**PRIME MINISTER'S SCIENCE, ENGINEERING
AND INNOVATION COUNCIL**

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AGENDA ITEM 6

AUSTRALIAN GREENHOUSE SCIENCE - ACHIEVEMENTS AND FUTURE DIRECTIONS

1. Introduction

The purposes of this paper are to discuss:

- *What have we learned about the science of greenhouse?* A summary of the current international scientific understanding of the science which underpins the greenhouse issue according to Australian scientists and the Intergovernmental Panel on Climate Change.
- What are Australia's research achievements? *Some key achievements by Australian scientists in this research area over the past 5-10 years.*
- Role of research. *How this research serves the Australian community.*
- What is needed in the next 5-10 years? *Some priorities for future greenhouse research.*

2. The science says there is an issue

The Intergovernmental Panel on Climate Change (IPCC) is a United Nations body that coordinates periodic scientific assessments of the science of climate change. The most recent assessment was published in 1996. It concluded that:

- *Greenhouse gases have continued to increase in the atmosphere*
- Anthropogenic aerosols tend to cool the atmosphere.
- Climate has changed over the past century
- The balance of evidence suggests a discernible human influence on global climate
- Climate is expected to change in the future
- There are still many uncertainties.

This paper was prepared jointly by members of CSIRO Atmospheric Research and the Australian Greenhouse Office to aid discussions by the PMSEIC. It is not intended as an official statement of the Commonwealth Government.

Greenhouse gases

These are the gases in the atmosphere that tend to trap heat near the earth's surface, and thus make it warmer than it would otherwise be. They include carbon dioxide, methane, nitrous oxide and chlorofluorocarbons. The atmospheric concentrations of all these gases have continued to grow in recent years, except for the concentration of methane, which is stabilising. The concentration of carbon dioxide has increased by approximately 30% from pre-industrial times.

Water vapour is also an important greenhouse gas. Its concentration in the atmosphere is controlled by other factors, which influence the temperature of the world's oceans.

Anthropogenic aerosols

Aerosols (small solid or liquid particles) in the atmosphere are produced mainly during fuel combustion. They play two roles in the climate system. First they reflect sunlight back to space, resulting in cooling, and second, they increase the number of nuclei on which raindrops form, thus changing the reflective properties of clouds and their rain-forming characteristics. The increase of aerosols in the atmosphere over the last century is thought to offset some of the warming that may have been expected from greenhouse gases.

Climate has changed

Atmospheric measurements from meteorological observatories, measurements from ships of the surface and deep ocean, and indicators of warming such as the growth of tree rings, the melting of glaciers, the isotopes of water in polar ice, and so on, all suggest that the planet has warmed over the last 100 years. This warming is estimated at about 0.6^0C.

Australia's temperature and rainfall patterns have been observed to change.

Human influence

Global temperatures have fluctuated in the past. But the size of the recent warming and more particularly the pattern of that warming through the depths of the atmosphere and across the world, suggests a human influence. Changing atmospheric composition of greenhouse gases, increased aerosol levels and decreased ozone support this indication.

Climate will change in the future

The growth in human population, economic development and the commitment to the use of fossil fuels as a source of energy means that the levels of the main greenhouse gas, carbon dioxide, will continue to increase in the atmosphere for many decades. Indeed, a doubling of pre-industrial atmospheric carbon dioxide concentrations is quite possible well before the end of the next century, with tripling thereafter.

Further warming is expected as the climate system responds to these increases in greenhouse gases. The extent of warming is uncertain, just as the extent of climate response to particular changes in the gases is uncertain. But more directly, the extent of warming depends on the effectiveness of international action to reduce emissions of greenhouse gases and the role of technology to improve the effective delivery of services from energy resources.

There are still many uncertainties

The climate system is extraordinarily complex. We do not understand all of its features, and thus cannot predict its exact response to changing concentrations of greenhouse gases - even if we knew what these might be.

Perhaps one of the most challenging uncertainties is how global warming will manifest itself at the regional level. We need to know this if we are to predict with any confidence the impacts of change or assess the potential to adapt. The sooner we can do this, the better shape we will be in.

Our current forecasting capability at the regional level is quite poor, because climate change is only one of many simultaneous large-scale changes affecting the environment. These include biodiversity, land degradation, land-use conversion, urbanisation and industrialisation, which are all changing through other causes such as population changes, economic influences and technological advances. All of these and more interact with climate change.

3. Achievements and roles of Australian science

Australian greenhouse science is world class, internationally recognised and contributes to greenhouse policy decisions. Outputs include:

- expertise in climate observations, analysis and modelling, and measurement and interpretations of greenhouse gases;
- contributions to international research programs including International Geosphere-Biosphere, World Meteorological and International Human Dimensions Programs;
- tools to better understand and examine the greenhouse effect and interactions among natural cycles and systems;
- investigations of potential impacts of climate change on communities, industries infrastructure and economic systems.

The science is performed by many organisations - a multi-divisional program in CSIRO, the Bureau of Meteorology, a range of university and other institutions. It has focussed on observing, monitoring and modelling critical parts of the climate system including the role of the oceans, the carbon cycle, sea level changes and the effects of aerosols.

The drivers of Australia's climate are not the same as in the Northern Hemisphere. We are much more influenced by El Niño, monsoons and tropical cyclones than many countries. Our nation is subject to influences of the Antarctic continent and the circumpolar Southern Ocean. To our north, we have the world's most intense convective activity, so important in global atmospheric circulation. Consequently, extrapolation from Northern Hemisphere studies will not provide an adequate basis for understanding the effects of greenhouse gases and climate change on Australia.

Australian research over the past 5-10 years has generated many highlights, as listed below.

Greenhouse gases

The greenhouse gases and changes in their composition are the most accurately known components of the climate change issue. Knowledge about these is the main reason why interactions between greenhouse gas emissions and global warming are recognised as an issue.

The Australian contribution is twofold:

- Established in Tasmania over 20 years ago, the Cape Grim Observatory has provided the world with one of the longest and highest quality records on the background composition of the atmosphere and changes. The Bureau of Meteorology and CSIRO Atmospheric Research jointly manage the facility.
- Very accurate data on changing levels of greenhouse gases over the past 1000 years, from analyses by CSIRO and the Antarctic Division of air trapped in Antarctic ice to accurately determine age and composition. This complements French research which has concentrated on lower resolution but older air providing data of changes over 400,000 years.

Climate trends

It is well established that Australia's climate has changed over the last century.

Careful reconstitution of climatic records by the Bureau of Meteorology and CSIRO has produced data sets of exceptional and previously unattainable quality. These data have enabled examination of national and regional trends in pressure, rainfall, temperature and the occurrence of extreme events.

Climate variability

We now better understand the causes of year-to-year variability of climate.

Australia experiences the most variable climate of any nation, largely due to the El Niño effect. The inclusion of features such as the El Niño effect in current climate models promises significant improvement in forecasting seasonal climate variability in the near future. Australia is at the forefront of this work internationally.

Evidence suggests that global warming may interact with the drivers of climate variability and alter the frequency and the intensity of phenomena such as El Niño. Attempts are now being made to link this work with the potential application of forecasts to agriculture, hydrology and water management, and other sectors.

Climate processes

Greater understanding of climate processes has increased the confidence and accuracy of model simulations of future climate response changes such as high carbon dioxide concentrations.

Research has included high quality data for observational studies of the oceans of the Australian region, of clouds and their formation and effects on radiation, tropical cyclones, monsoons, east-coast low-pressure systems, etc. This has led to improved understanding of processes and their interactions, including mixing in the Southern Ocean, sea-ice and Antarctic bottom water formation, cloud formation and ice/liquid distributions in clouds and their impact on radiation, terrestrial ecosystem impacts, ocean-atmosphere interactions that form the basis of the El Niño phenomenon, etc.

Incorporating this improved understanding for each of these processes into the climate model has led to overall improvement in the realism with which the model can produce current climate patterns.

Climate modelling capacity

From no capacity ten years ago, Australia now has one of the top four global climate system models designed specifically for climate change studies and representing the real climate system. Such a high level of climate modelling capability has been an enormous achievement – and one that has enhanced Australia's standing in the international scientific community.

The Australian model, developed by CSIRO, ranks alongside those from the Meteorological Office (UK), the Max Planck Institute (Germany) and the GFDL (US). Climate models need very large computers, and recent pooling of resources by CSIRO and the Bureau of Meteorology now provides high performance computing capacity that is internationally competitive.

A high level of sophistication is necessary to represent the climate system well enough for the model to be an effective predictive tool at relatively large scales. An even greater level is required for prediction at more practical regional scales.

Australian computing capacity has enabled production, and update of a range of scenarios of internally consistent and plausible future climates. While there are still uncertainties about future increases in concentrations of greenhouse gases and the climate models themselves, such scenarios have been widely used by State Governments for planning and establishing policy.

Regional change and impacts

Better understanding of the climate system has provided insights as to what may happen to natural and managed systems in Australia as a result of climate change, including impacts and vulnerabilities.

The predictive climate model has provided policymakers with a guide to what impacts may occur at a regional scale within Australia and which regions and sectors may be most vulnerable to climate change. This is a first step to considering what adaptation may be necessary and assessing mitigation options. Studies have included impacts on the natural environment (including such things as the viability of national wildlife reserves, biodiversity, bush fire frequency, etc), agriculture and water resources, communities, industries infrastructure, insurance, tourism and the economy. The objective of future assessments will be clearly focused on minimising impacts and exploiting potential benefits.

THE BROADER CONTEXT OF GREENHOUSE SCIENCE

Science obligations under the Framework Convention

Australia has internationally recognised performance and capability in greenhouse science. These enhance Australia's credibility and international position in greenhouse policy development.

The policy agenda for the Framework relies on scientific support at national levels and through the scientific programs of the Intergovernmental Panel on Climate Change (IPCC). For example, Australian and Brazilian global carbon models were used at the November 1998 Conference of Parties as a basis for debate over future policy directions on the relative responsibilities of developed and developing countries in addressing global greenhouse gas emissions.

Australian scientists from a range of disciplines have sufficient international standing to have been appointed to lead preparations for the IPCC's Third Assessment Reports on *Climate*

Change Science and *Impacts, Adaptation and Mitigation of Climate Change*. This Report will significantly influence future directions in international and national greenhouse policy.

The Kyoto Protocol also requires national observation programs and scientific research. Australia's activities in monitoring atmospheric composition are a significant contribution to the global database supporting the scientific assessment of global scale climate change.

Sound science underpins sound policy

The science community has contributed to – and will continue to be called on to contribute to – international, Federal, State and local government and industry policy development on the greenhouse issue.

From the Federal perspective, science has underpinned the development of the National Greenhouse Strategy, and broader issues such as State of the Environment Reporting. Research capability to understand the science of forest and agricultural carbon sink activity, its measurement and Australia's international standing in the area are essential to achieving international policy outcomes which meet Australia's needs. Scientists contributed to evaluations of options for emission mitigation by land-use practice in Australia, and the purported greenhouse gas reductions from outcomes from policy proposals introduced by other Governments in the lead up to developing the Kyoto Protocol.

Companies have sought information concerning the strength of the science (that is, how likely is it that the issue will not go away), in deciding options for emissions reduction and mitigation as their contribution to the Greenhouse Challenge program. Companies have sought whole of life analysis of emissions for industrial and mineral processes to assess greenhouse gas emission implications of a particular approach and to identify where to make improvements. There has also been a rapid growth in the need for scientific and technical advice in the establishment of carbon trading guidelines by those who hope to benefit from such trading and those who may need to regulate the process.

Mitigation of greenhouse gas emissions

Clearly, the greenhouse issue is intimately connected to the energy cycle - what energy do we use, from what primary source is it derived, how efficiently do we convert it to the amenity (heating, mobility, manufacture, transformation of material) that we need? Ultimately technology is likely to provide many solutions to the global community for stabilising greenhouse gas concentrations in the atmosphere. Australia is conducting relevant science in renewable energy, combustion, efficiencies of chemical conversion, motive power generation, automotive technology, power transmission, and energy management, to name a few.

Mitigation approaches in non-energy sectors are important. Learning to manage our waste, agricultural and land-use practices to minimise emissions of methane, nitrous oxide and carbon dioxide will benefit Australia. Such skills will also be particularly valuable to developing nations that have yet to agree to the Kyoto Protocol.

A very positive side of the greenhouse issue is that all of these areas may offer opportunities, such as Australian positioning for trade in information systems, solutions, products and equipment.

It needs only the acceptance that the way things might be in the future, do not necessarily reflect the way they have been in the past.

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4. Future issues

Scientists and policy makers will need to consider some of the issues below.

Climate change to continue

Warming of the oceans and impacts on polar ice sheets and vegetation cover are processes that respond relatively slowly to the changes in available heat. So, for example, sea levels are expected to continue to rise for several decades after atmospheric greenhouse gas concentrations have been stabilised.

Stabilisation of concentrations if possible

It is important to understand that stabilisation of concentrations of carbon dioxide will only be achieved when the emission rates balance the capacity of the oceans (and perhaps for a short period, the biosphere) to take up the emitted carbon dioxide. Currently the oceans are capable of taking up about 2 thousand million tonnes of carbon (as carbon dioxide) each year. That is, to stabilise concentrations at today's levels, we would need to reduce emissions from about 6 thousand million tonnes to 2 thousand million tonnes a year.

Even to stabilise atmospheric concentrations at 2 or 3 times pre-industrial levels of greenhouse gases, there will need to be significant reduction in the *current* rates of emissions. This is without factoring in growth in populations and energy usage.

This is going to be a significant challenge to the entire global community - both the developed and developing world. Human population is expected to increase, as is the desire/need for increased global average of per capita energy. With the continued reliance on fossil fuels, it is difficult to see global emissions of carbon dioxide slowing in the short term.

Some adaptation will be necessary

As atmospheric concentrations of carbon dioxide are likely to continue to grow well into next century, some change to the climate system is inevitable.

We will need to manage the inevitable impact of that change on Australia, by:

- understanding how the changes impact on natural and managed ecosystems, agriculture, water resources, coasts, and industries including tertiary industries such as insurance, etc.
- improving understanding of biological responses to both climate and atmospheric carbon dioxide concentrations and the interactions with other changes occurring simultaneously.
- understanding how the changes on one part of the system affect other parts of the whole;
- assessing the vulnerability of natural and managed systems to the impacts of climate change; and
- developing appropriate adaptation strategies.

This area of research has been badly neglected and needs renewed emphasis.

Possibility of surprises

Given the incomplete knowledge of the climate system, particularly at a regional level, surprises are highly likely in some places around the world in terms of how strongly and in what form global warming will manifest itself.

Research tries to reduce the chance of such surprises by identifying where they are most likely to occur and detecting early signs of variations from the expected changes as early as possible.

For example, the most recent climate modelling predicts that continued warming might lead to the collapse of deep-water formation. Earlier, less detailed models had not enabled this connection to be identified.

This process of deep-water formation is the major driving force for the ventilation of the deep ocean. Should it be significantly affected by global warming, then the consequences would be devastating for the survival of life in the deep oceans. At worst, such changes could threaten the viability of the whole global system. It is too early to be certain whether this prediction from the model will actually occur, but this is an example of the kind of finding that can direct attention to appropriate monitoring and sound the need for caution.

Another potential surprise in the Australian region is the possible impact of climate change on the El Niño phenomenon. This is a major contributor to annual variability in the Australian climate and impacts on the environment and economy. We need to be sure that, as climate changes, we can predict as well as possible the frequency, intensity or nature of El Niño (and other important phenomena such as tropical cyclones, monsoons, etc.).

Verification of effectiveness of mitigation actions

As the developed world enters agreements to slow down the emissions of greenhouse gases, there will be a need to evaluate how effective those responses have been in preventing "dangerous anthropogenic change to the climate system". This evaluation will involve the assessment of the impact on the concentrations of gases, how that has impacted on changes to the climate and the impacts that those bring to the planet as a whole.

At a national level, participating nations will need to demonstrate and verify that set targets have been reached. We also need to be prepared to evaluate mitigation options and their potential impact on Australian systems. The science associated with this is diverse (energy combustion technology efficiencies, carbon storage by soil and vegetation in land-use policy changes, etc). We will need to be able to defend our position and question those of other nations.

5. What is needed for the next ten years

The challenges and opportunities of climate change are multi-sectoral - in terms of the impacts of the change itself and the implications of international responses to addressing the mitigation of the problem. They have been recognised by both Federal and State Governments, and many major companies. In particular, resource companies are responding to the potential changes in the conduct of their businesses.

This is basically the first major global issue of sustainable development.

It is about responding to a threat - about which not everything is understood - in such a way that protects the standards of living of current populations without jeopardising the economic, social and environmental options for future generations.

It is about precaution in the face of uncertainty and potential risk.

Equally, it is about preparedness for unknown potential opportunities.

In each of these facets, science, technology and innovation are key underpinning elements.

There is a need for science to find a balance between the:

- application of current knowledge to underpinning the immediacy of decisions concerning climate change and our responsibility through the Framework Convention and the Kyoto Protocol, and
- forward-looking science, anticipating future needs and instigating research to ensure that Australia remains well poised to respond to the climate-change challenge.

We need to:

- maintain a “seat at the table” of world class science so as to access the major activities internationally
- monitor the climate and the gases to underpin our knowledge of development of important processes, so that we can identify changes, and restrict occurrence of unforseen outcomes
- participate actively in International Geosphere-Biosphere Program, World Climate Research Program, the International Human Dimensions Program and the Intergovernmental Panel on Climate Change
- Facilitate closer science-policy linkages to reap the benefit of research and have the research well targeted strategically.

To accomplish the support of the scientific community we need to:

- reiterate the commitment of individual institutions to the various facets of study surrounding the climate change issue
- capture the support of such work through Governmental and private enterprise contract work
- seek continuation of Federal Government support for an Australian Greenhouse Research Program
- maintain strong channels to communicate the science across institutions and disciplines and particularly to the policymakers.

The Federal Government Australian Greenhouse Research Program was initiated in the second half of 1988, and has strongly leveraged institutional input to achieve many of the outcomes indicated above. In particular, it focussed on the development of an Australian climate change modelling capability.

Senator Robert Hill has requested the Greenhouse Science Advisory Committee to develop a forward strategic plan (1999-2004) for national greenhouse research priorities and directions. This Plan is about to be delivered to Senator Hill.

6. Conclusions

- ✓ The science of greenhouse is well based, there is a natural greenhouse effect, and human activity is enhancing that effect
- ✓ There is clearly a strong likelihood that significant global warming will take place over the next 50-100 years
- ✓ The nature of this change at regional level is still uncertain
- ✓ Some of this warming is unavoidable, despite current attempts to reduce emissions
- ✓ The science is diverse and there is a need for inter-institutional collaboration and sharing of responsibilities, and
- ✓ The results need to be rapidly integrated into policy-relevant advice.

Over the next 5-10 years the research will need to focus on:

- meeting obligations under the FCCC
- meeting emission targets, and
- positioning Australia to effectively meet climate change.

The question is no longer:

"Is climate change really happening?"

The question is now:

"How can we best manage climate change?"

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