RESUMED **[3.00 pm]**

<PROFESSOR DAVID KAROLY, UNIVERSITY OF MELBOURNE, VIA VIDEOLINK

[3.00 pm]

COMMISSIONER: Professor, good afternoon. We re-convene at 1500. Thank you very much for joining us?

PROF KAROLY: You're very welcome. I'm happy to assist the Commission in any way that I can.

COMMISSIONER: I'm just delighted that the technology is working, this time?

PROF KAROLY: Yes. Well, I'm sure you are, and I am as well. We've tested this a number of times, with video conferences everywhere, and it's not quite a matter of luck, but yes, having a tested system works better.

Okay. Mr Jacobi?

MR JACOBI: Professor Karoly is a Professor of Atmospheric Science in the School of Earth Sciences, and the ARC Centre of Excellence for Climate Systems Science at the University of Melbourne. He's an internationally recognised expert in climate change and climate variability, including greenhouse climate change, stratospheric ozone depletion, and inter-annual climate variations due to the El Nino Southern Oscillation, and he was heavily involved in the preparation of the fourth assessment report of the Inter-Governmental Panel on Climate Change, otherwise known as the IPCC, released in 2007.

He's a member of the Climate Change Authority, which provides advice to the Australian government on climate change policies. He's also a member of the Wentworth Group of Concerned Scientists, and he joined the School of Earth Sciences in May of 2007, as an ARC Federation Fellow, funded by the Australian government.

We call Professor David Karoly to the Commission.

COMMISSIONER: Professor, can I start with a broad question? We're clearly very interested in climate change, and the potential energy responses. We've had a brief from Professor Garnaut, and it's very important for us to get to the widest possible range of views, so please don't be inhibited. I'm sure you wouldn't.

Let's just start with the scientific consensus in respect to climate change predictions, and their affects. Could you just give us a brief overview of your view, and where you see this going internationally?

PROF KAROLY: Certainly, very happy to do that. Maybe I should start off by saying that I did provide input to Professor Garnaut's reviews of climate change and policy options in 2009, and so while you won't get, necessarily, completely different views from myself and Professor Garnaut.

I am a climate scientist who will use, in fact, much of the material that I will draw from is from the most recent inter-governmental panel on climate change assessment, which was released in 2013 and 2014.

I'm going to start by maybe just giving a little bit of background. To understand future projections of climate change, we also have to understand what has happened in the most recent century, because it provides a context for looking at how climate change is likely to change in the future.

If we could go to slide zero first of all, Lucy? This slide shows the changes in observed global average temperature over the last 150 years, in fact, from three different observational estimates. It shows that, not surprisingly, there are large year to year variations of climate and global average temperatures, but over the last 100 years, there's been a pronounced increase of about nine tenths of a degree over the last 100 years.

The period from 1850 to 1900 was relatively stable temperatures, but each of the most recent three decades has been hotter than the previous decade, and hotter than any other decade since 1850, in global average temperatures. So the conclusion then, from the Inter-Governmental Panel on Climate Change is, that warming of the climate system is unequivocal. There is no doubt that the climate system has warmed, and is continuing to warm, and that, in fact, many of these observed changes are unprecedented over time scales of the order of decades, to millennia.

If we go to the next slide, slide 0B, we then look not at the temperature or other aspects of the climate, but in fact, the greenhouse gas concentrations in the atmosphere. And in particular, this slide shows the carbon dioxide concentrations in the atmosphere, which are now close to 400 parts per million. The time scale on this slide is only from 1950 to the present, because that's, in fact, the period for which we have accurate instrumental observations, at a number of different sites remote from human activity, which is showing the background concentrations of carbon dioxide.

This concentration of 400 ppm of carbon dioxide in the atmosphere is higher than at any time, in at least the last 800,000 years. And that's why the IPCC talks about climate change being unprecedented, on the time scales of millennia; 800,000 years, nearly a million years, in this case. At no time in the last 800,000 years was carbon dioxide concentrations higher than 300 ppm. So we've actually had something like a 30% increase in carbon dioxide concentrations in 100 years.

There is lots of evidence, if you like, unequivocal evidence, that the main cause of these carbon dioxide concentration increases is the burning of fossil fuels and land clearing, which have led to the major increases in carbon dioxide. So if we want to understand how climate change is likely to happen in the future, we first of all have to look at how energy use is likely to either use, or not use fossil fuels in the future; how other human activities are likely to make use of fossil fuels, or lead to other increases in greenhouse gas contributions, like through agriculture or transport, or land clearing.

That was the reason for talking about the past 100 years, and you'll see that the conclusions from the IPCC on this slide 0B are, that it is, in fact, fossil fuel use, primarily through coal and oil and natural gas, as well as land clearing and other industrial activities that are the cause of the major increases in carbon dioxide.

I'm now going to go on, to a couple of simple slides, and then a couple of much more complicated ones, to help answer the question about what is likely to happen in the future. So if we can go to slide 1, please?

This slide now looks at projected changes in global average temperature, over the next 100 years. And it looks at this for two separate scenarios. The sort of, and I don't actually have colours in front of me, I've printed out black and white, but I think it's the upper slide, sorry the upper line is a projection of temperature changes for the period in the 21st century, relative to the average for 1986 to 2005, under high greenhouse gas emissions, or under business as usual greenhouse gas emissions.

So this is really the scenario that the world is tracking on at present, and it goes: essentially, temperatures in the late part of the 20th century showing increases for a best estimate, which is the thicker line in the middle, increasing by a best estimate of four degrees, relative to the late 20th century. If we compare the late 20th century to pre-industrial temperatures, there's been an increase of about six tenths of a degree, because this average is, in fact, in the late 1990s. So the combined temperature increase, relative to pre-industrial for that mid-range estimate is about 4.6 degrees, a little bit more.

And then there's an uncertainty range; uncertainty because there's decade to decade natural variability, and because there's uncertainties in response from different climate models associated with different representation of processes in the climate simulations. That uncertainty is represented by that shaded band, which represents a two-thirds chart of the future temperatures, lying within that range. In other words, there's about 17% chance of temperatures higher than that, and 17% chance of temperatures lower than that, leaving 66% chance within, or actually 66.67%, but that's near enough.

If we look at the upper range, it's five and a half degrees on that scale on the right-hand side, but you've got to add six tenths of a degree; it's actually more than 6 degrees above pre-industrial levels. The planet has not seen temperatures that warm for more than 10 million years. It's a very different climate.

Human society, all our civilisations have developed over the last 10,000 years, a period called the Holocene, for which temperatures haven't varied up and down more than half a degree, except in the last 100 years.

So the warming we are projecting under business as usual conditions is way, way, way outside the range that human societies have developed in over the last 10,000 years. It is a very different planet. The other scenario that is shown here, the blue – well, the blue plume as we call them, shows warming which stabilises around 2050 and only increases by about one degree relative to the 1986 to 2005 level. This is a rapid emission reduction scenario. The acronym used for that scenario is called RCP2.6. You don't need to know it; it is not a character from Star Wars, although it sounds like it. The name or the formal name for this is represented concentration pathway but again, it is jargon used only by scientists. It is in face a rapid emission reduction scenario and I will show the emission reductions on two slides later on, I think. Yes, three slides later on. But the important thing here is this stabilises at one degree above late 20th century, has warming of about one and a half degrees above pre-industrial – sorry, above late 20th century and if you then add to the six tenths of a degree there is a reasonable, no a good chance that temperatures will not warm above two degrees above pre-industrial.

The reason that I point this out is that the governments around the world, as part of the UN Framework Convention on Climate Change have agreed to limit global warming so that it does not exceed two degrees above pre-industrial. So this scenario, the blue one here, or the RCP2.6 stabilises temperatures with a good chance of temperatures not exceeding two degrees above pre-industrial. But it still has more than one and a half degrees warming above pre-industrial and that magnitude of warming is either half as much to – well, another half to one degree above current levels and already we have had significant impacts due to climate change, on a range of different natural and human systems. I will talk about some of those in a second.

If we can go to the next slide please. This shows two different maps of the patterns of global temperature change, the right hand map is the patterns of temperature change without additional warming – sorry, without additional mitigation or efforts to reduce greenhouse gas emissions. That is the planet that we haven't seen for 10 million years but notice that the warming is predominantly – well, is larger on land areas than it is in the oceans because the oceans take longer to warm up. So for Australia, we are talking about four to five degrees of warming in inland areas. For the high latitude of the northern hemisphere we are talking about six or seven degrees of warming. Really interesting thing is when we discuss climate change, scientists talk typically about global average temperature. But the really interesting thing, as far as I am aware, most people do not live in the oceans. If we look at land average temperature it is 25 per cent higher than the global average temperature. So that is what affects people and the terms of temperatures that are important for people, I would have thought politicians should be talking about the land average temperature but they don't. Scientists generally talk about the global average; land average for the high warming scenario is about seven to seven and a half degrees at the upper range. But there is still a 10 per cent chance of exceeding that, or a more than 10 per cent chance of exceeding that. If we look at the lower warming scenario, warming in Australia is about two degrees and you can see the same sort of pattern. More warming on land than on the oceans.

Can we now go to slide two? One of the biggest and most confidence impacts from climate change is rises in sea level. This slide shows the projected increases in sea level for the two different scenarios that I talked about before. The high warming scenario or the business as usual scenario and the low warming scenario, or the rapid greenhouse gas mitigation scenario. For the high warming scenario the best estimate is 80 centimetres of sea level rise, relative to the late 20th century. Although I haven't talked about it, there has been 20 centimetres of sea level rise in the 20th century, so this is one metre of sea level rise as the best estimate and more like 1.2 metres or 120 centimetres of sea level rise relative to pre-industrial. That doesn't – well, I am actually not quite sure that I know where you are in Adelaide, or whether you are on the ground floor or the first floor, 1.2 metres of sea level raise, certainly has major impacts on many of the coastal areas in Adelaide and all around Australia.

The sea level notice doesn't stop in 21.00 it continues. And even for the low emission scenario when climate change and the warming of the climate system stabilised in 2050, that low warming scenario still has ongoing sea level rise, not slowing after 2050 but continuing almost unabated. The reason is that it takes a long time for the oceans to warm up throughout their depth and for large ice sheets in Greenland and Antarctica to melt. The last time that global average temperatures were between two and three degrees warmer than pre-industrial, sea level was 25 metres higher. Over a long time period but there are six metres of sea level rise in Greenland and six metres in the west Antarctic ice sheet and they are likely to melt for two to three degrees of warming, stabilised for at least 1,000 years. The 1,000-year time scale is important because I will come to that in a little bit. But we are talking about not a sea level rise of one metre but sea level rise potentially of 10 to 25 metres. Even if greenhouse gas emissions are stabilised at two degrees warming. That is why the Pacific islanders were not particularly happy about comments that may or may not have been made by Peter Dutton to the Prime Minister.

Can we now go to the next slide, slide 3? This is a slide that I have borrowed – no, I have taken with permission from the latest IPCC assessment and it contains a lot of information. I will try to go through it fairly slowly. So the first thing that I would like you to look at to start off with is the sort of graph in the middle right hand side which has two axes. The vertical axis is temperature change in terms of global average temperature change and the horizontal axis is labelled as cumulative anthropogenic CO2 emissions. And shown on it are a series of ellipses that represent the temperature changes for a range of different scenarios with the top right hand one being described as the base line or business as usual scenario, high cumulative emissions of carbon dioxide and high warming. The sort of – not the filled in small ellipse but the one that is furthest to the left in that sort of diagonal sloping line, that represents and is labelled as 430 to 480 which represents the stabilised concentration of carbon dioxide at any time in the future, associated with greenhouse gas, cumulative greenhouse gas emissions of the order of three and a bit billion tonnes. That corresponds to that low warming scenario that I talked about before and you can see that warming is in that one between one and a half and two degrees. Notice that the slope of that line, it's approximately a straight line between higher cumulative emissions of carbon dioxide and higher warming.

The reason for that is that, if you like, the one new conclusion from the scientific studies that have been undertaken, is that cumulative emissions of carbon dioxide are the essentially the main determinate of global mean warming at any stage in the 21st century or beyond. It's not the emissions at any given time. It's the cumulative emissions since pre-industrial times. This is because temperature change is determined by carbon dioxide concentrations and although carbon dioxide is emitted into the atmosphere and is taken up by the oceans and by the plants, long-term removal of carbon dioxide requires that carbon dioxide to either be precipitated as ocean sediments through biological activity, fish, photoplankton, zooplankton taking up the carbon dioxide and then sinking to the bottom, or taken up into rocks.   If it's just in the upper layers of the ocean, it gets cycled around. If it's just in plants, in leaves, it gets cycled around as well.

The best estimate of the lifetime of carbon dioxide removal through natural processes is between a thousand and 10,000 years for the carbon dioxide that we've added in the 20th century to be reduced to 10 per cent of the increase in concentration that we've seen in the 20th century. In other words, to go back from 400 parts per million down to 310 parts per million just due to natural processes will likely take 10,000 years. This is a long-term problem. A little longer than a single political cycle.

The importance for making that is that what we're talking about is that if we emit more while we're trying to make decisions about reducing emissions, that commits to more warming. That's very important when we come a little bit later on to the rates of time needed to address climate change. There is another important aspect on the left-hand side of this, and there's a range of sort of red and orange vertical almost like thermometers - they're scales. This is what's called a burning embers diagram in the jargon. It tries to represent the increasing risk of adverse impacts in a range of different sectors from greater levels of warming.

The conclusion from many studies is that the greater the magnitude of the warming, the greater is the risk of adverse impacts due to climate change. Across there are a range of different sectoral impacts from, on the far left-hand side, unique and threatened species, across to large-scale singular events, global aggregate impacts. But the largest impacts at the lowest temperatures are occurring already for increased risk for one degree above pre-industrial levels - essentially the current observed warming - including risks to unique and threatened species and extreme weather events. We have already seen increases in heat waves and increases in wild fires and increases in risk to many unique and threatened species for this level of warming.

Remember that UN climate convention and governments around the world have agreed that limiting warming to under two degrees will seek to avoid dangerous climate change, although the impacts from climate change are already occurring. These impacts include increases in heat waves, increases in extreme precipitation events, increases in sea level, reductions in snow cover, impacts on water resources, and many, many other impacts. I'm happy to answer questions on those but the Australian government and many governments around the world - in fact almost all governments around the world - have signed up to the UN framework convention on climate change which seeks to avoid dangerous climate change by reducing greenhouse gas emissions.

The next slide - probably the last one that I'm going to cover on this context - looks at a series of greenhouse gas emission pathways and in particular looks at the scenario that is described as the baseline scenario or the high emission scenario that I showed before RCP8.5. Now the axis that's shown is not temperature but annual greenhouse gas emissions from all sources in billions of tonnes of greenhouse gas emissions per year. Not just carbon dioxide emissions but other greenhouse gas emissions like nitrous oxide or methane.

Also notice that there's a RCP2.6 scenario, which is that low emission scenario with rapid greenhouse gas emission mitigation. So first of all notice that for that scenario the peaks in emissions are essentially between now and 2030. The best estimate is a flattening off essentially from 2010 to 2020, although greenhouse gas emissions globally are estimated to be rising at the order of 1 to 3 per cent per year. Under that scenario there are good chances that the total emissions of greenhouse gases fall to zero before 2100.

So this is the contrast and we'll come back to those I think probably in response to the next question, which is in some sense what might need to be done in the future and what has to be done in terms of emission mitigation targets. So I will hand this back to you.

MR JACOBI: I was hoping that in addressing the second question, which is this issue about whether there's agreement on the pathways to reach that RCP2.6 scenario, you might flesh-out the sorts of options that governments and policy-makers have identified to achieve that overall target line.

PROF KAROLY: Sure, I'm very happy to do that. Maybe what I should do is just go through a couple of the emission reduction scenarios that are discussed in that context in response to the question 2 that you had given to me before. But the first part that's critically important in response to that, if you like, intermediate question of, "Are there intermediate steps that you can follow?" the important point to understand is that if the cumulative emissions of carbon dioxide are the dominant driver of future temperature change, the longer it takes for emissions of carbon dioxide to be reduced from present day levels, the greater warming is committed because that will add to future emissions. So delay in reduction increases the cumulative emissions and increases the future warming target.

In some sense this then leads to the concept of something called a carbon budget, the total amount of carbon dioxide that can be emitted by human activity to have a good chance of avoiding two degrees of warming. That carbon budget, relative to 2010 emissions was about a thousand billion tonnes of carbon dioxide, which sounds like an enormous amount until you divide that by 7 billion people, which is the current world's population, and you get 140 tonnes roughly per person. That arithmetic is not in this. Fortunately or unfortunately, I remember the numbers reasonably well.

So 140 tonnes per person at Australia's current rate of emissions is 20 tonnes per person. We blow our share of the global budget in seven years from 2010 in two years' time. After that Australia is in debt to the rest of the world. Now, we'll talk about more per capita emissions and things like that, as to whether that's appropriate, but delaying action burns up the carbon budget more quickly. If you don't exceed that carbon budget, if the countries still want to avoid two degrees of global warning, because of the adverse impacts of higher rates of warming, they have to reduce emissions even faster.

The slide number 5 shows a range of different if you like scenarios for changes in the use of low carbon energy sources, low and zero carbon energy sources, such as renewable energy or possibly nuclear power as their contribution to energy demand at three different times in the future, 2030, 2050 and 2100, for a range of different final stabilisation scenarios and notice that the far right-hand one is the scenario which stabilises greenhouse gas concentrations at a level that's below two degrees or about two degrees and that essentially has in 2050 80 per cent of the global energy supply being produced by - sorry, 60 per cent of the global energy supply being produced by low carbon energy sources.

If we look at this not just in terms of electricity but a range of other energy sources, that's shown on slide 6 and what this now contrasts is between the base line or business as usual scenario and the rapid mitigation or low greenhouse gas emissions scenario or the low temperature scenario, the actual emissions associated with the different sectors in those different scenarios and when we should focus on 2050 and the middle panel where it says electricity, in 2050 the best estimate from a range of modelling scenarios is that the emissions from the electricity sector have met zero emissions.

So this is a slightly different message to the one in the previous slide and that's because in this scenario there are assumptions that there are associated activities that are drawing down carbon dioxide from the atmosphere through enhanced biological uptake of carbon, through carbon capture and storage from the atmosphere, but notice that in 2100 there is large net negative. Now, at present we don't have vacuum cleaners that can suck out carbon dioxide from the atmosphere. We have some chemical processes and biological processes; chemical processes are expensive, biological processes are essentially photosynthesis. There's a lot of it but just not enough to suck it all out, in addition to what it's doing at present.

The reason for pointing this out is that there are a range of different options for achieving these emission reductions but they all require - to achieve these low emission scenarios in this ICP 2.6, it requires significant activity in terms of reduced emissions from a range of different sectors including transport, housing, industrial activity, electricity generation, agriculture and what they say are non-CO2 emissions.

MR JACOBI: Is there any sector that you identify as a need to move first or as a priority?

PROF KAROLY: Well, the electricity sector is often seen because it - and I haven't got my figures here but I think you may have seen them before and I will show it in a second for Australia, the electricity sector is the major - the largest proportion of emissions are generated from the electricity sector and there are options for electrifying transport and electrifying industrial processes that allow for zero carbon or low carbon electricity generation to replace the energy sources for many areas in transport, in buildings and in industrial activity. So increased electricity generation can reduce the emissions in a range of other sectors, particularly transport and industrial processes.

MR JACOBI: Is that as true elsewhere in the world as it is in Australia?

PROF KAROLY: Yes, perhaps even more true in some other parts of the world but it is very true in Australia as well. The difference is not the proportion of the contribution but the fact that Australia has very high greenhouse gas emissions per unit GDP and very high emissions per person, in fact the highest in the world per person for any developed country.

So then if we go to the next slide it focuses more on the Australian sector but I wasn't sure whether you had any other questions about options for emission reduction and the international sector.

MR JACOBI: Yes, I'm interested to understand what you see as perhaps the priorities and then also the issue with respect to the sort of time lines that you envisage the sorts of reforms would need to take place but if you had to pick somewhere to start, where would you start and then if you had to express a view as to how quickly you would need to start, over what sort of time frames do you have in mind?

PROF KAROLY: Sure, so the how quickly to start was 10 years ago and some countries have done that. And which sectors? It is clear that energy efficiency is the best place to start because it's a win-win situation, because reductions in energy use through improvements in energy efficiency not only reduce greenhouse gas emissions but they save the consumer money. And so I'm not an expert in many of these different areas but even I know that if I can do something that saves myself a buck and is potentially good for the environment, it's probably a win-win situation.

In practice, given that both globally and in Australia the electricity generation sector is the major contributor to carbon dioxide emissions, that would be also very, very important in changing to low emissions or zero emission technologies for electricity generation but we should also recognise that energy efficiency is critically important as well.

MR JACOBI: I think, professor, if we can go to what we've identified as a fourth question which is where you think the opportunities in future energy policy lie to reduce greenhouse gas emissions from particularly domestic energy generation. You have identified efficiency.

PROF KAROLY: Yes.

MR JACOBI: I'm just interested to understand where else you see Australia being likely to go in terms of reducing emissions, particularly in its electricity sector.

PROF KAROLY: Sure. So I'm not an energy expert, I'm a climate scientist. I've been involved in the Climate Change Authority for the last three years, have been following that closely but you have to recognise that these are things that I haven't actually, you know, specifically worked on but have been doing a lot of reading and providing advice but it's clear that for Australia most of our electricity at present is drawn from fossil fuel sources, particularly from coal. The emissions intensity of electricity from both coal and in particular in Victoria brown coal are exceedingly high and so there are major opportunities for closing coal-fired power stations and replacing them by zero carbon energy sources.

At present this is already happening through the increases in opportunities for wind power and solar power, particularly solar panels on rooves and solar hot water systems. South Australia should be proud that at various times it has had more than 50 per cent of its daily electricity generated by wind power, but that needs a much greater source to power the rest of Australia and a much wider distributed source to maintain a stable network as well as increases in a range of other renewable energy sources if they're to provide the electricity that's needed in this country.

So, you know, I can't provide details of how would I say, the mix of energy sources that's optimal. That will depend upon both current and potentially new technologies being introduced in Australia and the advice that certainly I have received from economists and from energy experts, is that there is unlikely to be a single solution providing this. What we do know is that in terms of Australia and Australia's emission reduction goals, if we go to slide eight Lucy, the climate change authority undertook an assessment of what Australia's national target should be, prepared a national greenhouse gas emissions budget, or a national carbon budget based on an assessment of what would be a fair and reasonable share of the global emission reduction budget. Then worked out what would be the need or the rate of emission reductions consistent with that, given that Australian emissions and particularly per capita emissions are very high and the conclusion was, at the stage of the 2014 targets and progress review by the climate change authority, that Australia should reduce its emissions by 19 per cent by 2020, 40 to 60 per cent by 2030 and even then the emissions budget would be zero by 2045. In other words, Australia would need to have zero net emissions of greenhouse gases by 2045. That is certainly in the time scale that infrastructure that the Royal Commission is considering would be, you know either in place or – and operating.

It is also important to understand, in the context of this budget, that given that the current government's target is only five per cent emission reductions by 2020, that that brings the time at which the cumulative emissions budget would have been exceeded earlier to 2040 or before.

MR JACOBI: So am I right in understanding that the point at which the linear reductions would then cross the X axis at a point sooner?

PROF KAROLY: That is correct.

MR JACOBI: Yes.

PROF KAROLY: 2040 or earlier.

MR JACOBI: I am interested to understand – I understand this is a projection so as to meet the goal that has been identified but in terms of the range of possible outcomes, do you have a view that it would be possible to reach with the targets, or to abate faster than is projected in this model?

PROF KAROLY: There are certainly possibilities of technologies that could reduce emissions even faster but not using existing technologies or even anticipated innovation. The developments that we used in here, both in terms of economic modelling and the need was based around anticipated, you know, innovation and developments in technologies. It does assume efficient and economically viable carbon capture and storage which does not exist as yet. So you know, some people would say that this emission reduction rate, which is how would I say, an assumption, a scenario is potentially wishful thinking because it does require carbon capture and storage, or it requires purchase of international carbon credits to achieve this significant and substantial emission reduction rate within Australia.

MR JACOBI: Going forward to the projected possibility of what the future might look like, do you think - - -

PROF KAROLY: Yes.

MR JACOBI: - - - it's possible that there is a range where, in terms of what is ultimately achieved in Australia, that it can't in fact (indistinct) by 2045, that is in fact it goes the other way and in essence there is an overshooting?

PROF KAROLY: Sorry? You mean it over achieves and the - - -

MR JACOBI: No, sorry I am - - -

PROF KAROLY: - - - scenario goes below zero?

MR JACOBI: No. The other way. That there is in fact under achievement in abatement - - -

PROF KAROLY: Okay. So if – yes, that is certainly a scenario and in fact, you know business as usual in Australia projects by 2030 a – gee, I don't have the numbers right in front of me but I believe it's a 17 per cent increase in emissions by 2030 from the 2010 levels, not a decline. So business as usual in terms of both industry growth, population growth, has growth in emissions in Australia without significant climate policies. So there are also options where greenhouse gas mitigation is successful for a period of time and then is not possible to actually go to zero emissions because of continued agricultural activity, industrial activity and things like that. Even with close to zero emissions from electricity generation.

MR JACOBI: You have explained that inherent in the model there was efficient carbon capture and storage. I am just interested to understand to what extent is there inherent in the model and when does it occur, that the coal fired power stations, or the large ones, particularly Victoria would be expected to close within that particular structure?

PROF KAROLY: I can't tell you the exact timing for that but my understanding is, and the information is in the climate change authority's report, essentially between now and 2030 brown coal electricity generation would be completed phased out. Most of that happens in the next 10 years.

MR JACOBI: As I understand it, it is – we touched on it earlier, it is possible to express those emissions reduction goals in terms of per capita emissions and I think that might be on our next graph?

PROF KAROLY: That is correct. That is correct. And so the next graph, graph number nine shows the per capita variation, well, changes in Australia's emissions in terms of per capita greenhouse gas emissions. And these include emissions from electricity generation as well as from land clearing and essentially all sources of greenhouse gases. Notice that the Australian emissions are significantly higher than even those in the United States in a per capita basis for the period since 1990. One of the reasons that per capita emissions are considered as an appropriate base, is that we have a carbon budget and we want to allocate that in some fair way around the world, it is much the same as dividing a birthday cake at a children's birthday party and make sure that the slices are roughly the same or someone is going to be unhappy. Whether that is an appropriate way for politicians to divide up the carbon budget amongst different countries or based on the population in different countries is unclear, but it is clear that developing countries have much lower per capita emissions because their energy consumption is much lower.

Even now, China's emissions, although they have grown rapidly, are still substantially lower than the United States or Australia. They are in fact now more consistent with the emissions in the EU, of the order of 10 tonnes per person and still rapidly growing. The reason for pointing this out is that even with the substantial emission reductions projected by the climate change authority, Australia's emissions still remain at the – at or about the highest per capita emissions of any country in the world, even with 40 to 60 per cent emission reductions, assuming that other countries also meet their emission reduction targets. The point for making this is that there are a whole range of metrics that can be used for comparing one country's emission reductions with another. There is no perfect comparator and this is one that perhaps emphasises the relatively high and relatively disproportionate share of global greenhouse gas emissions that Australia is making. Australia has .3 per cent of the world's population and is contributing 1.3 per cent of global emissions. In other words, Australian emissions about a factor of four higher on average than the average emissions per person and someone has to decide whether that is fair or not. That's beyond me, it's probably an ethicist, or a philosopher.

You asked before about the time line projected for emission reductions in different sectors in Australia, and I have added a slide overnight, that shows the time line for reductions in emissions in a range of different sectors. That's slide 10. This is not work from myself, but from, in fact, work that Anna Skarbek and Frank Jotzo had done for the UN De-carbonisation Project.

I'm not sure whether Anna showed this slide earlier on, but it directly addresses one of the questions you asked, which is, the time variations of energy generation from a range of different sources. It particularly shows that all coal essentially goes to zero by 2040, and certainly all brown coal will have gone to zero by between 2020 and 2030.

This is assuming, even then, some level of, modest level, of carbon capture and storage. I think it's assuming that by 2050, carbon capture and storage is not a major contributor, but then has emissions associated with natural gas, hydro, wind, solar and other renewables.

In this scenario at least, there was no nuclear option considered. But I know that in this de-carbonisation pathway for Australia, Anna Skarbek and Frank Jotzo did include an option for nuclear, although it made up a significant but relatively small, I think it was only about of the order of 20% of the low-carbon electricity generation by 2050.

COMMISSIONER: Yes, we did see that graph from Anna.

MR JACOBI: I think that leads us into, perhaps, where we might finish up, and that is whether you have a view as to whether or not energy generation from nuclear fuels might have a role to play, in terms of delivering the emissions reductions that are projected to be necessary, to avoid serious climate change?

PROF KAROLY: So you know, in my respective, nuclear electricity generation is critically important around the world at present. In terms of the per capita emissions in France or the United States, or Germany, they would be significantly higher without nuclear power. And, I should've mentioned the United Kingdom.

China and other countries are using nuclear power generation as an important contributor to their increases in energy generation, while trying to reduce, or maintain and reduce, their greenhouse gas emissions.

So it is clear that around the world, nuclear energy generation, or electricity generation from nuclear fuels will be a very important, and probably increasing source of electricity generation over the next 50 to 100 years.

How much, I'm not an expert in that, and how much there will be decisions made on safety, as it appears that Germany has put a ban on, and will be phasing out their nuclear power generation, primarily because of safety concerns over the next five years. I don't know whether that will be taken up in other countries. I mean, that will depend upon the frequency of serious nuclear accidents like Fukushima or other major nuclear accidents around the world.

I hope that none of them happen, and that the nuclear reactors used for electricity generation remain completely safe all around the world over the next 50 and 100 years, because it's a terrible disaster when there's a nuclear accident.

COMMISSIONER: Professor, I won't say it was good news, but very enlightening and I thank you for your time. I think it quite likely that we might ask some further questions down the track, when we've got a little more information?

PROF KAROLY: Sure. Look, I'd be happy to do that; I provided some extra references. I'm happy to try to answer questions.

I mean, there was one final thing that I just wanted to add, and recognising that I'm not an expert on nuclear power, and nuclear waste disposal, my view is that both energy generation due to fossil fuels, and energy generation due to nuclear fuels are primarily waste disposal problems, as one of the major concerns in the use of that fuel.

For fossil fuels, although most people haven't recognised this, for fossil fuels, the waste disposal problem is a one to 10,000 year waste disposal problem, because that's how long it takes for the natural systems to remove that carbon dioxide from the atmosphere.

My understanding of the natural processes of radioactive decay for nuclear waste: it's a 10,000 to 100,000 year waste disposal problem, and it's not clear to me that replacing a one to 10,000 year waste disposal problem with a 10,000 year to 100,000 year waste disposal problem is a good idea. But again, as I said, I'm not an expert in this.

COMMISSIONER: Thank you very much. We'll adjourn now, until Friday.

MATTER ADJOURNED AT 3.56 PM UNTIL FRIDAY, 18 SEPTEMBER 2015