OFFICE OF THE PRIME MINISTER'S SCIENCE ADVISORY COMMITTEE

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Sir Peter Gluckman's speech at the conference of the New Zealand Society for Sustainability Engineering and Science, Auckland

'Addressing the perfect storm – the central role of science'

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Thank you for the invitation to speak.

The first part of my title is borrowed from my colleague Sir John Beddington, who is chief scientist in Britain and who used the metaphor to describe the conflation of issues now confronting the world community – food security, water security, energy security and climate change – all of which represent the interacting and multiplying influences of a growing global population putting pressures on our planet. As I think you are all aware, we face an increase in the global population from just under 7 billion now to somewhere between 8 and 10 billion by 2050. The middle of that range represents a rise of more than 25%. Optimistic projections see the world's population levelling out at about that number. There will be little or no increase in the population of the developed world during that period, and essentially all that increase will occur in populations in developing or least developed countries, which have the justifiable expectation of economic advancement.

Such increase in population brings with it demands on the world's food and water supplies. Food and water insecurity are growing concerns in many countries and not only in the least developed countries: China for example is investing large effort particularly in Africa to future-proof its food supplies, Australia is facing major issues of water scarcity. The population growth and the impressive economic developments occurring across many developing nations, including China, India, other Asian nations and the Latin American states, will drive a greater demand for energy. Against this background we have other factors in play: environmental degradation, the burden of waste disposal, loss of biodiversity and ecosystems and of course climate change with all its complexities and implications from changed ecosystems to ocean acidification and its effects on the food chain.

All these systems interact – for example, the reason New Zealand took the lead in developing the Global Research Alliance to reduce agricultural greenhouse gas emissions, a consortium now including over 30 countries, is the fact that we have to work out ways to increase the world's supply of food and protect food security without adding to the burden of greenhouse gases. Remember that agriculture directly and indirectly generates as much greenhouse gas as does transport – about 18% of total estimated emissions.

And there are other issues associated with population growth. For the first time in our history as a species, more than 50% of us live in cities and we are now seeing the appearance of the megacity. The implications for interhuman dynamics are poorly understood. For example, there is ample evidence that the human brain evolved to cope with about 150 people – how

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much do our rates of antisocial behaviour and mental illness reflect the pressures of this increased population density?

The rapid and recent exponential growth in population is largely a result of human technological capacity leading to better nutrition and public health in the 19^{th} century. Human technology has also generated other burdens. Perhaps the one of greatest importance is the change in the nature of what we eat. Industrial agriculture started in the 19^{th} century and was reinforced by the food science revolution of the post-war period. What we now eat is a long way from what we evolved to eat. As a result of our modern high-energy diet we face an epidemic of obesity and its associated non-communicable diseases such as diabetes and heart disease – not only in developed countries like our own and the USA, where it is estimated that within decades 40% of the adult population will have diabetes, but also in developing countries where the epidemic arising from the nutritional transition is even more acute and urgent. Both India and China now have over 100 million people with diabetes, and that disease is appearing at relatively young ages with enormous implications for the economy and health care systems of those countries. We are seeing the emergence of the same problems in Africa, the Middle East and Latin America. We are talking in terms of 15-20% of the population being affected – in New Zealand we are alarmed by 6% being so affected and at much older ages.

And we have not understood the impact of the new technologies of communication and particularly the information and social networking available on the internet. They change the way people get information, but they also change the way people think and interact. Indeed they change the nature of authority and of relationships. We have hardly begun to think about the social implications of these technologies, but they cannot be ignored. At least 98% of human evolution occurred in relatively stable social environments and the implications of these very rapid environmental changes are very poorly understood.

So I would extend Sir John's metaphor to include not only the impact of humans and their technologies on our physical environments and our supplies of food and water but also on our health and social well-being. We have not had a conflation like this in the past. It is not simply an extension of the Malthusian argument – the impacts on our environment, on our ability to live our lives as we would want and on our health make this an urgent and recent challenge.

I would also argue that failure to address this convergence of issues will have geopolitical consequences. Populations will not acquiesce to food insecurity, water insecurity and energy insecurity, particularly when inequity abounds. The risks of regional and sub-regional conflict are multiplying.

In half an hour I do not have time to rehearse every domain and every perspective, so I will largely talk in generalities and use climate change as the exemplar to make a number of points.

Sustainability can be considered at multiple levels: we need to think about it at the level of the planet, by region, by nation and by locale. In the case of climate change we tend to focus on the global but in many ways the first impacts will be at the local level. Last week I was in the Antarctic and while visiting the American science base at McMurdo I met a scientist from Santa Barbara in California who was studying ocean acidification as a result of rising CO_2 levels. She made the point that even subtle changes in ocean acidification can affect shellfish development by weakening their shells. Areas of particular risk were those where there were

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deep ocean currents rising to the surface as colder water contains more CO_2. The north-east coast of the USA is at particular risk and she sees the oyster fishery collapsing early with its impacts on the small towns that are totally dependent on that industry. She is not being alarmist – there is already early evidence of shell thinning and the issues of how to respond are already being considered. Can more resistant strains of oyster be identified as an adaptationary response, as mitigation seems unlikely given the long ocean cycle time for CO_2?

And this highlights the enormous challenge in how we respond to these issues. In general, responses can be one of three kinds: first, denial and delay, which is understandable at a human level and about which I will say a little more soon; second, mitigation in which we try to reduce the magnitude of the change, for example by controlling greenhouse gas emissions; and third, adaptation, where the response is to try and cope with the change, for example by finding crop varieties that can withstand a degrading climate. There are inevitable tensions that emerge at global, regional and local levels and inhibit finding solutions.

Such tensions may be geopolitical in nature – an example would be the north-south divide in debates over control of greenhouse gas emissions. Why should the south be denied the capacity to use high density energy consumption to grow their economies when climate change has its origins in the energy consumption patterns of the north? Indeed this north-south divide pervades many aspects of the storm we are considering and the divergent perspectives are perfectly understandable depending on where you come from. Getting beyond this is a real change for the diplomatic community and that is why I chose to highlight the Global Research Alliance earlier, for here we do have an alliance of developed, developing and less developed countries working together on a mitigation strategy. Science can indeed get beyond immediate policy divides.

But the tensions can also be ideological in nature, for example the Republican-Democratic debate over climate change in the US Senate. Here the ideology is complex and caught up in libertarian and in some cases even religious perspectives. The ideological debate in many cases cannot be separated from the economic debate.

Other tensions can be more philosophical – for example, a debate is already emerging in some countries between those with strong green ideals and those who argue that ensuring food security will require the use of GMOs with higher yields or with the ability to grow where the environment is degraded – for example in salinated soils.

Science is essential to addressing every components of the “perfect storm”, from food insecurity to handling the epidemic of non-communicable disease, from finding economic and effective sources of sustainable energy to addressing the issues of degraded water supplies, from defining how to protect biodiversity to dealing with environmental degradation.

Yet the type of science needed will often involve complex non-linear systems such as atmospheric dynamics and ocean food chains. In such models, predictions may have high levels of uncertainty, making the science easier to reject or ignore. Uncertainty may also invite exaggerated claims. We do not live in a Platonic society where the pronouncements of scientists are taken as authoritative, and conveying an understanding to the public is complex. Neither can it be done in a patronising way. The issue of public engagement and understanding is already a real challenge and will grow. But if as scientists and engineers we fail to engage and motivate the public on these complex issues, then the more likely it will be that the necessary sustained and consistent approach to solving our problems will fall victim to vested interests and contestation of dogma.

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The interaction between science and society has always been complex. What we now call science emerged in the 16th century as an iterative process of observation, experimentation and concept formation whose purpose is to understand the natural world. The key word in this definition is "**process"** – science is not just about facts, it is the process by which the validity or otherwise of knowledge about the natural world and the universe is established and becomes convincing. Science is also organised scepticism. Scientists may speculate, but cannot interpret beyond their data. A single observation is an anecdote and is not conclusive; proper experimental design and sampling, repetition and independent expert review are required. Over time, observational or interpretative errors are corrected, bias is addressed and the relatively rare episodes of fraud are exposed, and hypotheses are either discarded or reinforced.

For many years science was dominated by the physical sciences with their focus on the discovery of natural laws, whereby science, mechanics and mathematics combined to produce a rather Pythagorean and linear view of science – one in which science was about achieving certainty. But it was particularly with the explosive emergence of the biological and then the environmental sciences that science has had to develop ways to handle complex systems. Deterministic science has been augmented with ways to handle probabilities and understand the confidence limits around uncertainty. And importantly, a feature of many of these systems is that they are non-linear – that is, the response may involve thresholds and complex interactions and feedback loops.

Let me expand on this by exploring climate change, and in particular the reasons for the gulf between what the science is telling us and the lack of effective action by society to deal with the likely consequences.

The key to climate science is the application of models – that is, mathematical models of future climate trends based on what has happened in the past. There is no capacity to test these models prospectively as we have only one planet. The models were initially simplistic and have since then become increasingly complex in their endeavour to determine how the global climate changes over time and how it is affected by a multitude of factors including sunspots, reflection, pollution, volcanic activity and greenhouse gases. There are aspects of climate science we are very certain about, an increasing amount we are pretty certain about, and much we have yet to better understand. For example we have very clear records of changing greenhouse gas concentrations in the past 50 years, but we do not fully understand the lag between rising CO_2 concentrations and mean global temperature, the relationships between deep and superficial sea temperatures, the rate of methane release from warming tundra and so forth.

I do not want to go further into climate science itself. Rather, I want to explore why there is a debate and its implications for sustainability science as a whole. The general scientific consensus is that anthropogenic actions are affecting the world's climate and at some time in the not too distant future there will be significant impacts. This is the consensus view reached by every credible scientific body that has examined the question. True, there remain uncertainties as to how fast warming will occur and to what degree, and there remain many technical questions.

But these conclusions are not universally accepted – despite the strong scientific consensus there has been considerable scepticism and frank rejection of these conclusions. This discord has been well reported in the media and as a result the public is confused. It is worth noting that climate science is but one example where the interface between science and society

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exposes different agendas and worldviews and these latter differences, rather than the science itself, becomes the point of focus. We have seen it in the past regarding fluorocarbons and ozone, the link between smoking and cancer, and creationism and evolutionary biology – to name some obvious examples.

In understanding those who reject the scientific consensus it is important to distinguish between those who are genuinely questioning the science and those who really debating the response to it. In most part it is the latter that is the primary driver of the current controversy – although the debate often takes the form of creating scientific confusion. Many accept the world is warming but do not think there is any need for immediate action to mitigate it, at least any action that might affect their economic position, and they justify this view by appearing to deny the science. But beyond these obvious vested interests, there are others who have trouble accepting the need for immediate responses. In particular, some with a libertarian ideology do not accept that the state should control how they live their lives, particularly when the actions required will not, in their view, impact for a generation or so. The economic libertarian believes growth is paramount and if there is a problem then technology will eventually solve it. There seems to be some irony in accepting that science may solve a problem but that it cannot correctly identify the problem.

Acceptance of anthropogenic global warming brings with it the acknowledgement that both immediate mitigation and eventual adaptation are necessary. However it is also clear from the models that mitigation effects have a long latency – climate prediction models show little effect of mitigation for another generation and this raises important questions around issues such as intergenerational equity. However, governments have been moving gingerly towards accepting the need for early mitigation approaches. While there is hope in the long-term for technological solutions such as carbon sequestration or other forms of geoengineering which will now be incorporated into the next IPCC report, immediate mitigation requires regulatory approaches including the use of incentives that shift people towards reducing fossil fuel use and thus emissions. Many of the same measures are equally important in reducing other pressures created by our species' impact on the planet – in shifting energy usage patterns and promoting food and water security.

Technological choices will have to be made to address these multiple issues, and conveying to the public an understanding of the inevitable balance of risk and benefit of any action will also challenge the scientific and political leadership. However the counterfactual of an inadequate scientific and technological effort is obvious.

Not surprisingly the media is both part of the problem and essential to a way forward. The modern media like controversy – they feed off it. Entertainment is more important for most media outlets than information transfer. In their desire to appear balanced, they give equivalency to each side of a scientific argument when there is in fact a broad consensus on one side and not much more than individual opinion on the other. The issue that concerns me here is that of how to communicate complex science. The public has a right to understand these issues and in the end they determine how society will respond. However without responsible and capable media it is not clear how this can be achieved. Publishers, editors and journalists all have a role in ensuring quality in the information exchange.

Scientists also face a real challenge in communicating these complex issues – we only have to look at the University of East Anglia affair. Most scientists are not well trained in public communication, some try and debate as if it is a scientific debate when the domains and responsibilities of the protagonists are almost always very different. Many scientists get angry

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and defensive in this situation and this raises suspicion. Some scientists also worry that release of raw information will be an invitation for a wave of uninformed interrogation and harassment. This is a real conundrum – we live in an open society – information is now made widely available and should be.

Politicians then have to judge what actions they should take to manage the risk, because in the end these issues are about risk management.

In the case of climate change, the community of climate scientists are saying on the basis of what we know now that the risk of significant global warming is high – there is at least a 50% chance of the average global temperature in 2070, the lifetime of our children, being more than 2 °C higher than in pre-industrial times and a 33% chance this will be reached by 2050, which is within the lifetimes of some of you, and this is a level which has real problems associated with it. Would you get on a plane that had only a 90% chance of landing safely? Would you not take out insurance if you were told there is a 70% chance of an earthquake destroying your house in the next 30 years? Governments have to act in the same way.

I will conclude by pointing out that many of the issues I have discussed around complex science and technology, public engagement, capable media and partisan politics will reappear in different ways as we respond to other elements of the "perfect storm". Governments are now rightly focusing on economic growth in their response to the events of the recent recession.

The challenge for science and technology, and in that I include the economic and social sciences, is to provide ways for the world to transition to sustainability while not denying the understandable demands in many societies for economic advancement but they cannot do so unless the dialogue between scientists and the community is truly effective and informed.

Thank you.

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