OFFICE *of the* PRIME MINISTER'S SCIENCE ADVISORY COMMITTEE

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Climate change

The world's climate is influenced by a number of factors interacting in very complex and not entirely understood ways. Over the last million years there have been periodic shifts in the temperature of the planet initiated by changes in the orbit of the earth around the sun and in the tilt of the earth's axis of rotation. These changes have led to periods of global warming and global cooling – the more recent of the latter are termed the Ice Ages. There are also shorter-term fluctuations brought about by a number of factors, including linked atmosphere-ocean changes with an irregular period of several years (El Niño and La Niña events) and sporadic changes brought about by major volcanic eruptions. Global warming does not mean that every part of the globe changes temperature to the same degree or rate.

The coal-burning Huntly power station on the Waikato river is responsible for over half of New Zealand's emissions from electricity generation.

Measuring global temperatures over time is complex, but there is a general agreement that the world is experiencing an overall warming trend (with year-to-year fluctuations superimposed). The warming trend over the past 50 years is nearly twice as great as that over the previous 100 years. These escalating temperature changes have been reflected in a number of environmental and biological changes.

These include rises in globally averaged sea level, shrinking of summer Arctic sea-ice extent, losses from the Greenland and Antarctic ice sheets, retreat of mountain glaciers, poleward and upward shifts in the range of some plant and animal species, and earlier timing for some species of spring events such as leaf-unfolding, bird migration and egg-laying. That this is happening is not contentious. This change in temperature is different in nature to past temperature changes. In particular, carbon dioxide concentrations are rising in advance of, rather than as a result of, the warming trend.

The vast majority of the world's climate scientists consider it very likely, based on several lines of evidence, that the current warming trend is of human origin and is associated with increased production of the so-called 'greenhouse gases' as a result of fossil fuel use, agriculture and deforestation. Humans had little impact on the global environment until the advent of agriculture about 10,000 years ago. The flow-on effects of this agricultural revolution were mutually reinforcing – domestication and farming of ruminant animals such as sheep, cattle and goats, clearing of forests for pasture and crop growing, population growth because of greater food availability, and technological advances leading to dependence on coal and other hydrocarbon fuels for utilisable energy.

Increased concentrations of the greenhouse gases trap heat (ultimately of solar origin) within that part of the atmosphere closest to the earth. The major greenhouse gases emitted from human activities are carbon dioxide, methane and nitrous oxide. Carbon dioxide has a very complex and slow cycle such that once concentrations in the atmosphere increase, some of this increase will remain there for millennia. The other two gases have much shorter cycles, and thus their atmospheric concentrations could be

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changed quite quickly. Warming of the atmosphere also leads to an increase in water vapour content which further amplifies the warming, since water vapour is itself a strong greenhouse gas.

Ominously, the extent of human-induced global warming may be magnified by feedback effects that release even more greenhouse gases into the atmosphere as the world warms (carbon dioxide is less soluble in warmer sea water, and more methane may be released as the Arctic permafrost thaws) and cause less of the sun's heat to be reflected by the melting polar ice caps. Other effects of increased carbon dioxide concentrations in the atmosphere include the gradual acidification of the ocean, which could compromise the many marine organisms that build shells from calcium carbonate (such as molluscs, krill and corals) and itself cause a feedback effect by slowing the uptake of carbon dioxide from the atmosphere.

Understanding the complexity of climate science requires the involvement of many scientific disciplines, and this creates difficulties in reaching conclusions. There are unknowns, such as what will be the effects of altered cloud patterns on climate as global temperatures increase. Nevertheless, there is a high degree of agreement among scientists about the situation and the probable path ahead for our planet. Much of this agreement is encapsulated in the reports of the Intergovernmental Panel on Climate Change (IPCC), which is the scientific group charged by the global community to assess the state of understanding and integrate that understanding across these different scientific domains.

The periodic Assessment Reports of the IPCC – the fourth was in 2007 and the fifth will be completed in 2014 – inform policy-making in the area of climate change. But confronting climate change brings controversy. The impact of climate change is largely in the future, but to ameliorate it will require action in the present. The nature of the political process makes it difficult to commit significant resources in the short term for long-term benefit. Furthermore, because climate change requires global action, countries have difficulties suppressing national interest for united global interest and there is a large amount of positioning between nations. The whole matter is compounded by the reality that science cannot provide absolutely precise predictions about a future scenario for which there are no precedents. Action on climate change therefore depends on a set of political decisions that in turn must be made on the current assessment of the science and on the basis of scientific assessment of probability and risk.

While most scientists try to be detached and free from bias, they are never absolutely independent of their philosophical and political views, and thus one would expect some strong and passionate debate. But in general there is a high level of agreement on the trends and on expected future directions of change. Nevertheless, there are some scientists, although few of these are active climate researchers, who dispute the generally held conclusions. Some objections are based on faulty analysis or very narrow perceptions of what is important data.

Other objections reflect personal philosophical or political views. But there are some genuine uncertainties in the details of global warming, just as there are in any other science. Such sceptical views are important, as they force the scientific community to seek carefully for flaws in the analysis. A similar debate occurred about AIDS, where a minority of scientists maintained for a long time that the disease was not caused by a virus. This view was manifestly wrong in the eyes of most scientists, but nevertheless some distinguished scientists, albeit usually not experts in virology, took different views until the science became irrefutable. The political consequences of this denialism had tragic results in some African countries.

Unfortunately, because of the complexity of control of planetary temperature and because we are having to construct predictions about the future rather than looking for a single present-day cause like a virus, efforts to calculate what the global temperature might be in (say) 2090 involve estimates, and estimates always have a range – the likely upper and lower values – and a level of uncertainty associated with them. For climate change, the uncertainty of the estimates is further compounded by changes in human behaviour – will there be sustained efforts to reduce the emissions of greenhouse gases and protect

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forests? Because some of this is happening outside the formal climate change initiatives, these changes are already reflected in the more optimistic projections of the climate experts.

The scientific community has estimated the extent of the global temperature change at the end of the 21st century compared to the end of the 20th century for a range of possible future scenarios if there are no policy-driven efforts to reduce greenhouse gas emissions. Their best estimates are for an increase of between 1.8 and 4.0°C.

There is no specific global temperature rise above which we can say changes will be 'dangerous' and below which changes will be 'safe'. Any rise will have effects – indeed we are already experiencing some. However, the higher the rise the greater the effect on our lives, and the scientific literature indicates many risks for more than a 2°C rise in global temperature compared to pre-industrial conditions. The international view, supported by the actions of several countries, has been to adopt a global warming limit of 2°C or below (relative to pre-industrial) as a guiding principle for mitigation efforts, even though 2°C would still mean some changes in sea levels, in plant and animal ecosystems, in agriculture and in environmental quality. In New Zealand, even this small increase will have effects on our agriculture, coastlines and regional climates. The associated sea level rises will dramatically affect some of our Pacific Island neighbours.

But this rise of 2°C is well below most estimates of what is likely to happen if the current pattern of emissions production and rates of deforestation continue. In the absence of effective action, the mid-point of the IPCC estimates is a global temperature increase of about 3.3°C, compared to pre-industrial conditions, by about 2090. For this reason, there needs to be a global commitment to control the temperature rise. If the temperature rose by this amount then the scenarios become quite scary in terms of changes in climate, flooding of low-lying areas, new patterns of infectious disease, and reductions in the capacity of many parts of the world to support agriculture and therefore to support our continued existence as we know it. New Zealand would not be immune from these changes.

Accordingly, the collective wisdom of the scientific community is that action is needed now. It is inherent in the time scale by which emission targeting can affect temperatures that action sooner will have a greater ameliorating effect. This means making decisions in the absence of absolute certainty. Certainty can never exist regarding the precise magnitudes of temperature, rainfall and sea-level changes in advance of the periods you actually make the measurements. We are dealing here with probabilities, and indeed dealing with probabilities is the normal business of science. Science has done its best to reduce the uncertainty and now has a high level of confidence that something must be done now, and that if nothing is done we will all suffer as global temperatures rise.

There is a remote possibility that if we did little or nothing then the temperature would not rise to unacceptable levels. But we cannot gamble the future of the whole planet on the low probability of that occurring. We do many things in life that are based on the balance of probabilities, for example we think it prudent to insure our houses and wear seat belts in our cars not because we plan to have a fire or a crash, but rather because we are weighing the cost of the insurance premium or the minor inconvenience of putting on the seat belt against the significant risk of damage to our finances or ourselves if those events were to happen. It is the same with climate change – the collective wisdom of the scientific community is that action is needed to address global warming because without action the potential risk to the planet and ourselves is too high.

The problem that overlays all of this is one of economics. To reduce emissions and to protect forests, which absorb carbon dioxide, has costs. The greater the degree of emission reduction required, the greater the cost. There are no easy and economical 'silver bullet' solutions to prevent the carbon dioxide and other greenhouse gases produced by human activity from ending up in the atmosphere, so substantial reductions in emissions are required. Global warming is indeed a global issue, and much of the international political debate is over how to share the effort in reducing the rate of temperature rise when some large emitters such as China and India wish to accelerate their economic development to

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reach the living standards of countries such as Europe and the USA who have already had the benefit of industrialisation and economic growth. Indeed, over the last year we have seen how central are the emerging economies to our own economic health. Political arguments then flow as to the most equitable way of doing it – in absolute terms China and India are large emitters, but when expressed per capita of population a different picture emerges and their emissions per person are less than a quarter of those of the most developed countries. The global political community has yet to solve these conflicting expectations.

New Zealand has a particularly unusual situation because about half of our emissions are derived from our farming industry, as ruminants expel methane into the atmosphere. We have significant forests that offset our carbon emissions and relatively low fossil fuel consumption, as we do not have much heavy industry. We are a long way from being able to reduce emissions from sheep and cattle unless we reduce herd size, which would affect the heart of our economy. Active research is starting to look at ways to change ruminant biology so they expel less methane; however while the research is promising, it is still some way from application. So if we commit to reducing emissions by a certain percentage, say 20%, and we cannot change livestock emissions much we would have to have a 40% reduction in other emissions to meet that target. This highlights the debate and dilemma over what emission target New Zealand should have. There is no scientific answer to this question of what our target should be. For New Zealand is a small emitter by world standards – only emitting some 0.2% of global greenhouse gases. So anything we do as a nation will in itself have little impact on the climate – our impact will be symbolic, moral and political.

The 'tragedy of the commons' is a concept well understood in economics. If a pasture is owned by no-one but everybody can graze their cattle on it without responsibility, then in time the common field will be available to no-one because the field will have been overgrazed by some users at the expense of others. If that is the only field, then the community can no longer support cattle. Such scenarios are not unusual and our species has fallen into this trap more than once. On Rapanui (Easter Island) there were no trees left by the time the first European explorers arrived, and the Rapanuians had thereby lost the ability to make canoes and to fish, except from the shore. Their lifestyle and indeed their sustainability were forever radically altered.

The risk is that the consequences of a changing global climate will become another tragedy of the commons – if collective action is not taken then everyone will suffer. The conundrum for the politician is real – how to achieve collective action. That is not easy, because it means spending resources now to protect the world for future generations and it is inevitable that every player is looking to protect their own short-term position. Unfortunately, science cannot provide the complete answer – it can define the problem and investigate mitigating actions, but achieving a solution is a matter of politics.

There is no easy answer – the science is solid but absolute certainty will never exist. As part of the global community, New Zealand has to decide what economic costs it will bear and what changes in the way we live will be needed. We must be involved. This is a global challenge, and a country like ours that aspires to be respected as a leading innovative nation cannot afford to appear to be not fully involved. Indeed, such a perception would compromise our reputation and potential markets.

ENDS.

This paper was written by Professor Gluckman following briefings with climate scientists and a review of the literature. The paper was peer reviewed by the Chair of the Royal Society of New Zealand's Climate Committee, Dr David Wratt. Other useful inputs came from Dr Alan Beedle of this Office and the Rt. Hon. Simon Upton, who has chaired the OECD Round Table on Sustainable Development. This paper is intended to give interested parties an overview of the science related to climate change; it is not intended to be a comprehensive treatise on the subject.

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