RESUMED **[11.14 am]**

COMMISSIONER: Good morning, we reconvene at 11.15 with analysis of electricity generation from nuclear fuels and I welcome Mr Robert Riebolge and Mr David Lenton. Mr Jacobi.

MR JACOBI: Quantitative viability analyses of electricity generation from nuclear fuels. Quantitative viability analyses will be undertaken to assist the economic viability of integrated nuclear power generation technologies in to the suite of renewable and fossil fuel technologies that are likely to supply the national electricity market during the years of 2030 and 2050. To that end, explaining that analyses are Mr Robert Riebolge and Mr David Lenton.

COMMISSIONER: Mr Riebolge please start.

MR LENTON: Thank you. (indistinct) take you to describe (indistinct) our approach. So this morning's agenda breaks down in to four areas, two slides or (indistinct) objectives and (indistinct) approach. My colleague Robert – we are just going to run through our approach to forecasts in South Australian demand and the (indistinct) mix in South Australia. We have then got a review of the economic model, the (indistinct) principles that have been applied and the cost and benefits of being assessed and then our approach doing sensitivity and Monte Carlo analysis. I put this break down as following, first is to quantify the economic viability of a nuclear generator being commissioned in South Australia in either of the years 2030 or 2050. So we are looking at two entry points. In either of those situations, the construction and the pre-construction activities would need to take place several years earlier if the plant is to Commission on those dates. To try and make it a realistic assessment we are comparing four separate alternatives. One being small nuclear, the second being a large nuclear plant but we are also considering more conventional plants such as CCGT and also a CCGT with carbon capture and storage.

We will consider the viability against a range of scenarios for demand in terms of how demand growth may rise over the next 10 years and if we go to 2050 the next 35 years and also a range of mixes of renewable generation. The model allows you to test a variety of different options that could emerge. Finally, we are producing a flexible and transparent model that allows the user to modify many of the assumptions and the inputs themselves and consider what impact that has on the relative MPVs of the four options. The net present value is basically a summation of the present value costs and benefits of the different options, a really good way of comparing the four options.

MR JACOBI: Just before we move on, perhaps you could just explain what CCGT is?

MR LENTON: Okay. CCGT is a combined cycle gas turbine plant which is one of the more efficient gas turbine plants that exist at the moment. So our approach breaks down in to the following steps. First is an assessment and projection of demand for South Australia and that will be built up from a number of historic demands, that’s broken down in to discreet elements and my colleague Robert will say a bit more about that in a minute. We will then forecast the amount of renewable generation in South Australia, building it up with projections of PV, of wind, of storage and of solar thermal technologies. Using those two inputs we can then calculate the output that may be required from South Australian generators and the potential to send energy over the interconnector, with a range of interconnectable (indistinct) that can be applied. Moving on to the economic models then we applied some generator assumptions around fuel costs and how they may operate, to determine the costs and benefits of the different options and then run some Monte Carlo analysis to assess the sensitivity of the results.

The model runs as an integrated model, so changing any of the demand renewable assumptions right at the top of the model, will flow through and impact the MPV of the different generation options that we are considering. I am going to hand over now to my colleague Robert Riebolge and ask him to talk through the demand and renewable.

MR RIEBOLGE: Thank you Dave. We have been fortunate to have historic data sets of half-hourly intervals from the South Australian grid and these have been provided courtesy of SA Power Networks. They disaggregated in terms of demand by a major customer category, business category, residential category and hot water load and renewables, photovoltaics and wind generation. Here is an example of a data set for the business category with the settlement day on the left hand column, settlement hour – half hour sorry, next to the settlement date and across the top is the months and then the entries, the measured entries are in the table there as an example of half hourly data. The importance of half-hourly data is that we can measure characteristics of different consumer categories in terms of peak load values and durations. We can identify temporal and seasonal variations. We can identify characteristics of consumers by disaggregated business and residential. The finer half-hour granularity means that load shapes more closely mimic the real-time load shapes which gives greater confidence in terms of forecasting load shapes and leads to statistically more credible forecasts.

Here we see a residential load shape mapped against the background of a system demand and we can see for the load to normal demand month on the top slide there's not a great degree of variability. However, on the bottom side we see that there are significant peaks which we can pick up with this finer granularity. Those peaks basically are driven by the residential demand and the air-conditioning load on a period of hot days. You can see that trend upwards to the maximum on the lower side. For business, however, we don't have that seasonal variation but what we do have is a temporal variation. You can pick out five peaks during the weekdays and on weekends it falls away to virtually nothing. It is simply that underlying base load for the business category.

With photovoltaics takes are mapped against the background of the system requirements. We can see that they are fairly small at the moment. We can't quite see the seasonal variation but we'll see that in a couple of slides to come. Wind, on the other hand, is getting close to meeting almost the entire system requirements on a normal to low-demand day. Peak-demand day it falls away somewhat. There's a fair amount of deficit there to be made up. This is an interesting slide. It shows the fossil fuel generation in the South Australian grid with intermittent renewables. We can see that there's hardly any base load there. Consequently, to have fossil fuel plants operating in base-load mode they have to take advantage of the interconnector which connects the South Australian system into the National Electricity Market which includes Tasmania, Victoria, New South Wales and Queensland.

Now we're going to zoom down on particular days, a maximum-demand day and a normal minimum-demand day. They're the system requirements. Here we have the components that make up those system requirements. At the bottom is the major customer load, almost flat. Next comes the hot water load which contributes to a mini spike, a mini peak. Then we have the business load which is significant in terms of the total system demand. The residential load makes up the entire system requirements and we can see the peaking impact of residential load in a summer month.

Here we have a slide which shows the variability of photovoltaics at the top. We can see that during summer fairly constant sunshine, during winter cloudy cover and the demand falls away and is variable. It's only half the production of the summer month. The bottom slide is winter. We can't really detect any seasonal variation there. All we can say is that there's variability across the day. This is mapped out at period of months and again we can see the seasonal variability of photovoltaics but not so much in terms of wind. It's just an intermittent supply.

Here we zoom into the historical generation which is meeting the South Australian system requirements and these are photovoltaics. At the moment not much in terms of total system requirement but is increasing very rapidly. However, wind is a significant contributor and you can see in the top slide there that between wind and photovoltaics they make up about 40 per cent of the total system requirements. Bottom slide, a significant amount of deficit to be made up. That is made up with fossil fuels at the moment and we can see that in the beige-coloured area.

In terms of the system model we're forecasting an example here to the time horizon of 2030. We need to forecast out the categories of demand that we have already which are business, residential, major customer and hot water load but we have two further categories that forecast out to 2030 and that is cogeneration and electric vehicles. The four categories of cogeneration, we can set values at high, low or medium. Cogeneration can be set on or off and electric vehicles can be set as a percentage of the total vehicle population in the 2030 time horizon.

MR JACOBI: Could I just stop you there. Could you just explain a little about what high, low and medium might mean in the context of those categories?

MR RIEBOLGE: Just about to do that. We can see here the example of inputs to the demand model in 2030. The high, low and medium values select a growth factor or an application factor, parameter factor. In the case of business we've selected medium, 1.2 per cent growth per annum. Residential, medium, 1.5 per cent growth per annum. Major customers, medium again, .2 per cent growth per annum. Hot water load is a regression of minus .2 per cent per annum. Cogeneration we've set to off and electric vehicle market we have set to 25 per cent of the vehicle operation in 2030.

Having inserted those into the model, the model generates these load shapes, the system requirement, on a low to medium day at the top and a high demand day at the bottom. We can see that the major customer load forecast of 2030 is still a very small component, flat, of the total system requirement. Hot water loads still contributes to some mini peaks but not a significant part of the system requirements. Business, of course, makes up a substantial amount, as it did in the historic slides that we had a look at just before. Of course, residential continues to contribute to that peak. However, we have another load here and that is electric vehicles. Interestingly, electric vehicle demand makes a significant contribution in a low demand day but in a high demand day it exacerbates the peak, which has to be dealt with.

Now, we have to imagine ourselves in 2030 with what sort of technologies are going to be available to us. The models identify the number of technologies. One is the penetration of PV in the business sector. The other is PVP with storage which are basically batteries. There'll be batteries in the home or in the residence. Wind paired with storage. This would be grid storage, wind-installed capacity, solar thermal plant, nuclear plant, interconnector constraints and vehicle to grid penetration. Vehicle to grid is simply a mechanism which enables the grid to tap into the energy store in power batteries. Again, we have variables that we'll go through in a moment that we can allocate to the model.

In this case we have allocated a variable of medium penetration for business categories which is 30 per cent, penetration in the residential sector is saturated, PV paired with storage high we've selected at 80 per cent, wind generation paired with storage we've selected at high of 60 per cent, store capacity of wind 2000 megawatts, SDP, medium at 200 megawatts, interconnector constraint medium at 650 megawatts and vehicle to grid penetration at 40 per cent. The technology parameters for PV and wind generation are either the historic data sets and for the others simply the installed capacities which determine the power that is generated. This reminds of us of the system requirements but in these sequence of slides we will have a look at how the generation meets the system requirements. PV on its own is still making a minor contribution but a contribution to the system requirements. But next we have PV generation paired with storage and what we see here is that in this instance the generation is flowing right throughout the day, not just for a period of the day. It also assumes future knowledge of the system demand which we all know in a probabilistic world is an impossibility. However with the distribution of distributed generation throughout the smart grid which is happening with photovoltaics and photovoltaics paired with storage and the advent of big data which we have alluded to, it is very likely that by 2030 mathematical algorithms will have been written which can predict fairly closely the demand curve. Consequently this is a fairly good approximation of what will happen in terms of the rules for releasing from storage.

Here we have wind on its own, not much we can do about that, simply goes in to the system to meet the system requirements and here we have wind paired with grid storage which releases the wind in a rule similar to what photovoltaics paired with storage does. We then have vehicle to grid which is very small amount but then the population that we have assumed is small and as the population of electric vehicles increases, this will increase as well. Here we have the solar thermal plant which generates at its installed capacity and we can see on the top slide that renewables have made up almost the entire system requirements. On the bottom slide, there is still a significant gap to be met. This is nuclear generation which satisfies all of the requirements on a medium to low demand day and is significant the amount of generation on a high demand day. The remainder is met by fossil fuels that are in the system at 2030.

In terms of exports, quite clearly on a low demand day, we have substantial amount of surplus power and we can make use of the interconnector which I have alluded to just previously to transfer surplus power in to the NEM. The model generates this profile for the export, for the example that we are looking at and we can see that the first renewable to be exported is just a small bit of wind paired with storage followed by a small bit of vehicle to grid and a reasonable amount of solar thermal plant. The remainder however is nuclear plant which is being dispatched after all other renewables have been dispatched. However, we are limited in terms of the amount that we can export by the interconnector constraint. Consequently, we have one or two options, well we have two options, one is to remove some of the constraints or relax some of the constraints of the interconnector or alternatively if we look back at this slide here to insist that the nuclear plant is dispatched ahead of some of the other renewables. The model then is able to do all of those things and it populates this table with information which is needed for the amount of energy sent out in the South Australian grid and the NEM. In the different dispatch modes for the different types of plant under consideration, including CCGT, small nuclear, large nuclear and CCGT with CCS. This is input to the economic model which David then works on.

MR JACOBI: Perhaps before we go to Mr Lenton, I just – perhaps if we could just clarify that you have shown us a series of slides that I assume are based upon a series of assumed technological inputs and technologies within the network and that they are examples. Is that right?

MR RIEBOLGE: That’s right. That’s correct. Yes, they are all examples and they can be varied at the user’s discretion.

MR LENTON: The economic model then builds on the information that will come from the demands and generation scenarios and it is worth just recapping on a couple of high-level principles. The first is that we are focussing on the commercial viability of a nuclear generator or a gas fired generator in 2030 or 2050 but we are looking only at the viability for that specific generator. We are not looking more widely at societal benefits or some of the jobs that may be created or some of the other (indistinct) that are not captured by the market place. We have assumed that the value of carbon will be captured through some form of carbon price. It is fairly uncertain at the moment exactly how carbon will be priced in the future, so we have applied a proxy which is a form of carbon price but within the model we do allow the user to select different carbon price options which can materially affect the results. The user can also select a number of other inputs that will affect the generation requirements from any of these plants and that includes the amount of renewable generation, the demand scenarios, the dispatch mode that Robert has just mentioned and also the level of (indistinct) availability that may be assumed from the different options.

So the model breaks down in to a number of different costs and benefits that were assessed and I have got one slide on each of these coming up in a minute. But on the major cost side we have got six main elements, we have got the capital cost from the construction of the plant, we have got the variable fixed operating and maintenance costs during the life of the plants. We have got fuel costs and carbon costs for the different options, decommissioning costs for – particularly for the nuclear options and then connection and network upgrade costs where these are required. Then benefits divide up in to two areas, firstly there will be sales of electricity in to the South Australian market and then sales of electricity via the interconnector in to the NEM. So the first and the most significant cost, particularly for the nuclear options is the capital costs of plant and this has been built up from overnight in dollars per kilowatt capital cost that are being supplied by some of the other advisers that have been employed by the Commission. We have taken these inputs and we've taken a profile of those costs and we applied interest during calculations and for the nuclear option we have also taken appropriate exchange rates to come up with a cost that go in to our economic model.

The model has been set up to allow different discount rates to apply separately for all generation options to reflect the different levels of risk that may be applied for the different technologies although we are still working with the Commission to decide what discount rates should be applied for the different options. And the model will also include the option for the user to assess the impacts of scenarios around budget overruns or delays in project completion. At the central value is that (indistinct) they can be varied to understand what impact that may have on the relative (indistinct) of the solutions. So the next element of cost is the operation and maintenance costs. On the fixed side, the fixed maintenance costs are almost all the nuclear costs have been assigned to this bucket and it breaks down for the nuclear stations in to insurance costs which have been separately split out, costs for overseas work which has been captured in US dollars and then local work that is required to maintain the plant. We have also got fixed costs for the local plant as well. The variable costs are far more significant for the gas-fired plants where some of the maintenance costs are based on running hours and therefore as running hours are incurred, the variable costs (indistinct) incur that way.

One thing that is different about these costs to some of the other costs is that they escalate in real terms over the course of the model, so the percentage at which they increase is greater than CPI and therefore an escalation factor has been built in to the model for these costs. Fuel costs have obviously been included within the model for the nuclear costs, so being providers and dollars per megawatt hour sent out option and they include the cost of enrichment as fabrication as well as the cost of fuel itself. They have been provided in US dollars so the model will convert back to Australian Dollars in its comparison, and clearly the exchange rate used will impact the working viability.

Gas prices are going to be provided as a gas price trap with full prices of gas prices over the lifetime of the model. Gas prices have changed a little bit recently where there's been some significant movements, but this is a long term price production that we've produced by one of the Commission's adviser. It means that a very significant amount of the total cost for either of the two gas part options and that total cost is obviously reflective of both the actual price of gas, but also the assumed efficiency of the gas plants, and one of the expectations within the modelling is that both gas plants improve their efficiency between now and 2028 when they'd need to start being built, and again that's based on the advice of other advisers that have been appointed by the Commission.

Carbon costs have been included within the model and for the CCG2 part they're based on calculation of the tonnes of CO2 that were emitted, and the carbon price that is assumed to apply, and that's been calculated again separately by an adviser to the Commission, but it's going to be based on the 450 parts per million target, but there will be options with the modelling to consider other targets for carbon reduction and what that does to the carbon price.

For the CCCG2 with carbon capsule storage there's a cost for carbon preservation and transportation, so for storing the carbon and a carbon capsule - carbon cost for the uncaptured percentage of emissions, typically the CCS will economically capture around about 85% of emissions with the remaining emissions still needing to attract some carbon price. The model assumed that there were no carbon costs association with nuclear fuel, so it's ignored any carbon costs that may be associated with fuel mining and decommissioning cycles, but that is consistent with how we've treated other fuels within our analysis.

We would also be separately calculating the total carbon amelioration benefits from the four options, although that won't feed into the MPV analysis, that will just be provided as separate information in terms of what the tonnes of CO2 saved from the various options may be. Connection costs will be included for all plants. These are reasonably small in comparison to some of the other costs that we've seen. We also have infrastructure costs for each option which could be road and (indistinct) upgrades that might be needed for some of the plants.

For the large plant option we've also included an assumption that a transmission inter-connector upgrade will be required, that will run all the way from Victoria through to South Australia. But we do have an option to determine what level of contribution from the large nuclear plant should be made for this upgrade. This upgrade will obviously be useful for the large nuclear plant, but it could also be useful for other renewables within South Australia, because they would be able to export a large amount of time if the inter-connector was upgraded.

The final cost line is on decommissioning costs. These are costs (indistinct) plant will apply at the end of the plant life and we've been provided with estimates of these costs, and we'll be applying an escalation factor which is assumed to apply to the end of the model. We've also included separately cost estimates for dry storage, which is based on a dollars per megawatt hour levy expected to cover the cost of the facility. There will also be costs for wet storage, but they've been covered within the fixed operation and maintenance costs that we mentioned earlier.

Some (indistinct) costs is going to depend on the expected cost, the life of the plant and the assumed discount rate. The higher the discount rate, the longer the life of the plant (indistinct) appear smaller in their present value terms. For completeness, we have also included retirement costs for the gas plants, but these are relatively low in materiality, in the scheme of things. So on electricity sales - these have been split between sales in South Australia and sales across the inter-connector to the rest of the (indistinct) and we've made adjustments for the margin or loss factors that will need to apply in both of those instances.

Robert's already mentioned that the model can test different levels of inter-connector capacity and we'll also be applying differential prices which should arise out of the market modelling results, and put those into our modelling. Just one slide there and up on the data sources that we have used within the model. They've all come from recognised sources and one thing that I want to be stating is that within our model we will be carefully lifting each data source for each input so it's very clear how everything has been devised, and if people disagree with it that's their right, but it should be clear how the model's been put together and where that information's been derived from.

I've got three slides to wrap up on sensitivity and Monte Carlo analyses, and I'll try and be reasonably brief - I know we're towards the end of our time. So I guess the first - it's just a question why do we need sensitivity analysis? I guess there's a lot of uncertainty in this MPV modelling because we're looking at plants that won't start for 15 years or 35 years, and then will run for up to 60 years after that point. So we've got a lot of uncertainty around a number of the variables, and therefore what we've done is to create a most likely value and then a high or a low value to assess what the impact will be if the high or low value were to apply in the model, and we've selected a number of variables that are picked up here.

We've got fuel cost variations, we've got parameters that relate to the initial capital cost - that will be the overnight cost, the discount rate, et cetera - the efficiency of the plant, the variations in wholesaling carbon prices, the operations and maintenance costs and for the nuclear option, the exchange rates where a number of the costs have been applied in US dollars, and this range of likely values is tested in a tornado diagram and a Monte Carlo analysis, and I've got one example slide of both of these coming up.

One thing I do want to stress is that these examples are based on illustrative data, they're not based on the final set of datas. They're provided as an example, so users can understand the sorts of outputs a model will produce but these aren't final data. So this is an example of a typical analysis for the MPV of the CCG2 plant. The central line shows the most likely prediction and then the bars either side indicate the impact of each individual variable applying separately from the other end of the high and low extremes. So the first example is the variation in the wholesale price with the carbon element taken out - could increase the MPV if it was 10% higher by looking at those two bars, $200 million - the bars each represent $100 million movement.

So we can see that some of these variables are highly important in terms of the MPV. Obviously the options - and the sort of things that are showing up high up on the list for the combined (indistinct) gas turbine plant and the wholesale price, the efficiency of the plant - but obviously that will impact how much gas is used - and the percentage change in the gas prices, the gas prices different from what we predicted then clearly that will impact on the viability of the plant.

So my final slide is just to give an example of the Monte Carlo analysis that will be produced by the model and this is applied using an Excel add on from Oracle called Crystal Ball, but there are many other similar tools that can also be applied - and what it does is it enables you to vary all the key parameters according to a defined distribution and provides the range of possible results by doing a large number of trials. This particular option we see, that the trial's ended up with a mean of minus $100 million, but a fairly large range that goes from positive $260 million to minus $460 million. So a reasonably large range of outputs with 30%, be it above zero and the aim within the model is obviously to understand the range of results, but also to find - come up with a reasonably tight range for the key parameters, so that the overall range that you get from your simulated model gives you some certainty around the expected number that will be derived from the model.

COMMISSIONER: Gentlemen, thank you very much. We'll adjourn to 1200 when we'll regroup to discuss the general equilibrium modelling assessments.

ADJOURNED **[11.50 am]**