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Science, Scientists, and a Sustainable World: Views from Down Under

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Thank you. It is an honour to be here.

May I begin by thanking my host, Professor Raoul Weiler, president of the Brussels EU Chapter of the Club of Rome, for this invitation to deliver the Aurelio Peccei Lecture today. I would also like to acknowledge the counsellor to His Royal Highness the Crown Prince of Belgium, Mr Boudewijn Dereymaeker and members of the board of the Club of Rome, as well as Ms Rhonda Piggott, the Charge d'Affaire of the Australian Embassy and mission to European communities and all of the ambassadors or representatives of embassies and missions to the EU, distinguished guests that are here today.

This year is a very important year for science. We are celebrating two important scientists - Galileo and Darwin. Four hundred years ago this year, Galileo refined a Dutch design of the telescope and with it he discovered some remarkable things about the world in which we live. He discovered that the earth moves around the sun in its orbit. He discovered that the heavens are not perfect as they had been imagined, but changeable. The heavens indeed change; they're complex. And due to this and a huge variety of other discoveries, we may think of him as the father of modern science. In his honour, we're celebrating the International Year of Astronomy in Paris in the next two days.

Then about 200 years later this man, Darwin, was born and 50 years after that he published a seminal work The Origin of the Species. The primary messages were that the organisms that are most suited to their environment are those that survive. Different environments, changing environments lead to diversity and this causes species to change or adapt over time.

As we will see, these two lessons from hundreds of years ago still are valid today. I will return to these messages from our forefathers. I should also mention that about the time that Galileo was doing his work, indeed a little bit before in 1606, a small Dutch ship called the Duyfken sailed from the Indonesian island of Banda in search of gold and trade opportunities. They didn't find gold I'm afraid, but it did "find" the northern coast of a huge continent called Australia.

Now Australia is a very young nation, certainly by European standards. It became a nation only in 1901. Its population is also young in many ways. For example it has doubled in size just from 1960. The population of the United States, on the other hand, has doubled since 1930. A remarkable statistic is that 24 per cent of the citizens of Australia are born elsewhere; I'm one of them. And 40 per cent of Australian citizens have a parent who was born overseas. It's really a remarkable environment for a new nation. But that new nation sits on an absolutely ancient land.

We see here off the coast of Western Australia, Shark Bay, and we see colonies of stramatolites that are still living in Australia today. Stramatolites are collections of cyanobacteria - blue green algae if you will - and some of these specimens that are living today have been alive for 2000 to 3000 years. Their ancestors date to much, much before that. In fact, the one that we have been best able to date is more than 2.7 Giga years - 10 to the ninth years - old, a fossil record. And indeed we believe that stramatolites were on earth perhaps 3.5 Giga years ago. Ancient, ancient creatures that we also believe are responsible for the rise of early oxygen. So we have these creatures to thank for the oxygen that we breathe. They did this through photosynthesis in the briney seas in the early earth.

I was reminded of stramatolites as I was thumbing through the January 2009 issue of Scientific American that reminds us of a lesson that is coming out of evolution, as well as game theory. From two completely different directions, mathematics and biology, this is the notion that in biology is called quorum sensing. It's the ability of individuals - any individual organisms - to sense, to somehow sense when they have a certain critical mass and this sensing then elicits a behaviour that is beneficial to the whole group. So it's called 'quorum sensing.' Said simply, it's the notion that while selfish individuals may win over cooperative individuals - and I'm sure we've all seen examples of that in our life - nevertheless cooperative groups win over groups of selfish individuals. These creatures (stramatolites) were perhaps the first creatures to understand quorum sensing and to use it for their advantage.

But that's not the oldest thing you can find in Western Australia. Zircons have been dated to be 4.4 plus a few more significant figures Giga years old. Truly remarkable, even for an astronomer: The earth is a little bit over 4.5 Giga years old! These zircons are indestructible packages that contain within them a record of the extraordinary early earth and, although it's controversial, articles in the scientific literature indicate that the composition of those zircons and their isotopic abundance, in particular, may indicate that they formed in the presence of water. If that's true, it means that there was water on the very, very early earth. Still controversial, but whichever way scientists come to an agreement on this issue it is sure that zircons will play a role in the evidence and they're found in Western Australia.

While we are speaking of age I have to also say, of course, that one of the oldest continuous cultures on the earth is located in Australia in its many groups of Indigenous peoples. So a young nation on an ancient land with very old cultures.

Now, Australia has been called the antipodes. Actually, if I'm fair, I have to say that New Zealand is closer to being the antipodes, at least if you have a UK perspective. What you see here is a map and any place that the blue and the purple overlap are places that are antipodal to one another. So you see that pieces of Europe have New Zealand as their antipode. Australia actually has no land mass that is its antipode, but both its immediate area and the area that is antipodal to it is ocean. Ocean is indeed very important to Australian culture and to Australian science.

Now many things in life are a matter of perspective. Here is one perspective of the globe as seen from the EU. If we take a similar view of the globe as viewed from Australia it would look like this and you can see, I think, how different these two views are. First of all, the Australian land mass is about twice the land mass of the EU. It is surrounded by ocean rather than by predominantly neighbouring countries. And the map from the Club of Rome, where you notice Australia – oh… it would be very hard to find Australia on this map. No, can you find it? I think maybe if we turn the map over we would see it on the back. But because we are surrounded predominantly by water and by Antarctic to the south, the neighbours that we do have are very important to us and those neighbours are our neighbours in Asia. Of course they're your neighbours too, but then you have many neighbours.

Now there are many ways to look at the earth and this is one of them, by population. Here we see that the darkest colour represents nations that have more than 1 billion people. Then in the next lightest colour 100 million, 50 million and so forth. It's easy to see where the concentration of population is on the earth. So Australia's closest neighbours are very populous nations. This is also very important to our future and indeed to all of our futures.

I thought I might just compare Australia and the EU to give you a sense of some of these differences and similarities that I've been talking about. I already mentioned the difference in land mass. There is also a difference in the amount of area that's devoted to water and that's a very important difference to Australia, only 1 per cent of our accessible jurisdiction is fresh water. Our population, of course, very much smaller at 21 million compared to around 500 million for Europe. I mentioned that 24 per cent of our citizens are naturalised or born elsewhere. I believe that this number from my best research is more like 4 per cent for the EU. Population increase per year: a huge difference by a factor of 10 and I will speak a little bit about that --- 1.2 per cent for Australia and just a tenth of that for Europe. The reason for that is predominantly due to the migration rate. Huge migration to Australia with about six migrants per thousand every year compared to about one sixth of that for Europe. So that accounts for the bulk - not all - but a bulk of that difference in the population growth. That's important to remember; I'll point to that again later.

The buying power of our populace is rather similar. The inflation rate is rather similar, a bit higher in the moment in Australia. Who knows how that will go with the current

economic crisis. Unemployment currently not bad in Australia, but again we are all quite nervous as I'm sure you are in Europe as well. If you take together these two facts of the lower population and the larger land mass it means the population density of Australia is almost one 50th that of Europe; also a very important consideration.

Let's talk a little bit about trade because this is also important in thinking about the different perspectives Europe might have than Australia. I have listed the major exports and imports for the EU and for Australia. The exports for Australia are coal, iron ore and gold in decreasing order and the imports are crude petrol, vehicles and refined petroleum products. In the EU, we see the exports are vehicles, machineries, appliances - that's industrial machinery there in the second column, while its first import, in terms of dollar figures, is petroleum followed by telecommunications' equipment and appliances. I have highlighted in the lighter colour those that are related to our common global issues of energy and through that actually to climate change.

What about our trade partners? First, at the top I list the extent of the trade between Australia and Europe and you see that the total of this trade is over $60 billion Australian dollars a year, so certainly the EU is an important trade partner. But if we actually look at the major trade partners, the primary trade partners for Australia, with the exception of one, lie in the Asia/Pacific region. And for Europe they lie, not surprisingly, in the US, Switzerland and Russia, but China again appears as an important trade partner for Australia and for Europe.

Now as I was preparing for this talk I looked in the library - our personal library at home - and I found this book *The Limits to Growth*. If you have very keen eyes you will see that there are stains on it, you will see that in fact this is the second edition, the second printing of the book, which at the time one could buy for $2.75. So, although my talk to you and my research for it is rather recent - you can rest assured that this book has been in the family library for quite some time. And I think there are --- as I am sure everyone in this room is likely to agree --- some very important enduring lessons from this, the Club of Rome's project on the Predicament of Mankind. I have picked those that I want to particularly stress today:

> Population and economic growth are absolutely linked and bounded. That is limited by the shrinking resources, on one hand, of the planet and the increase in pollution that growth entails.
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> Technology is important in extending the time scale over which we may have to deal with fundamental problems, but doesn't necessarily solve the fundamental problems themselves.
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> The limits and the tragic consequences of overshoot [that is not reaching a sustainable equilibrium, but overshooting that equilibrium] are dramatic, tragic and will require new thinking to solve.
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> Importantly, development [and we can think of this in many ways, but let's call it economic development] and environment must be conceived together as a joint issue, rather than seeking separate solutions to each one.

I was struck by the sentence in this book that said, "This is a challenge for our generation." This was in 1972. "It cannot be passed on to the next." Well I think every generation has its

challenges and the generation in 1972 has made some important strides in helping the next generation. But as you are all aware, the current generation does indeed have many issues left to solve and I hope that we will do that. People of my generation must be able to do that and not pass most of the issues that we're currently talking about on to the next generation.

CO_2 as a pollutant in the atmosphere is mentioned in this book in 1972. I think maybe it has a page or one half, not a great deal of attention, but it is mentioned. And of course we now know that this is one of the primary pollutants, along with other greenhouse gases, that is a challenge for us. That may not have been entirely clear in 1972, but it is more than entirely clear in 2009.

Now Australia is preparing for a changing world. This slide is actually one of the introductory slides to an event called "20/20" that the new Government of Australia initiated asking for people from all walks of life around Australia to contribute ideas about what would be most important to the nation in looking with a "20/20" vision, if you like, toward the year 2020.

As an introductory slide these three challenges were presented:

Ageing population: it is predicted that in 2030 almost a quarter of Australia's populace will be 65 years of age or older.

Climate change, which affects Australia greatly, not only through warming, but in terms of the amount of rainfall.

And then finally dramatic shifts in how the world's GDP is distributed around the globe with the emerging players of China and India, in particular, as more and more important partners in terms of the share of GDP. All of these things are changing underneath our feet.

And that world, that world that we look forward to into 2030, is a world that still depends on coal. The 2008 World Energy Outlook makes it clear that that will be the case for quite some time. And therein lies another challenge, not only for the world, but for Australia in particular, because Australia is the largest world exporter of coal. So if you were wondering how Australia is important to your life in Europe, at least this fact alone ought to be enough to convince you how important Australia is: Australia is the largest exporter of coal which the world will need going forward.

I should say that between now and 2030, the World Energy Outlook from the IEA tells us that the world energy demand may grow by as much as 45 per cent - that's about 1.6 per cent per year - and that one third of that increased energy use is likely to come from coal.

Climate change is important to Australia for all of the reasons and more that I've listed here. I've already said to you that

fossil fuels are an important part of the economy and we must find a way to find that global solution between energy and economic development on one hand and climate change on the other. The rising sea levels that climate change entails particularly threaten Australia because most of its population lives on the coast. Water is already scarce in Australia, frighteningly scarce, so increased droughts will have differentially important effects on our society. Droughts and bushfires are already common and are expected to increase in severity with increasing global warming.

We have a very large number of endangered species that will be increasingly endangered by global warming and they're unique, nothing like it in the rest of the world. Just one of those remarkable environments is the Barrier Reefs that surround parts of the nation, not only on the eastern side, but also on the north-western side of Australia. These issues are very much in the minds of Australians.

So because climate change is so important to Australia, it is also very high on the Australian agenda. I hope everyone in this room is aware that one of the very first acts of the new Government --- that has now been in place for one year in Australia --- one of its very first acts was to ratify the Kyoto Agreement.

Very recently - last month in fact - Australia announced carbon emission targets for 2020. These are to reduce, unconditionally, by 5 per cent of the levels counting from 2000 and to further increase that target to 15 per cent if an international agreement is put into place. So we'll be looking toward Copenhagen in particular. A long term target, looking

forward now not to 2020 but to 2050, is to reduce emissions by 60 per cent; these have recently been announced by the Prime Minister of Australia.

Also announced, and yet to go through the legislative process, is a cap and trade scheme for carbon emissions in Australia. Already in place is a target of 20 per cent of Australia's domestic energy use to be provided by renewables - renewable energy sources. Major assistance has been announced for industries that are in transition to meet these targets and assistance as well for businesses and for individuals. The Prime Minister has declared climate change as a national security priority. In other words, something that not only the Department of Climate Change and the Department of Energy must be placing emphasis on, but also the Department of Defence.

Funds have been announced for research and development of new green technologies. In particular I wanted to mention that a new global Carbon Capture and Storage, institute has been announced by Australia. It will be funded from the Australian side at $100 million per annum. We have some founding international partners and we are seeking more partners to explore this one important piece of the puzzle, which is to examine to what extent we can capture the CO_2 that comes, for example, from the use of fossil fuels, capture it and store it in natural depositories under the earth. At the moment the technology is there, but there are no large industrial-scale facilities. So the idea is that 20 industrial-scale (albeit small industrial-scale of about 1 mega tonne per annum) projects must be developed quickly. Why 20? Because one wants to place them in different geologically areas as test sites. Up to 20 of those might be developed by 2010, quickly, with the notion

of looking forward to that 2020 mark for having these in large scale production.

Here is a plot of the world's CO_2 emissions, and you know what "the business-as-usual scenario looks like ". That's what will happen to CO_2 emissions if we do nothing. Many of you in this group will know what the 550 part per million scenario looks like. CO_2 rises less steeply and then it begins to flatten at values that may provide global warming of say something in the order of 2 degrees Celsius. But the result very much depends on how we go about it and whether it overshoots.

Then you are aware of the 450 part per million scenario which rises, flattens and then actually decreases with time after 2020 or so. If we are to implement either the 550 parts per million that the IPCC has investigated, or the 450 scenario investigated by the IPCC, either one relies [on the current models from the IEA] on carbon storage and sequestration as one of the methods that we need to employ. It will not solve all of our problems, but it is a key piece, at let's say about the 10 per cent level. And this is a key area in which Australia - with our international partners - is taking the lead.

Now I am going to show you two maps of the world and one of them is how I imagine nature sees CO_2. How does it see emissions? The atmosphere does not really care which nation is emitting carbon. It only cares, at least in first order, about how much carbon is emitted. That's the important point. So nature - our atmosphere - when it "looks" at a map of the world sees this. It sees where the most total carbon is emitted. It doesn't matter to nature whether those nations have many

people or few people. Nature and climate change only cares about the total amount of CO_2 being put into the atmosphere.

Now I'm going to show you another map. This, I think, is how society sees CO_2 emission. I believe that societies think of CO_2 as the amount of emissions per person. These two maps of the world look very, very different and I think herein lies a fundamental challenge for us, for humanity: To reduce the total amount of CO_2 emissions to an acceptable level --- a level that we would agree is perhaps not ideal, but acceptable --- on one hand. And on the other hand, to ensure that we're not disproportionately burdening certain societies, but think about an equitable approach to CO_2 emissions per person. That is a huge challenge: the difference between these two maps of the world.

So I would like to ask you to think about this difference and ask whether or not we can imagine, in the long term and it will be the long term, can we imagine a global equity in carbon emissions? At the moment what you see here are the top 15 countries in terms of their CO_2 emissions per person per year. The blue shows the emission per person per year in 1990 and the red in 2004. You see I've marked Australia, I've marked the US. I didn't mark individual countries in Europe because they're not among the top 15, but they lie perhaps - depends on the country, but at something like two-thirds to one-half the level of the US perhaps, something like that.

Then I've listed at the end of this plot Mexico, China and India. Remember, this is the current level of CO_2 emissions per person, (how society sees it) in Mexico, China and India. But you remember that when we had a look earlier at the

population of the world, Mexico [I also gave this talk in the US] Mexico, India, China are populous regions. So if we want global equity, and if we say to ourselves that in the long term it is fair, it is equitable that citizens of the globe should be allowed to emit the same amount of CO_2 to live their lives, then either these countries rise or ours will lower, or a little of each. But importantly, the **total** CO_2 emissions [the way nature sees the map] will almost certainly rise, because of the very, very large numbers of people in countries like Mexico, China and India. This is another way to express the challenge that is in front of us.

So can we imagine a long term global equity? It will require a lot, it's an important goal, but it will require a lot. These are some of the things that I think it will require.

We will need to account for emissions that are embedded in trade, in the production of items that are traded. Some nations emit CO_2, other nations buy the related products. We need an accounting system that fairly distributes that CO_2 to those that use the products.

We need to take into account the movement of people. If we think that it is equitable and reasonable that the CO_2 per person in the long term should be about the same, then when people move we will need the accounting system to take that movement from nation to nation into account.

Well, this next one is no surprise.

We will absolutely need not a revolution, but I would say several revolutions in a clean energy and in efficiency in order to maintain the balance between the way nature sees CO_2 emissions and the way society sees them.

This will require political and social will on a scale that I would maintain we've not yet seen demonstrated.

I also believe that it will require a new meaning for what we think of as economic success.

Now I want to show you another map of the world. Some of you may be familiar with this map. As an astronomer I am very familiar with this map. This is a map of the earth, and what you see there are city lights. This was created from data from a defence and meteorological satellite program. So you see all the places on the earth that are lit up due to bright lights. How you see this map is in the eye of the beholder. What do you see? Do you see progress where there are lights or do you see pollution where there are lights? If you are an astronomer I will tell you what you see. You see light pollution. But I have heard this map referred to as a map of innovation: that where the lights are located is the place where there is innovation in the world. I would submit to you that we have to delink the notion that the most innovative are also the ones that pollute the most.

So how do we get from here to sustainability? What I've argued to you is that we must not see emissions --- we must not see that previous map --- as a proxy for wealth, for social wellbeing, for economic growth. Not only can it not be seen to be a proxy, it must not **actually** be a proxy. We have to disrupt the link between wellbeing and wealth, and pollution. That means we need to find a new way. Indeed, it means we need to find many new ways.

So what's the role of scientists in all of this? I think the world is listening; I think the world is listening to scientists more

than it has in the past. My question is what is the world hearing? Because what one says and what is heard are two different things. I think that scientists have a special role to play that is increasingly critical. One of them is to engage the public and engage governments on matters of science and matters of policy. That might move some scientists into zones that are discomforting to them, but I think they need to do so. I think that whenever they have the opportunity they should explain concepts that are relevant to all that I have been talking about, perhaps using their own examples from their own discipline. And those things include non linear processes, how scientists measure probabilities, how one prepares for risks, interconnectivity, feedback loops, exponential growth, what equilibrium means, what overshoot means; these can be illustrated in many areas of science that are explainable to people. Then those notions can be transferred on to the discussion of climate change.

I think that all scientists should learn about science that's outside their discipline: cross disciplinary work is increasingly important. But at the same time, I also think that when asked to speak, they should speak as an expert within their own discipline. We should tell all others about lessons that we've learned from Galileo and Darwin and since I'm running out of space on this slide I've abbreviated those lessons quite a bit. Those lessons are: Things change. Adapt. And I will add this lesson from my own discipline of astronomy and in fact from some of my own research: There are a lot of planets in the universe, but not all of them are habitable, and so we really need to take care of this one.

With that, I thank you for your attention.