putting those two bits together. So it's essentially very traceable methodology.

MR JACOBI: The Commission has seen a number of actual learning curves associated, particularly with solar PV and batteries and I am just interested to understand how they are fitted to the assumptions in the model? That is how is the model set up such that actual experience in terms of learning rates are built in to the outputs from the GALLM model.

MR GRAHAM: So the observable learning curves, so the historical learning curves are built in, in the sense that they are assigned to each technology if they are – if we are able to observe them, so for wind and solar, we can see from deployments in the past that a particular technology is achieving this learning rate and we can assign that and we will generally allow an historical learning rate to continue for a while but then we might assume that as it matures that learning rate should slow down and eventually it will get very low indeed. So we generally assume that most – we have to make an assessment about whether a technology is at an emerging stage, an intermediate stage or a mature stage and we assign it a location on that sort of curve and then we allow it to move through the different steps remaining. So the most difficult technologies to deal with are those that actually there isn't any real historical learning observed because they haven't been built or they have got very low levels of demonstration globally. In that case, what we generally have to do is just assign a learning rate that is commensurate with other very new technologies. So as I said a bit earlier, most new technologies have very high learning rates of around 20 per cent or higher. So we give them that learning rate and then again, we sort of assume that if they – as they become mature they'll start - their learning rate will start to decline.

MR JACOBI: We have heard quite a bit about the effects of scale in terms of production and its affect on the ability to drive down costs, particularly again with solar PV and batteries. And I'm just interested to understand the extent to which increased future investment, or how that's factored in to what is done in terms of what the models predict.

MR GRAHAM: Yes. So in some senses the learning curve is a bit of a catch-all, so it catches lots of different ways in which costs might decline, so they might decline because there's been a technological breakthrough, or they might decline because there's been economies of scale in manufacturing and we can't actually necessarily separate those two things when we apply the learning rate, but there's no doubt that efficient global scale manufacturing has played a big role in the cost reductions we've seen, for example, in things like solar, solar panels recently.

MR JACOBI: I'm just interested, did you have any views now having used this particular model for some years, whether there are any particular advantages or disadvantages in using this model as compared to the other approaches?

MR GRAHAM: The main disadvantage is that because it's a fairly sort of purely mathematical approach it projects future reductions in costs but you can't necessarily say what exactly happened to make that lower cost, so as I was just saying, did it happen because of a technological breakthrough or was it efficient scale manufacturing or was it something else, we don't know, we just know that there is the potential there and that's the likely outcome that we can predict.

Whereas another approach where it might, say for example, their approach is where engineers might take a careful look at every component in a technology and think about every component's conceivable potential for cost reduction so that they can build a road map and pinpoint exactly how they are going to achieve all the cost reductions by stepping through each component, that gives you a really good sense of exactly where in that technology the cost savings will come from, but I guess the flip side of that is you don't exactly how that's going to occur and when that's going to occur. So ultimately this is (indistinct) is a good approach but it doesn't tell you exactly what you need to do from a science perspective to achieve it.

MR JACOBI: I think finally, to what extent are the outputs validated, and that is in terms of once the model has been running, have you been able to recalibrate the model, I guess, to take account of overestimation or underestimation?

MR GRAHAM: So the main validation process we use is to actually run the model from 2006 and see if it can reproduce the period to the present, and the main issues we had in trying to achieve that was that there was some very volatile things happening in the market during that time. There was a big price bubble, for example, in solar at the time because there was restrictions on silicon production and also with lots of wind being deployed worldwide and there was lots of coal as well going in, but similarly there was some increases in the costs of different power stations that wouldn't have been normally predicted by a pure learning curve approach, so we had to build in some other concepts around how the global technology market reacts when you try to build a small number of technologies quickly. So we built in some market dynamics around that and we were eventually able to satisfy ourselves that we could represent the past and that gives us more confidence in projecting forward.

MR JACOBI: I think as we come through to the slide that you were referring to before, I was just wondering about how you could explain how the outputs from your model are, I guess, reflected on the particular research that's done there against a particular scenario.

MR GRAHAM: Yes. So this - one of the things you have to consider when you're doing a projection is what's happening in the rest of the world because Australian deployment and learning doesn't necessarily drive cost reduction, it's what happening in the world generally. So to do the AETA 2012 projection we had to assume a world that was moving towards constraining emissions by aiming for a sort of 550 ppm carbon dioxide equivalent concentration which essentially means putting in some sort of proxy global carbon price which drives technological deployment, and so that's how we ended up getting some fairly significant cost reductions in low emission technologies like renewables, like carbon capture and storage, which you would expect would be deployed in that type of global environment.

MR JACOBI: Does this come back to I think something I asked earlier about investment? Does this mean that in essence the constraints - there isn't really one costs future, it depends upon the constraints that are imposed that drive investments in the system.

MR GRAHAM: Yes, that's a very good point. So, for example, when we looked at other scenarios for other clients who were interested in - and for ourselves, I should add - who were interested in worlds where we're doing even deeper decarbonisation such as a 450 ppm target, that actually drives even deeper global deployment of those technologies and so the cost curves are sort of - the cost projections are lower again. So if you think about it, if you could have everything from a no climate change action world up to a sort of decarbonisation world, there's actually a full spectrum of potential future cost curves, because what really drives cost reduction is when people actually use these technologies, not - so the more you use them, the more cost reduction you get.

MR JACOBI: I think stepping through to the third slide under this particular package, I just wonder whether you can offer an interpretation of the outputs that are shown there as out to 2015 - again this is with a constraint of 550 ppm world.

MR GRAHAM: Yes, exactly. So this shows the world transitioning to low emission technologies over time. The most common sorts of technologies used in power generation globally at the moment are sort of coal or gas, nuclear, hydro, and a small amount of renewables as well as some combined heat and power systems in some countries, but as we move forward if we've got a carbon constraint, and particularly around that sort of 2030 period where we're assuming that both developed and developing countries are all participating and we would see the stock turnover from the existing technologies towards low emission technologies like more nuclear, more carbon capture and storage, more renewables, and that's kind of the picture that we see there.

COMMISSIONER: How different would that look, Paul, under 450?

MR GRAHAM: Under 450 you get slight - you get less carbon capture and storage.

COMMISSIONER: Yes. That's what I would have expected.

MR GRAHAM: And more nuclear renewables, because carbon capture and storage doesn't quite remove all the carbon, so it's just not quite as effective emission reduction technology as the zero emission renewables and nuclear.

MR JACOBI: Am I right to understand that with respect to this particular chart, that one is looking at the constraint that's imposed is the carbon emissions constraint, but otherwise the shares of each of the technologies are driven by cost?

MR GRAHAM: Yes, that's right. There are some considerations of - so different regions of the world have different access to different resources and there's also some consideration of local - some local policies, for example, feed-in tariffs and around solar, so there's some other smaller drivers, but certainly cost is the main driver.

MR JACOBI: Perhaps we can move away from the Australian electricity generation technology cost projections report and move to a more recent report which concerns electrical energy storage, technology overview and applications published by the CSIRO this year.

MR GRAHAM: Yes.

MR JACOBI: I'm just interested to understand the particular - we have had some discussion today with ZEN Energy about battery technologies and with LHS about thermal storage, and I was just interested to understand from an economic point of view the particular battery technologies that you thought were important to analyse for the purposes of that report.

MR GRAHAM: We considered the different characteristics of the batteries and their costs, and what you find is that there are some batteries that - what some of the key things that I understand about batteries are they're sort of - their (indistinct) discharge and their cycle life, and how quickly they can do the charging and re-charging, and that tends to lead you towards different applications. So for example, for the batteries that we use in our vehicles, we actually need to turn those batteries on and off quite a lot, but we don't need to deeply discharge them so for that we use lead acid and some of the advanced lead acids are an improvement on those.

There are also other battery chemistries, so for example, zinc-bromine flow battery is quite good at discharging a lot of power quickly, but if you did that too often its life runs out quite quickly, it only has about a cycle life - about a thousand charges and discharges before that battery has degraded, and I've sort of shown the (indistinct) battery there - that has a particular operating constraint in that it operates at 300 degrees and comparing those three to lithium-ion, the big advantage of lithium-ion is that it's very well suited to sort of daily charge and discharge. So if you think about 7,000 cycle life, one cycle a day, you know, 365 days a year you're sort of easily going to get, you know, a decade or more out of that battery.

No - probably not more than a decade, but at least a decade and it's really suiting that sort of - if I've got an electric vehicle, you'd expect to charge that once a day, so it's just eminently suitable that outcome and it's also low cost, that's why we've seen kind of very much a movement recently towards a strong focus on lithium-ion, just because it matches exactly what vehicle manufacturers are looking for and it also appears to be matching a sort of use that people are looking for when they're talking about using batteries for home energy storage.

MR JACOBI: I understand - - -

MR GRAHAM: But - - -

MR JACOBI: Sorry, go on.

MR GRAHAM: But I guess it just highlights how important it is to think carefully about the application as well as the different batteries that are available.

MR JACOBI: I understand that the GALLM models' being used for the purposes of making some projections about lithium-ion and I think some of it might be reflected on our next slide. I was wondering whether you could explain what the projections are with respect to lithium-ion from GALLM and then perhaps explain that by reference to the chart.

MR GRAHAM: Yeah, that's right. So I have to say, to put this in context, I think even three years ago we probably would not have been thinking about batteries being a very significant thing for the power sector because they were just quite high costs and so we didn't, until recently, have a version of GALLM that included batteries because we didn't think they were relevant and the whole electricity system is really predicated on the idea that you can't store electricity so you've got to set it up in a certain way to make sure you can always provide power around - you know, that's why we have a network system that can meet the highest power demand probably expected of any year. I think we're kind of not quite familiar with the concept that a small percentage of - a large percentage of the power in the electricity sector only gets used a small percentage of the year.

So batteries could change this and we've recently put batteries in the GALLM model because we really now need to understand what the future costs is and you'll see some research there from Nature Climate Change and it's just demonstrated historically why things have changed so much just in the last few years. So costs have come down, they've sort of tumbled down by, you know, several - you know, they've sort of halved several times and you can see the batteries are sort of heading towards that - this is the lithium-ion battery, I should say - is heading towards that sort of $200 a kilowatt hour and we're projecting that we've run (indistinct) recently, including batteries in the model, and we think that will get below $200 - sort of more towards the hundred, $125 a kilowatt hour in the long run.

MR JACOBI: Now I'm right in the fact that the green dots that appear on the graph - they're not projections themselves from GALLM, they're projections from others, is that right?

MR GRAHAM: They are projections from that article in Nature Climate Change and our own projections. But our own projections are fairly consistent with those.

MR JACOBI: Again from the perspective of the economics, I'm just interested in understanding the extent to which customer category is a driver in terms of what sort of - when batteries become economic for customers and I think we've got a slide that might reflect this.

MR GRAHAM: Yes, one of the most difficult things about understanding the economics of batteries is there's so many different applications and so many different dependencies within each one of those applications. So if you think about people using it in their home, to actually get a return on that battery, it depends very much on what type of character you've got. So for example, you could use a time of use tariff, and try and shift your power from the high cost part of the day to the low cost part of the day, so batteries could be very useful for that.

Or you might be using the battery to make sure that you maybe run a volume tariff and you've got solar, and you're trying to avoid exporting your solar - instead of exporting your solar for 6 cents a kilowatt hour, you're going to use that solar later in the day by using a battery and then avoiding having to import power for 45 cents a kilowatt hour. So you can do (indistinct) on the difference between your solar export price and your retail import price, and so there's lots of different combinations of tariffs and solar ownership, and so forth, that you have to work through just to figure out whether it's economic for someone to use a battery in their house.

For a larger customer, the issue we think that's probably where batteries might be the most economic is in avoiding connection costs. So when a large customer connects to the network, they have to - as opposed to most smaller customers, the larger customers have to pay a fee for that connection and that's determined by how big their connection has to be, and if they can use storage to reduce their peak demand profile, then they can reduce the size in their connection and actually save money.

They're sort of user-side applications, but if you think about grid-side applications where a network might decide to use a battery for themselves, they might think about using a battery to avoid either strengthening a line - so rather than building a - either replacing a line or adding a new power line, they might decide if they place a battery in a certain part of the network, they can avoid that. So that might be a cheaper way for them to provide reliability. If we think about the generation sector, there's a couple of different applications. One is that batteries could eventually have a role in meeting peak demand. So rather than building, say, a gas peaker, we might eventually think about putting in storage and shifting that demand rather than having to meet that demand. The other thing is obviously that renewables and their intermittency could require not just peak in capacity but generally load following capacity to fill in those peaks and troughs around intermittent renewables. All that depends on what existing capacity is already in the electricity generation system but the final application is a little bit outside the electricity sector but in electric vehicles but obviously with some implications for the electricity sector because the more batteries enable electric vehicles then that feeds back as demand to the electricity sector. So that is a lot for one technology to be doing and it’s really opened up like the world of trying to understand the economics across so many different applications.

MR JACOBI: Do you have an expectation that that’s likely, given the vast possibility of applications that that’s likely to drive investment and drive costs?

MR GRAHAM: Yes, that is our expectation. When we look at – when you have got a technology like that, that has so many possible end uses, you are going to get some economies of scale around the fact that starting with the application that is the most economic, that starts to build some deployment which then drives costs down and then that opens up another application and so you start to build efficiency in scale and cost reduction around – well, in the end when we looked at all of these, we actually found in the long run that there’s potential for nearly all of these applications to be economic at some point, as the costs reduce but some of them are very specific. So it depends particularly around the network and the large customers, it does depend on very specific circumstances.

MR JACOBI: Perhaps if we can move off that report and come to the Change in Choice report. I think perhaps better known as the Future Grid Forum report and I am just interested to work very quickly through one part of it and then spend a bit more time on the scenarios. I’m just interested first of all, we understand that there were a number of motivations for people to participate in the Future Grid Forum but one of them in particular was the particular costs that – well, the drivers for cost increases and I’m just wondering whether you might explain that?

MR GRAHAM: Yes, there was a lot of change happening in the industry around 2012, 2013 when we were doing that work. Solar was just coming on, battery costs were reducing as we talked about retail prices were increasing but I think one of the surprising things on top of that was that the component of the price that increased wasn't where we all thought it would come from. We probably spent the previous decade, public discussion on electricity prices worrying about the impact of shifting to low emission technologies and possibly increasing the costs of generation. But the surprising thing was that most of the cost increase actually came from network costs and that was because of several factors that happened at once. There was increase in the cost of financing network builds. There was historically a lot of older network assets that had to be replaced. There was also the fact that peak demand hadn't been increasing a lot faster than volume and so as the revenue had to be recovered in volume terms that – the revenue price had to go up and there was also some strengthening of the networks going on and as reliability standards in some states had tightened up, so it was a bit of a blind side for the sector. Although in hindsight, we understand why it happened.

MR JACOBI: I think in terms of one of the challenges facing the Commission is that we have had explained to us by many people, the sorts of uncertainties that they see exist in the electricity sector and I am just – at the time that the Future Grid Forum work was done, you had a view about the sorts of uncertainties that you faced in that work and I think our next slide might show that. I am just wondering whether you might explain what you consider to be the key uncertainties that you faced in the work you were doing?

MR GRAHAM: Yes. As the participants in the Future Grid Forum sat down we could easily make a list of 30 uncertainties that we were worried about as a sector but what we decided was to narrow in on what are the – there are lots of uncertainties but what are the ones that really mean that the sector is at risk of not being able to retain its current structure. And the three things that we came up with, and we called them megashifts, was low cost storage. I guess I've just explained why that's such a significant change for the sector. Load demand essentially supplying your electricity which is another way of saying an increase in on site generation, particularly solar, and greenhouse gas reduction. So all of those things really challenge the current structure of the sector and how well it can actually continue in its current form.

MR JACOBI: And I think against that background, for the purposes of the Future Grid Forum's work, you developed a range of possible scenarios which contained assumption sets. And I'm just hoping you might be able to take us through each of those scenario sets that were used for the purpose of the modelling that was done?

MR GRAHAM: Yes, there was four scenarios that the forum decided to explore along those megashift themes. And three of the scenarios really explore different reactions to how consumers might engage with the sector. So set and forget is the idea that consumers will engage with new technology but would like the sector to be there agency in understanding those technologies, so that they would set it up for them and they wouldn’t have to control them on a daily basis. Whereas rise the (indistinct) which is another scenario really looked at the idea that consumers would not be as passive as they have been in the past, and actually take a much more central role in managing their electricity demand, their use of new technologies and how they are connected with the markets. Even in a sense becoming proactive in to finding products that they needed and trading power, so that they’re no longer just a customer. Another scenario, leaving the grid, it was centrally looking at this idea that – well, will all customers necessarily stay on the grid? Because of the opportunity that storage presents, could it be possible that people might eventually fully disconnect in the sense of having no real physical wired in contact with the grid. And then the last scenario, renewables (indistinct) was really about this concept of we can sort of see how well storage could support renewables and so because renewables have always been constrained by this issue of intermittency, if that problem goes away because of storage then how far could we take renewables. And this scenario takes renewables to 100 per cent of the centralised grid electricity supply.

MR JACOBI: Now am I right in understanding that each of the scenarios you have just described is really just a set of assumptions that is used to underpin a model?

MR GRAHAM: That’s right. So there are certainly assumptions that are hard wired in to those scenarios and there are outcomes though in modelling where we project the outcomes as model projections. So things that we assumed, for example, we generally across the scenarios – so if we sort of made general decisions about how much on site generation we thought would be in there and that ranges from about – from just under 20 per cent, set and forget up to about 46 per cent in (indistinct) and I should say that in the renewables thrive scenario, we did make a conscious decision to force in a hundred per cent renewables in the centralised generation sector.

Apart from that, I should also say that we assumed, across the scenarios, that there would be some sort of carbon constraint. When we talked to the Future Grid Forum participants about this, they said they didn’t really think it was plausible not to have a carbon constraint. So all of the scenarios assume something consistent with a 550 ppm world, in terms of the carbon constraint.

MR JACOBI: In that sense, they assume some form of market price for carbon, or some equivalent policy setting?

MR GRAHAM: Exactly, yes.

MR JACOBI: I just want to go through a number of the key outputs from the change in choice, where they are modelled. Perhaps if we can go to projected network utilisation, I was wondering what the key findings were under those scenarios, for the use of the electricity network.

MR GRAHAM: One of the other assumptions we made was, we were very conscious that with the amount of on-site generation in each of the scenarios, that there wouldn't be much growth in the volume of power being consumed. And we were conscious that, if that was the case, and we didn't do anything about the peak demand, then we would be stuck with rising network costs.

So we put in a lot of peak demand reduction assumptions across the scenarios, where we were doing things like controlling commercial air-conditioning systems to come off at certain times of the day, and those sorts of activities. But as you'll see, even without a network utilisation projection, in most cases we still, sort of, if you like, failed in a sense, to prevent the decline in network utilisation, because the increase in on-site generation has kind of swamped some of those demand management activities, so that for all of the network that we've got, we're still using it at a lower rate than we are today, out into the future in most scenarios, some worse than others.

That's what leads to the result in the following slide, which is that we've still got increasing prices projected. That's because we've got the distribution unit costs are still increasing because of the utilisation issue, and because in the generation sector, we've shifted to, with the assumption of a carbon constraint, we've got higher cost technologies like renewables and so forth.

So we've got increasing costs in both the network and the generation sectors, leading to increasing retail prices.

MR JACOBI: Sorry, am I right in thinking that that's skipping through to the wholesale electricity prices, which is the next slide? Am I to understand that it's the increasing distribution component of residential prices that drives – sorry, no it can't be. I'm sorry, I'll start again.

What are the key drivers for increases in wholesale electricity prices, in the next slide?

MR GRAHAM: There are two different things going on. One thing is, that we're in a situation right now where wholesale prices are depressed, because we've got excess capacity. So as that situation unwinds, we'll have to get an increase anyway, because prices at the moment don't really reflect the replacement cost of power generation.

In fact, if you look at – we do a scenario 1, with zero carbon price, if you like.

That indicates just the cost increase that you would get with an unwinding of that situation of excess capacity.

MR JACOBI: Sorry, could you identify which two curves you're comparing here?

MR GRAHAM: There's one called "Scenario 1 With a Zero Carbon Price."

MR JACOBI: Yes.

MR GRAHAM: That's the price increase you get without a carbon price, so you still get an increase, just because the price has to come back up to closer to 70 or $80 a megawatt hour, as compared to the sort of, $40 a megawatt hour that we're experiencing right now. Because you can't build a power station in Australia for $40 a megawatt hour, we can only experience the prices we're experiencing now because the market is in excess supply.

So there's that factor. And increases on top of that really reflect this sort of, carbon constraint, which creates the pricing environment for low emission technologies to compete, so we have to have another increase in electricity prices to support that.

MR JACOBI: Is there anything to be drawn between the scenarios, in terms of which ones produced the highest wholesale electricity prices?

MR GRAHAM: Yes. The highest wholesale electricity prices under renewables thrive, and that's because they're solely using renewables in the centralised generation sector, which is more costly, whereas the other scenarios are using fossil fuels and renewables together, which is cheaper.

And the minor differences between set and forget versus rising to pressure and leaving the grid just represents that there's a stronger demand for set and forget than the other two. So you tend to get higher prices with stronger demand growth, because of how it changes the market balance. When the market's a bit tighter, you get higher prices, as opposed to right now, when the market's very weak and we've got low prices.

MR JACOBI: A sensitivity case was done, which included nuclear, as that was in 2012, and I just wondered whether you could explain that and any observations you've made subsequently about the reason for, or any different view that you've come to now, in terms of the prices that you'd use.

MR GRAHAM: Our standard approach, because nuclear is currently prohibited is, that we don't include it in our technology set, but the model can select it. So when we do a nuclear scenario, we have to change the model to allow it to select nuclear power. When we run that type of scenario using the Australian Energy Technology Assessment 2012's cost assumptions, nuclear power is cost competitive under those assumptions. So we find that nuclear power becomes a very significant share of the electricity generation mix, and you get a lower wholesale electricity price.

So that just reflects that the AETA 2012 cost assumptions are allowing for that outcome.

MR JACOBI: Do you have a view about those particular cost assumptions now, whether they've changed?

MR GRAHAM: They have changed, they've put an update out in 2013. It was unfortunately after we did this report, so we haven't rerun that. They increased the cost by about $2000 a kilowatt, which is sort of, roughly, 50 per cent. So it was a significant increase, but that wouldn't be enough to rule out nuclear power; it's still cost competitive at higher cost (indistinct)

MR JACOBI: I think we've got a slide that might show the table. I assume the 2013 figures are the brief figures?

MR GRAHAM: Yes, that's right. So the Bureau of Resource and Energy Economics had its 2012 figure, which we used for the change in choice: The Future Grid Forum work, and then they updated that in 2013 and we used that another piece of work we did called the Climate Work (indistinct) work and, as I said, yes, it was a significant increase.

MR JACOBI: Now, perhaps we can move away from the change in choice in 2013. We understand that there is to be an update of the future grid formwork in 2015?

MR GRAHAM: Yes.

MR JACOBI: Can you explain what the objective and purpose of that is going to be?

MR GRAHAM: So we're currently working with the Electricity Networks Association to think about - given the issues that the Future Grid Forum highlight in 2013, we're looking to understand how we can address some of those issues, but before we do that we're updating and refreshing the modelling of those four scenarios that I discussed earlier. So as part of that process, we're looking at all of the assumptions and trying to understand how the situation has changed in the last two years.

MR JACOBI: We've got a document which is entitled Workshop Draft of the

Electricity Network Transformation Roadmap. Does that contain what will be the final figures, or what's the purpose of that document?

MR GRAHAM: In that document we set out our initial ideas about what had changed and how we might go about changing our assumptions. Yes, we made that freely available on the Internet and we also took it to a workshop to get some feedback. So it's not the final assumptions, but will be - it's fairly close to our thinking and we're publishing the final assumptions in about a month's time.

MR JACOBI: Right, and in terms of the re-running of the Future Grid Forum scenarios, when is that likely to occur?

MR GRAHAM: That's happening at present, yes.

MR JACOBI: And so in terms of a revised FGF, will that be done in a month or is that going to be at some later time after that?

MR GRAHAM: It's in about the same time frame, yes.

MR JACOBI: Now, I think we've got a slide that picks up the key changes that you've identified from 2013. I'm just wondering whether you could take the Commission through those key changes.

MR GRAHAM: Yes. The major change that we noticed from our 2013 perspective was we - in 2013 we underestimated how quickly solar and battery costs have fallen. So they've fallen faster than we expected, and looking back on 2013 we didn't have much of a view about how solar would be distributed across the States and they are quite different. So, for example, South Australia and Queensland have very high solar adoption rates compared to some other States. On the issue of demand, we rely on input from the Australian Energy Market Operator and we do know that they have decreased their projections for demand since 2013, and they've also increased the range to the extent that their highest and lowest scenario is now much wider than it was in 2013. So I suppose we could say the outlook for demand is lower but more uncertain.

On regulation there's probably two important things to note. One is that in 2013 it was quite obvious that tariff reform would be required to address some of the issues that we'd identified, and so we had expected that moving forward retail prices would change quite a bit, but so far retail tariff structures haven't changed significantly in two years. The other thing is that there's been quite a significant reduction in networks' costs imposed by regulators. So that's significant in terms of the outlook for network charges.

On the policy side, there has been a revision to the renewable energy target.

There's the reduction from 41 down to 33 terawatt hours for the large-scale renewable scheme. We've got some clarity around Australia's emission reduction target that we're going to take to Paris, but the form of the carbon policy still isn't settled. And finally, on fuel prices we had quite a significant crash in the oil price at the end of 2014 and that's flowing through to gas prices, and also the coal market is very weak as well. So overall, fossil fuel prices are a lot lower in the medium term compared to what we thought they would be in 2013.

MR JACOBI: Now, with respect to the refreshed Future Grid Forum outputs, are the four scenarios to remain in substantially the form that they were when it was originally modelled in 2013?

MR GRAHAM: They are fairly similar. So we'll be updating all of those things that I just talked through, but other than that, we're really keeping the essence of the scenarios, as I had explained them, just as they are, because we wanted to recognise that assuming it worked that the electricity industry (indistinct) developing those scenarios in 2012 and 2013.

MR JACOBI: And will there still be a sensitivity case done against set-and-forget and nuclear?

MR GRAHAM: We're looking at a number of sensitivity cases. To some extent, at this stage we weren't thinking about doing a nuclear case, mainly because I'm not sure that we're learn anything more, but we'll have to see. I think if we impose the 2013, which is the last update, what you'll still find is a similar answer, in that if you allow nuclear it'll come into the electricity mix if you assume it's not prohibited. But having said that, at the moment we're waiting on another update to technology costs which is being conducted by CO2CRC. If we look at their update and we see that nuclear costs have risen substantially again, we might have to take a look and see if under those new costs whether that changes the outlook for nuclear or not.

MR JACOBI: In the transformation roadmap there's a chart that sets out and describes particular pathways or potential pathways for electric vehicle adoption, and I think we've got it on a slide.

MR GRAHAM: Yes, that's right. One of the things we had to consider was whether we should take another look at electric vehicle assumptions across the scenarios, because at the time these were projections that came from our model and we wanted to check whether people were finding different outcomes. Our reading of what's available is that people are fairly confident that electric vehicles would eventually have a place in the right vehicle (indistinct) what we're mostly uncertain about is the timing rather than whether they have a role, and that timing is very difficult to predict.

We need global electric vehicle production to scale up to an efficient scale to bring down the costs of electric vehicles, but if you look at our factory cost projections, if we're assuming batteries get down to that sort of $200 KW level, and if we consider the amount of batteries that an electric vehicle needs, if you put the two figures together you kind of arrive at a point where an electric vehicle - at least the batteries should only cost about four or $5,000, which you can kind of easily recover that cost within a few years from fuel savings.

So it's kind of chicken and egg situation in the sense that it appears that electric vehicles will be cost effective once they're produced that efficient scale but we have to wait until they reach that scale before the costs come down and that's what makes it so tricky to project. Having said all of that, the conclusion that we arrived at was that the update that we were projecting across the scenarios, which was sort of between about 20 and 40 per cent was still plausible. We'll be making some minor adjustments, but that's still the range that I'm thinking about. There has been some work - you'll see there's an outlier projection in that chart which is some work that says ClimateWorks did decarbonisation project and - - -

MR JACOBI: Does that require positive government policy?

MR GRAHAM: To be honest, with electric vehicles, in the long run everyone's channelling cheaper. So it's the technology where, once we head down that pathway, we'll be able to - we'll actually get lower cost travel so the question is how do you get it started. For that particular scenario, what's sitting behind that is that we're looking at a particular scenario where Australia was doing a very deep decarbonisation. So that has driving that a fairly high carbon price environment.

MR JACOBI: So consistent with ClimateWorks, it's a 450 ppm outcome, is that right?

MR GRAHAM: Exactly, yeah, and in fact to make it even simpler, the goal there was for Australia to have zero emissions by 2050.

MR JACOBI: Am I right in understanding - I think I may have read somewhere that represented the maximum adoption rate, that is essentially it reflected the vehicle turnover rate in Australia?

MR GRAHAM: Yes. We - what we did there was to decarbonise - or to electrify every vehicle that we thought was suitable for electrification and so the only vehicles that we didn't think were suitable for electrification were the long haul trucks, because of the pay load and distances that they travel. So you can think about every light vehicle and some of the (indistinct) trucks fully electrified. Some of them are still hybrid - plug in hybrids, but they might have an internal combustion engine to suddenly be longer range driving. In fact, that could be actually a significant part of the fleet, but when I say (indistinct) electrified, I mean they're doing 80 per cent of their trips purely on electricity.

MR JACOBI: I think that actually might bring us to the underlined work that was done behind the ClimateWorks decarbonisation that we've discussed a number of times, and about which Anna Skarbek's given evidence about in the Commission, and I think that might take us to her first slide, that there is an assumption of an increased use of electricity.

MR GRAHAM: Yeah, that's right. So when you're thinking about the question of how do I get to zero net emissions for Australian, it's - the pathway that we thought would make the most sense would be if you're going to make electricity zero emissions, that it then makes sense to use that electricity in every other sector where it's possible and so we've just talked through the transport sector, so it makes sense to - rather than use - because there isn't enough - we've got limited bio-fuels, so it's a matter if we can electrify the transport fleet and then rather than using gas in buildings, electrify all of the buildings so that takes gas and oil out mostly and then there's industrial processes again as well, where you can - not all of them are suitable but there's significant suitable for electrifying, and what that leads to compared to - for example, most of the future (indistinct) scenarios only get to about 300 to 350 TW hours by 2050, but this scenario takes you into a very high demand growth scenario of just over 600 TW hours by 2050 because of all that transport electrification, building an industrial process electrification, and I should say that the ClimateWorks team were a group that looked at all that building, and industrial process electrification whereas CSIRO was doing the modelling around the road electrification.

MR JACOBI: I've got a final slide which was one of the outputs of the ClimateWorks analysis where a nuclear was allowed into the analysis.

MR GRAHAM: Yeah, I should say that we looked at three different ways of achieving a zero or near zero emission electricity sector. We looked at doing 100 per cent renewable, which is sort of similar to the “renewables thrive” scenario we were talking about earlier. We also looked at combining renewable with carbon capture and storage and then we looked at the scenario which we see here, where we're combining nuclear and renewable, which is obviously another way you get very, very low emissions in the electricity sector, and what we've found was - we were a little bit surprised initially that nuclear was only 14 per cent of the share of the electricity mix and when we looked at it, what we realised was that because of the electrification that was going on in the industrial sector and the growth in mining that was still occurring in Australia, a lot of the electricity demand had shifted over to a number of mining states like Western Australia, and one of the rules that we had in our model was that Western Australia couldn't take up nuclear power because - well, I mean one of the very big issues is their north and southern parts of their electricity systems aren't actually connected and other parts of their electricity system are more like separate micro grids rather than a fully interconnected systems, and that's why we're thinking large scale nuclear power wouldn’t be appropriate there.

So when we thought about it, we thought well, we can't save much more than that at that stage. What probably really needs to happen there is more of an understanding about how the Western Australian electricity system would evolve under this job growth, but just so that we could get a bit better understanding, we did change the assumption in the model to allow Western Australia to take up nuclear power, so that either assumes that they build a stronger grid, a more interconnected grid, or maybe they switch to something like the small modular reactors. So either way, they achieve that. We assume they can do that and that doubles the amount of nuclear in that electricity mix from 14 per cent to just under 28 per cent. 27 per cent, yep.

COMMISSIONER: I think, Paul, that pretty much raps up everything. Thank you very much for the time you have spent with us and for your contribution.

MR GRAHAM: Thank you.

COMMISSIONER: Thank you. We will now adjourn until Thursday morning, 1 October, 0800.

MATTER ADJOURNED AT 3.39 PM UNTIL THURSDAY, 1 OCTOBER 2015