NEW ZEALAND
CLIMATE CHANGE CENTRE

A submission to the Emissions Trading Scheme Review Select Committee from the New Zealand Climate Change Centre.

February 2009

The New Zealand Climate Change Centre (NZCCC) is a joint initiative by all of New Zealand's Crown Research Institutes, the University of Canterbury and Victoria University of Wellington. Our vision is to enhance the capacity of New Zealand, both domestically and in partnership with other countries, to anticipate, mitigate, and adapt to climate change.

27 February 2009

To the Emissions Trading Scheme Review Committee:

SUBMISSION ON THE REVIEW OF THE EMISSIONS TRADING SCHEME AND RELATED MATTERS
from
THE NEW ZEALAND CLIMATE CHANGE CENTRE

1. INTRODUCTION

This submission is from the New Zealand Climate Change Centre, a joint initiative formed by all of New Zealand's Crown Research Institutes together with Victoria University and Canterbury University. It has been compiled by Dr David Wratt, Director of the Centre, in consultation with the Centre's participating organisations.

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We wish to appear before the committee to speak to our submission, represented by Dr Wratt. We wish that the following also appear in support of our submission:

- Dr Harry Clark, Section Manager Climate, Land and Environment, AgResearch
- Dr Brett Mullan, Principal Scientist, NIWA
- Dr Andy Reisinger, Senior Research Fellow, Victoria University

1.1 Overview of the New Zealand Climate Change Centre

The New Zealand Climate Change Centre (NZCCC) is a joint initiative by New Zealand's Crown Research Institutes (CRIs), Victoria University, and Canterbury University. Our goal is to enhance the capacity of New Zealand, both domestically and in partnership with other countries, to anticipate, mitigate, and adapt to climate change. We facilitate collaboration to develop, communicate, and apply science-based solutions to climate change-related issues.

The members of the NZCCC are:

AgResearch
ESR (Institute of Environmental Science and Research)
GNS Science (Institute of Geological and Nuclear Sciences)
Industrial Research Limited
Landcare Research
NIWA (National Institute of Water and Atmospheric Research)
Plant and Food Research
Scion
University of Canterbury
Victoria University of Wellington

Our member organisations possess much of New Zealand's research and technical expertise in climate change. They undertake research on: Past and present climate variability and changes in New Zealand and the South West Pacific, and causes for these changes; Projections of future changes (including the use of global and regional climate models); Climate change effects and vulnerability to these; Measurement and mitigation of greenhouse gas emissions (including research on emissions from ruminant animals, energy production and efficiency, renewable energy, carbon storage in terrestrial systems such as forests and soils, carbon capture and storage in geological systems, and transport); Adaptation to climate variability and change in New Zealand and the South West Pacific.

Staff from our member organisations provide information and advice on climate change science to policy advisors and other staff in central, regional and local government, industry, and agriculture. Some of our scientists have been active in senior roles in the Intergovernmental Panel on Climate Change (Working Group I and II Bureaus, Technical Support Units for Working Group I and for the preparation of the Synthesis Report), or as lead authors for chapters of the IPCC's Third and Fourth Assessment Reports. We have strong international links and research collaborations with scientific organisations in many overseas countries.

The NZCCC is led by its Director (Dr David Wratt). A governance group consisting of representatives from GNS Science, Landcare Research and Victoria University of Wellington guide the activities of the NZCCC. Representatives from all of the NZCCC's member organisations agree to these activities by consensus.

1.2 Consultation Undertaken in Preparing This Submission

In preparing this submission we have consulted with all of our member organisations, through the following participant representatives:

AgResearch: Dr Harry Clark
ESR: Dr Virginia Hope
GNS Science: Dr James Crampton
Industrial Research Limited: Mr Keith Jones
Landcare Research: Dr David Whitehead
NIWA: Dr David Wratt, Mr Richard Nottage, Dr Brett Mullan
Plant and Food Research: Ms Philippa Stevens, Dr Brent Clothier
Scion: Dr Tim Payn
University of Canterbury: Professor James Shulmeister
Victoria University of Wellington: Professor Martin Manning, Dr Andy Reisinger

1.3 Member Organization Submissions

In addition to this NZCCC submission, several of our member organizations are also making separate individual submissions in areas where they have particular expertise and interests.

2. SUMMARY

The key points we wish to make through this submission, which are expanded in our specific comments under individual terms of reference below, are:

General: We recommend the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) as the authoritative source for information on climate projections for various greenhouse gas emissions scenarios, and their uncertainties and risks. The reason for our confidence in the robustness of the IPCC's findings lie in the global, science-driven and peer-reviewed assessment process that it follows. This process has been outlined to the committee in an invited presentation by the Climate Change Research Institute of Victoria University, a member of the New Zealand Climate Change Centre.

T.O.R. 4 - Projections: The IPCC provides two classes of emissions and climate projections:

- "SRES[1] scenarios" which explore a range of development paths which do not include additional climate policies above current ones, and

[1] "SRES scenarios" describes a set of emissions scenarios outlined in the 2000 IPCC Special Report on Emissions Scenarios.

- "Stabilisation scenarios" which include global mitigation efforts to reduce emissions and eventually stabilise greenhouse gas concentrations in the atmosphere.

It is a consistent feature of all emission scenarios and climate projection studies that more greenhouse gas emissions lead to more warming. Global average surface warming projections for the SRES (no additional climate intervention) marker scenarios[2] assessed in the Fourth Assessment Report[3] range from[4] 1.8 [1.1 to 2.9]°C for the lowest scenario to 4.0 [2.4 to 6.4]°C for the highest scenario. These projections are for the end of the 21st century relative to the period 1980-99. A further 0.5°C should be added to convert these temperature changes to increases relative to the pre-industrial period.

The IPCC Working Group II assessment indicates significant negative global impacts in many sectors from projected climate changes as the 21st century progresses, especially once global average temperature increases by more than about 1.5°C above 1980-99 values[5]. This is why a target of limiting warming to 2°C above pre-industrial temperatures (1.5°C above 1980-99) is frequently discussed in the context of the United Nations Framework Convention on Climate Change (UNFCCC) negotiations. The IPCC best estimate projections for each of the SRES (no additional climate intervention) marker scenarios considered in the Fourth Assessment Report would lead to warming of more than 2°C above pre-industrial levels by the end of the 21st century.

Results from the IPCC's assessment of stabilisation scenarios (which include global greenhouse gas mitigation efforts) can be summarised as follows: Limiting long-term warming to 2.0 to 2.4°C above pre-industrial conditions would require limiting the build-up of carbon dioxide-equivalent concentrations to about 450 (445 to 490) ppm. This in turn would require global carbon dioxide emissions to peak by about 2015 and to be reduced by between 50 and 85% relative to 2000 emissions by 2050. Recognising different development stages of countries around the world, the IPCC Working Group III (Mitigation) assessment indicates that achieving such global emissions reductions would require Annex I[6] countries to reduce their collective emissions by 25 to 40% relative to 1990 by the year 2020. These emissions reduction ranges form the basis for current negotiations under the UNFCCC for a new international climate change agreement post-2012.

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[2] The IPCC organised the SRES scenarios into six "scenario groups" and for each group chose one representative "marker" or "illustrative" scenario

[3] Table SPM 1, Summary for Policymakers, IPCC Fourth Assessment Synthesis Report, IPCC 2007.

[4] The terminology 1.8[1.1 to 2.9]°C indicates 1.8°C is the best estimate of temperature change for a given emissions scenario, and 1.1°C to 2.9°C is the "likely" uncertainty range , i.e. there is a 67% probability that future warming will lie within this range.

[5] Figure SPM 7, Summary for Policymakers, IPCC Fourth Assessment Synthesis Report, IPCC 2007.

[6] Annex I countries are those listed in Annex I of the UNFCCC. They comprise western industrialised countries and countries of the former Soviet Union that are now transitioning to market economies

T.O.R. 6 - Relative Merits of a Mitigation or Adaptation Approach: We submit that choosing to take either only adaptation measures, or to take only mitigation measures, is not a viable policy for New Zealand. Both adaptation and mitigation are necessary globally and nationally. The IPCC concludes: "There is *high confidence* that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change."[7]

NIWA's regional climate projections for New Zealand based on the SRES (i.e. no additional climate intervention) scenario range include significant changes in temperature extremes, in the distribution of rainfall across the country, in rainfall extremes, and in drought risk through the 21st century. Thus adaptation will certainly be required in New Zealand if there is no substantial progress in mitigation of global greenhouse gas emissions from human activities.

However, the IPCC chapter on Australia and New Zealand[8] indicates significant vulnerability in some sectors even if global average temperatures rise by only 2°C above pre-industrial levels, particularly water security, coastal communities and natural ecosystems. On the other hand, national pastoral agricultural production may be able to adapt to such moderate changes. Higher and more rapid warming would increase vulnerability of all sectors and require greater adaptation efforts.

Since a 2.0°C target is currently being considered internationally as the most ambitious mitigation scenario, it is clear that adaptation should be planned in New Zealand even if the world is able to make substantial progress on mitigation. Both globally and locally the range and magnitude of projected impacts increase substantially as projected global temperature increases move through the 2.5°C to 5°C range, providing a strong argument for a major effort on mitigation so that this range of temperature increases does not occur.

Given the projected impacts of climate change on New Zealand, and also the likely international pressures on our trade if other countries agree to global mitigation policies but New Zealand does not, we submit that New Zealand should both contribute to international mitigation efforts and plan for adaptation.

T.O.R. 7 – Case for Increasing Resources Devoted to NZ Specific Climate Change Research: As noted in the National Party pre-election climate change policy statement, "good science is essential to quality decision making". Our members are undertaking critical research on both mitigation-relevant and

[7] Section 5: The Long-term Perspective. Summary for Policymakers, IPCC Fourth Assessment Synthesis Report, IPCC 2007.
[8] "Australia and New Zealand". Chapter 11, Working Group II Report, IPCC Fourth Assessment 2007.

adaptation-relevant topics, largely funded through the Foundation for Research, Science and Technology, the Pastoral Greenhouse Gas Research Consortium (an industry/government partnership), and the Ministry of Agriculture and Forestry (MAF). Submissions from some of our members identify areas where they consider more research investment to be desirable.

Between them our members contain a wide range of knowledge and expertise in climate change. They would be pleased to work together on any specific national assessments of scientific and technical issues related to climate change that are needed. Our members would also be pleased to work collaboratively with and support government agencies in identifying strategic research opportunities and gaps. This would provide early identification of significant new issues and developments from a scientific perspective, and identify the resources (including scientific capacity) and the international linkages that would be required to address them.

We consider that at a minimum, maintaining at least the current level of Research, Science & Technology (RS & T) is critical to New Zealand, for clearly no other country will do work for us that lies at the core of our national interests. New Zealand's credibility in international fora and our ability to identify and develop the most cost-effective responses to climate change depends on a credible and internationally recognised research, science and technology effort

T.O.R. 9 - Need for any additional regulatory interventions: We have not provided detailed submissions on this item, as our members are not experts in the field of government laws and regulations. Nevertheless, while the focus of this review is on the emissions trading scheme and/or other mechanisms to address reductions in emissions, we have pointed out under T.O.R. 6 that New Zealand should address adaptation as well as mitigation. Further consideration may be needed of government mechanisms to facilitate adaptation.

T.O.R. 10 - Timing: We submit that New Zealand should encourage international agreement to get significant emissions reductions underway as quickly as possible, and should match the timing and scale of its own measures to fit with this. The IPCC concludes[9] that "delayed emission reductions significantly constrain the opportunities to achieve lower stabilisation levels and increase the risk of more severe climate change impacts".

3. Specific Comments

We wish to comment in detail on terms of reference 4 and 6, and more briefly on 7, 9 and 10.

[9] Section 5: The Long-term Perspective. Summary for Policymakers, IPCC Fourth Assessment Synthesis Report, IPCC 2007.

TOR 4. Identify the central/benchmark projections which are being used as the motivation for international agreements to combat climate change; and consider the uncertainties and risks surrounding these projections.

Most of the projections which motivate the discussion and negotiations on international agreements are those collated and assessed in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). This assessment draws on published peer-reviewed international papers about underlying physical processes, models and their results and uncertainties, as well as an archive of climate model runs by many different research groups undertaken specifically for assessment in the AR4.

The IPCC process includes an assessment of the relevant available material by expert lead authors, together with two extensive cycles of review involving experts and then governments from all over the world. The process has been outlined to the committee in more detail in the presentation from NZCCC member, the New Zealand Climate Change Research Institute of Victoria University. The IPCC's strong and balanced process is why we recommend its Fourth Assessment Report as the authoritative source for information on climate projections for various greenhouse gas emissions scenarios, and their uncertainties and risks.

Emissions Scenarios on which IPCC Projections are Based

The IPCC provides two classes of projections: Those based on "SRES scenarios[10]" which explore a range of development paths which do not include additional climate policies above current ones, and those based on "stabilisation scenarios" which assume international mitigation efforts to eventually stabilise greenhouse gas concentrations in the atmosphere. More details are provided in Table 1

Table 1: Properties and Uses of SRES and Stabilisation Scenarios

	SRES Scenarios	Stabilisation Scenarios
Contain:	Different scenarios of greenhouse gas emissions for the period 1990 -2100, driven by different projected trends in economic growth, global population, and technology. They all assume that no additional climate change mitigation policies are implemented	International mitigation efforts which eventually stabilise greenhouse gas concentrations in the atmosphere. They cover the period from about 2000 and may extend beyond 2100.
Useful for:	Exploring what impacts we could face if there is no further mitigation action, and exploring the business-as-usual emissions relative to which emissions reductions would need to occur.	Identifying the levels and timing of greenhouse gas emission reductions needed to meet various targets for global temperature change, or atmospheric greenhouse gas concentration

[10] "SRES scenarios" describes a set of emissions scenarios outlined in the 2000 IPCC Special Report on Emissions Scenarios.

SRES Scenarios – Without "Additional Climate Policies"

The IPCC organised the SRES emission scenarios into four "scenario groups" and provided six representative "marker" scenarios to cover the range. Global average surface warming projections for the end of the 21st century for these marker scenarios[11] range from[12] 1.8 [1.1 to 2.9]°C for the lowest emission scenario to 4.0 [2.4 to 6.4]°C for the highest. These are relative to the period 1980-99. To convert them to changes relative to the period 1850-1899 a further 0.5°C should be added. (The period 1850-99 can be seen as indicative of temperatures prior to significant increases caused by industrial greenhouse gas emissions).

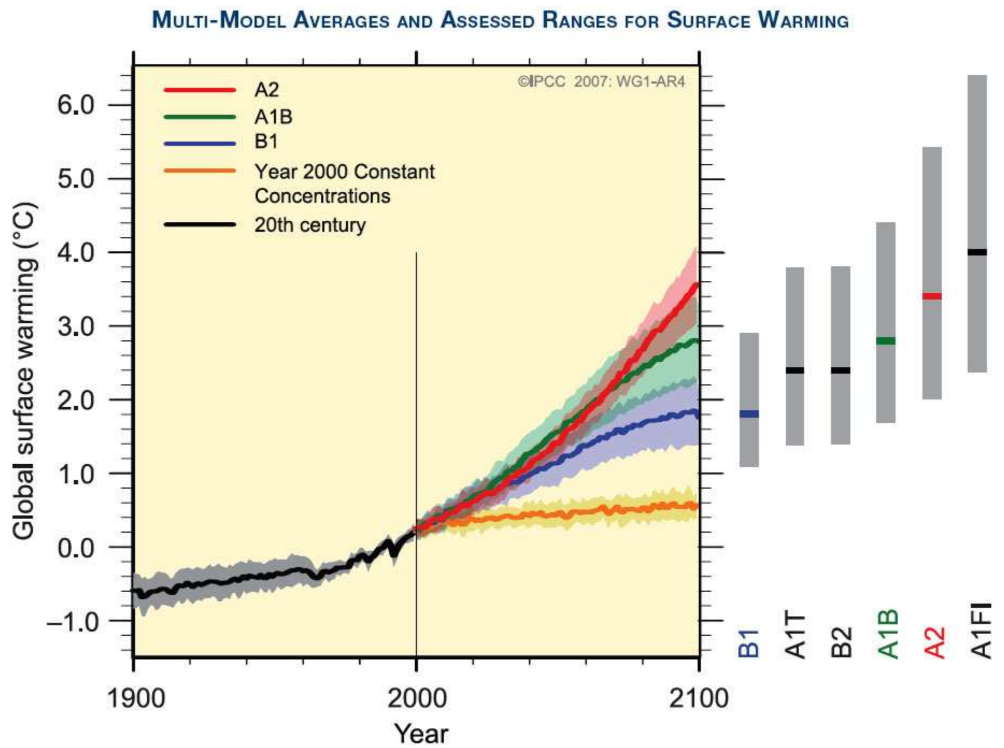

Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

Figure 1: Projections from the SRES Marker Scenarios, from the IPCC Working Group I Summary for Policymakers[13]

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[11] Table SPM 1, Summary for Policymakers, IPCC Fourth Assessment Synthesis Report, IPCC 2007.

[12] The terminology 1.8[1.1 to 2.9]°C indicates 1.8°C is the best estimate of temperature change for a given emissions scenario, and 1.1°C to 2.9°C is the "likely" uncertainty range , i.e. there is a 67% probability that future warming will lie within this range.

[13] Figure SPM 5, Table SPM 3, from Summary for Policymakers, IPCC Fourth Assessment Working Group I Report, IPCC 2007.

These SRES marker scenario projections are illustrated in Figure 1, which also indicates two measures of model "range" or "uncertainty". The shaded area around each line indicates the "standard deviation" from a series of runs with models from different modelling groups for that scenario – around 67% of the model runs would lie within this band. The grey bars on the right (and the "likely" range in Table 2) represent the assessment by the experts who assessed this material for the IPCC of the range of warming "likely" for each scenario, where "likely" indicates probability of at least 67% that the true value lies somewhere within this range, with the coloured lines indicating best estimates. The grey bands show larger uncertainties than the shaded area around each line because they include expert judgement on possible additional structural uncertainties in models (for example due to possibly imperfect simulations of the effect of clouds) and potential climate feedbacks on vegetation.

Table 2: Projections from the SRES Marker Scenarios, for the IPCC Working Group I Summary for Policymakers[14].

Table SPM.3. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a] Best estimate	*Likely* range	Sea Level Rise (m at 2090-2099 relative to 1980-1999) Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Table notes:
[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).
[b] Year 2000 constant composition is derived from AOGCMs only.

In addition to the SRES projections, Figure 1 and Table 2 also show a projection of how global average temperature would be expected to change if greenhouse gas and aerosol concentrations in the atmosphere were to remain constant at year 2000 values. This is an entirely hypothetical scenario, which would have required large global carbon dioxide emission reductions starting in 2001, far beyond even the most stringent mitigation scenarios currently considered to be practical.

The global sea level rise projections in the table do not include a possible change in the rate at which ice flows from the Greenland and Antarctic ice sheets due to new

[14] Table SPM 3, from Summary for Policymakers, IPCC Fourth Assessment Working Group I Report, IPCC 2007.

phenomena observed in recent years at the ice sheet margins. Nor do they include the full uncertainties in climate-carbon cycle feedbacks, because scientific understanding of these processes was too limited at the time of the completion of the assessment.

Since the Fourth Assessment, various estimates of sea level rise which include accelerated but plausible conditions of polar ice loss have been published in the scientific literature. These estimates range as high as global sea level rise of 2 m[15] by the end of this century, but without any obvious convergence.[16]

In the longer term, models suggest that if global average temperature increases in excess of somewhere between 1.9°C and 4.6°C were sustained for a long period, that could lead to virtually complete elimination of the Greenland Ice Sheet and a resulting contribution to sea level rise of about 7 m (over a period of many hundreds of years to millennia). The last time the world was a few degrees warmer than today for an extended period (about 125,000 years ago), paleoclimatic information suggests that sea levels were about 4 to 6 m higher than today, mainly due to the reduction of polar ice.

IPCC Working Group II produced a figure (based on their literature assessment) summarising some of the impacts expected to be associated with various amounts of projected global warming[17] in the 21st century. This is included in the Appendix to the present submission (Figure A1). It indicates significant negative impacts in many sectors, especially once global average temperature increases by more than about 1.5°C over 1980-99 values. (Note that this table refers to <u>global</u> impacts. We provide further information on projected New Zealand impacts under T.O.R. 6).

The information provided in this section indicates why there is international pressure to reduce greenhouse gas emissions. It is also why a target of 2°C above pre-industrial temperatures (1.5°C above 1980-99 temperatures) is frequently discussed in the context of UNFCCC negotiations. The IPCC best projections for all of the SRES (no additional climate intervention) scenarios would lead to warming above this target by the end of the 21st century. Note though that the IPCC itself does not advocate any specific mitigation target since this would be seen as policy-prescriptive and therefore outside its mandate.

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[15] Pfeffer *et.al*. (2008): Kinematic constraints on glacier contributions to 21st century sea level rise. Science 21, 1340-1343.

[16] Alley, R.B.; Fahnestock, M.; Joughin, I. (2008). Understanding Glacier Flow in Changing Times. Science 322: 1061-1062.

[17] Figure SPM 7, Summary for Policymakers, IPCC Fourth Assessment Synthesis Report, IPCC 2007.

Mitigation Scenarios with Policy-Driven Greenhouse Gas Emission Reductions

The previous paragraphs outline the reasons for policy negotiations on reducing greenhouse gas emissions. The findings outlined above, and the need for science to guide policy, have led to modelling work on future emissions pathways which would lead to stabilisation of greenhouse gas concentrations in the atmosphere at various levels, corresponding to various amounts of eventual global average temperature increase. Such “stabilisation scenarios” and some of the uncertainties associated with them are considered in Section 10.4 of the IPCC Working Group I Fourth Assessment Report. Work on emissions trajectories for stabilisation, and on temperature and sea level projections associated with these trajectories, is summarised and assessed in the IPCC Working Group III report, and carried through into the IPCC Fourth Assessment Synthesis Report.

Table 3, which is extracted from the Summary for Policymakers of the Synthesis Report, provides a summary of pertinent information.

Table 3: Information on Stabilisation Scenarios, from the IPCC Fourth Assessment Synthesis Report[18]

Table SPM.6. *Characteristics of post-TAR stabilisation scenarios and resulting long-term equilibrium global average temperature and the sea level rise component from thermal expansion only.[a] {Table 5.1}*

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d, e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes:

a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).

b) Atmospheric CO_2 concentrations were 379ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375ppm CO_2-eq.

c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure SPM.3).

d) The best estimate of climate sensitivity is 3°C.

e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150 (see also Footnote 21).

f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

[18] Table SPM 6, Summary for Policymakers, IPCC Fourth Assessment Synthesis Report, IPCC 2007.

Table 3 shows that to constrain long-term global average temperature increases (once the climate system has reached a new equilibrium) to within 2.0°C to 2.4°C above pre-industrial conditions (1.5 to 1.9°C above 1980-99 values), the stabilisation scenarios assessed in the IPCC's Fourth Assessment have a reduction in global carbon dioxide emissions in 2050 of between 50% and 85% compared to emissions in the year 2000. For a stabilisation target of 450 ppm carbon dioxide-equivalent (corresponding to the lower end of the 2-2.4°C scenarios discussed above) the IPCC Working Group III (Mitigation) assessment indicates a target reduction by 2020[19] of 25 to 40% in emissions by Annex 1 countries compared to 1990 emissions. The numbers outlined in this paragraph are the sources of the emissions targets for international efforts to mitigate climate change, which are being discussed in the negotiations about international agreements to follow the first commitment period (2008-12) under the Kyoto Protocol.

Even under this most stringent mitigation scenario, sea level is expected to rise inexorably by between 0.4 and 1.4 m due to thermal expansion of the ocean alone over many centuries. Additional contributions would come from melting glaciers and reduced snow cover mainly during the 21st century. In addition, reductions of polar ice sheets could add several metres over centuries to millennia. Partial melting of ice sheets cannot be ruled out even for the lowest mitigation scenario and would lead to major impacts on the world's coastlines and coastal cities.

The Uncertainties and Risks Surrounding Climate Projections

Climate models are based on solving a set of mathematical equations that describe the physical behaviour of the atmosphere and oceans (e.g. the equations governing fluid motion and heat transfer). They are therefore fundamentally different from most approaches to economic modelling (where statistical relationships between various factors built up from past observations are used to predict the future). The scientific community has put substantial effort into evaluating climate models, as documented in Chapter 8[20] of the Working Group I report of the IPCC. Quoting from the Executive Summary of that chapter:

Climate models are based on well-established physical principles and have been demonstrated to reproduce observed features of recent climate and past climate changes. There is considerable confidence that Atmosphere-Ocean General Circulation Models (AOGCMs) provide credible quantitative estimates of future climate change, particularly at continental and larger scales. Confidence in these estimates is higher for some climate variables (e.g. temperature) than for others (e.g. precipitation).

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19 Box 13.7, Chapter 13, Working Group III Report, IPCC Fourth Assessment, 2007.

20 Chapter 8: Climate Models and Their Evaluation. IPCC Fourth Assessment Working Group I Report, IPCC 2007.

There are various other lines of evidence in addition to global climate model studies that indicate the degree of sensitivity of global temperatures to changes in climatic forcing factors such as changes in greenhouse gas concentrations. These include:

- examination of the transient evolution of temperature (surface, upper air and ocean) over the last 150 years,
- examination of the rapid response of the climate system to volcanic eruptions(where particles sent into the upper atmosphere by the eruption scatter incoming solar radiation),
- changes to temperature and greenhouse gas concentrations in the past (over paleoclimate timescales of hundreds to hundreds of thousands of years), and
- studies carefully evaluating the physics of climate forcing by greenhouse gases (outlined usefully in a recent book by Archer[21]).

These lines of evidence point to similar amounts of warming from increasing greenhouse gas concentrations to the predictions from climate models.

IPCC lead authors carefully assessed the uncertainty ranges for the climate projections at the end of the 21st century for the SRES scenarios. These are shown by the grey bars on the right hand side of Figure 1. For any particular scenario it is assessed there is at least a 67% likelihood that the "true" projection lies within the grey shaded area. These ranges take into account results from different climate models, estimates of uncertainties in the carbon cycle, and observational constraints (such as those discussed above) to the sensitivity of global temperatures to climate forcing factors.

When developing policy, given the uncertainty ranges outlined above, it is also prudent to take into account the risks posed by the inertia of the climate and economic systems. The climate system has a considerable inertia, resulting largely from the long time the ocean takes to heat up in response to warming of the atmosphere. Temperatures would therefore continue to warm for a century or more after greenhouse gas concentrations have been stabilised, and the sea level would continue to rise for many centuries in a warmer world as its temperature increases and hence its volume expands and land-based ice continues to melt. The inertia of the energy system and the built environment, with their long-lived capital infrastructure, also means that the global diffusion of low-carbon technologies and substantial reductions in global emissions will take many decades even if investments are made financially attractive or represent no additional cost to existing technologies.

Thus waiting for several decades for near-absolute certainty that the globe is on a trajectory towards critical "dangerous" temperature levels, before beginning global efforts to abate greenhouse gas emissions, would be a very high risk strategy. Because of the inertia in the climate and economic systems, by the time such a stage

[21] Archer, D. Global Warming – Understanding the Forecast. Blackwell Publishing, 2007.

was reached we would be committed to substantial further warming and associated major impacts on natural and managed systems for many decades to centuries. The prudent global risk management approach is to begin abatement activities now, given the high risk and very substantial global impacts if we do not. Increasing observational evidence of climate change and its impacts further supports this approach.

TOR 6. Examine the relative merits of a mitigation or adaptation approach to climate change for New Zealand.

A Global Perspective on Mitigation and Adaptation

As can be seen from Table 2, a warming of around 0.6°C is projected by the end of the 21st century compared to 1980-99, under a scenario of holding greenhouse gas concentrations in the atmosphere constant at year 2000 levels. Such a scenario is virtually impossible in practice, given the inertia of the global economic system and hence in emission rates. The lowest set of "stabilisation" scenarios considered in our previous section have an eventual globally-averaged warming of 2.0 to 2.4°C above pre-industrial levels (1.5°C to 1.9°C above 1980-99). Figure A1 (in the appendix) indicates that substantial global impacts on various sectors are expected at this level of temperature change. Therefore even if global negotiations on greenhouse gas emissions are fully successful and lead to substantial emission reductions, it will still be necessary to adapt to various inevitable changes, some of which will have significant impacts in the most vulnerable sectors and regions around the world.

Figure A1 in the appendix indicates that substantially increasing impacts would be expected to result if global warming levels become higher than the "stabilisation" levels discussed above. In addition to changes in climatic factors such as temperature and rainfall, increasing carbon dioxide concentrations lead to acidification of the oceans. Surface ocean pH[22] has decreased by 0.1 units and is predicted to decrease by up to a further 0.3-0.4 units by 2100. This may impact a wide range of organisms and ecosystems (e.g., coral reefs and deepwater coral ecosystems). Organisms using aragonite (a form of calcium carbonate) to make their shells will be at risk and this will threaten ecosystems in regions such as the Southern and Arctic Oceans in which such organisms play a dominant role in the food web and carbon cycling[23]

We also discussed in the previous section the increasing risk of eventual near complete melting of the Greenland ice-shelf with further long-term temperature

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[22] Decreases in pH correspond to increases in acidity.

[23] Section 4.4.9, Chapter 4, Ecosystems, their properties, goods and services. IPCC Fourth Assessment Working Group 2 Report, IPCC 2007.

rise. The Stern Report[24] concluded that: *The costs of stabilising the climate are significant but manageable: delay would be dangerous and much more costly*. The recent Garnaut Review[25] estimates that by the end of the century, Australian GNP (Gross National Product) would be higher for mitigation at 550 ppm CO_2-equivalent than without undertaking such mitigation. The findings outlined in this paragraph provide an imperative for mitigating emissions.

Thus from a global perspective, both mitigation and adaptation are indicated – it is not a case of either / or. The IPCC concludes[26]: "There is *high confidence* that neither adaptation nor mitigation alone can avoid all climate change impacts: however, they can complement each other and together can significantly reduce the risks of climate change."

A New Zealand Perspective on Mitigation and Adaptation

It might be tempting to conclude that, for New Zealand, the implications of climate change are:

- We will need to adapt if there is no substantial international effort to mitigate, or
- We should not mitigate ourselves and should only adapt.

It is our submission, however, that from a New Zealand perspective (as well as from a global perspective) both mitigation and adaptation action are required.

The amount of temperature change, and the extent of changes in other aspects of climate, is projected to vary regionally and locally, compared to "global average" changes. NZCCC member NIWA has produced "downscaled" climate change scenarios for New Zealand, corresponding to the global SRES marker scenarios discussed in previous sections. These scenarios provide a basis for assessing the climate changes and impacts expected in New Zealand over the coming century if there are not substantial global efforts to mitigate greenhouse gas emissions. Many of our member organisations have undertaken work to estimate the impacts on various sectors and regions of New Zealand that would be expected as a consequence of these downscaled SRES-based climate projections.

Our members are also active in research into New Zealand emissions mitigation, including reducing methane emissions and nitrous oxide from ruminant animals, managing soil carbon dynamics, energy efficiency in buildings and industry, potential for renewable energy generation (to displace growth in electricity

[24] Nicolas Stern (2006). The Economics of Climate Change – The Stern Review. Cambridge Univeristy Press.
[25] Chapter 11: Costing Climate Change and its Avoidance. In: Ross Garnaut (2008) The Garnaut climate change review. Cambridge University Press.
[26] Section 5: The Long-term Perspective, in Summary for Policymakers, IPCC Fourth Assessment Synthesis Report, IPCC 2007.

generation from fossil fuels), carbon capture and storage, and transport and urban form.

The latest NIWA SRES-based climate change projections for New Zealand, obtained from downscaling global climate model runs undertaken for the IPCC's Fourth Assessment Report, are outlined in a recent guidance manual[27] for local government published by the Ministry for the Environment. Projected New Zealand-averaged temperature changes for a particular scenario are typically about three quarters of the global-average projection[28], because in most models the ocean at our latitude does not warm up as quickly as the global average.

A summary of the SRES-based projections is as follows[29]:

Temperature

The best-estimate projections for New Zealand temperature increases compared to 1990[30], obtained by NIWA by averaging downscaled results from 12 different global climate models, are:

- For 2090: Increases ranging from 1.3°C for the lowest-emission SRES marker scenario, to 2.9°C for the highest-emission SRES marker scenario.
- For 2040: Increases ranging from 0.6°C for the lowest-emission SRES marker scenario, to 1.3°C for the highest-emission SRES marker scenario.

Due to the increase in temperatures averaged over New Zealand during the 20th century[27], a further 0.8°C should be added to the values stated above to turn them into temperature increases compared to 1900. Note also that the rate of temperature increase under these SRES scenarios is projected to speed up over time. The projected increases are larger than the long-term trend experienced over the 20th century.

Rainfall and wind

Projected rainfall and wind patterns show seasonal variations, with westerlies projected to increase in winter and spring, along with more rainfall in the west of both the North and the South Island and drier conditions in the east and north. Conversely, the models suggest a decreased frequency of westerly conditions in summer and autumn, with drier conditions in the west of the North Island and possible rainfall increases in Gisborne and Hawke's Bay.

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27 Ministry for the Environment (2008) Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government. Second Edition.Publication number ME870. Wellington.

28 Chapter 2, Ministry for the Environment (2008) Climate Change Effects and Impacts Analysis: A Guidance Manual for Local Government. Second Edition.Publication number ME870. Wellington

29 These projections are summarised from the NIWA downscaling analyses used to produce Chapter 2, Projections of Future NZ Climate Change, in: Ministry for the Environment (2008) Climate Change Effects and Impacts Analysis: A Guidance Manual for Local Government. Second Edition.Publication number ME870. Wellington

30 In this section, "1990" refers to the climate over the period 1980-99; 2040 to the period 2030-2048, and 2090 to the period 2080-2099.

Sea-level rise

Rates of sea-level rise averaged around the NZ coast may be slightly higher (perhaps 5 cm more by the end of this century[31]) than the global projections we have outlined under T.O.R.4. A review of the state of knowledge in mid-2008 led to the following New Zealand guidance for planning and decision timeframes out to the 2090s[31]:

- a base value sea-level rise of 0.5 m relative to the 1980–1999 average should be used, along with
- an assessment of the potential consequences from a range of possible higher sea-level rises (particularly where impacts are likely to have high consequence or where additional future adaptation options are limited). At the very least, all assessments should consider the consequences of a mean sea-level rise of at least 0.8 m relative to the 1980–1999 average.

Other Climate Changes

Other projected changes include decreased frost frequency, increased frequency of high temperatures, increased frequency of extreme daily rainfalls, decreased snow cover, and a possible increase in strong winds.

Projected Impacts of Climate Changes on New Zealand

The literature on expected impacts of climate change on New Zealand, much of it written by scientists from NZCCC member organisations, is assessed and summarised in the Australia and New Zealand chapter of the IPCC's Fourth Assessment[32]. This chapter includes a statement that: *The potential impacts of climate change are likely to be substantial without further adaptation.*

For climatic changes typical of the SRES scenario range outlined above, the projected impacts for New Zealand identified in the IPCC Australia and New Zealand chapter include:

- stresses on and degradation of many natural ecosystems
- increasing water security problems in some parts of eastern New Zealand
- increasing risks to coastal development from sea-level rise and storms
- increasing risks to infrastructure from flooding, and some changes in health risk.

For agriculture, horticulture and forestry there may be some initial benefits due to longer growing seasons, fewer frosts, and enhanced growing conditions from higher carbon dioxide concentrations, "provided adequate water is available". But this IPCC chapter states that by 2050 agriculture and forestry production is likely to be reduced over parts of eastern New Zealand due to increased drought and fire.

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[31] Ministry for the Environment (2008). Coastal Hazards and Climate change. A Guidance Manual for Local Government. Second Edition. Publication Number ME870. Wellington.

[32] "Australia and New Zealand". Chapter 11, Working Group II Report, IPCC Fourth Assessment 2007.

The EcoClimate Report[33], to which several of our members contributed, was produced after the close-off for the Fourth Assessment. This report suggests that overall the impact of changes in climate on pasture production (and through this on New Zealand dairy and meat production) are likely to be small over the coming century. However this result masks some spatial changes – projected increased productivity in some parts of New Zealand and decreases in others, and may not include the full effects of changes in extremes. Also total national production in the “worst” years projected for later this century is expected to be lower than current “worst-year” production. For horticulture, changes in areas suitable for particular crops are expected due to regional changes in factors such as winter chilling, frost frequency, water availability, and growing degree days. A warmer climate would be expected to increase the risk of tropical plant pests and diseases establishing in New Zealand, including some which transmit diseases.

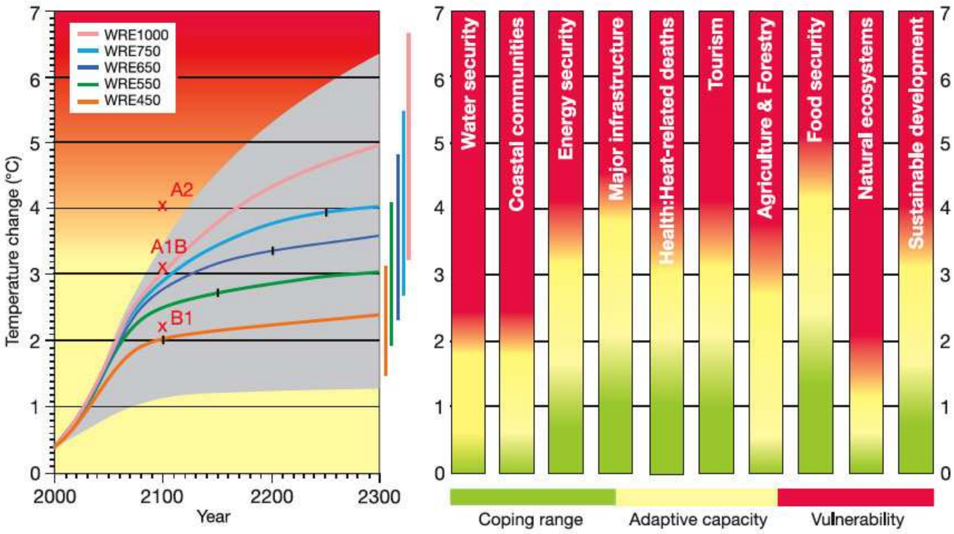

Figure 11.4. *Vulnerability to climate change aggregated for key sectors in the Australia and New Zealand region, allowing for current coping range and adaptive capacity. Right-hand panel is a schematic diagram assessing relative coping range, adaptive capacity and vulnerability. Left-hand panel shows global temperature change taken from the TAR Synthesis Report (Figure SPM-6). The coloured curves in the left panel represent temperature changes associated with stabilisation of CO_2 concentrations at 450 ppm (WRE450), 550 ppm (WRE550), 650 ppm (WRE650), 750 ppm (WRE750) and 1,000 ppm (WRE1000). Year of stabilisation is shown as black dots. It is assumed that emissions of non-CO_2 greenhouse gases follow the SRES A1B scenario until 2100 and are constant thereafter. The shaded area indicates the range of climate sensitivity across the five stabilisation cases. The narrow bars show uncertainty at the year 2300. Crosses indicate warming by 2100 for the SRES B1, A1B and A2 scenarios.*

Figure 2: Vulnerability to climate change aggregated for key sectors in the Australia and New Zealand region[34], as a function of global temperature increase above pre-industrial levels.

Figure 2, from the IPCC Fourth Assessment Report Working Group II report, summarises the authors’ assessment of the vulnerability of various sectors in

[33] EcoClimate Consortium (2008): Costs and Benefits of Climate Change and Adaptation to Climate Change in New Zealand Agriculture: What Do We Know so Far? Report for the Ministry of Agriculture and Forestry. Available at: http://www.maf.govt.nz/climatechange/slm/ag-production/2008the-ecoclimate-report.pdf .

[34] Figure 11.4, Chapter 11: Australia and New Zealand. Working Group II Report, IPCC Fourth Assessment. 2007.

Australia and New Zealand to various degrees of global temperature change compared to pre-industrial temperatures.

The findings outlined in this section indicate that under a “non-mitigation” global future, adaptation to climate change in New Zealand will be necessary in order to deal with the increasing risks projected for hazards such as floods, droughts, and fire, the potential impacts of changes in storms, landslips, sea level rise and storm surges, and the potential impacts on both managed and unmanaged ecosystems, including fisheries. From past experience we know that New Zealand is vulnerable to such hazards. For example, the estimated reduction to New Zealand’s GDP from the 1997/98 drought was NZ$618 million[35], and from the 1998/99 drought was NZ$539 million[36]. A Treasury report[37] concluded that “a detrimental climate shock (drought in eastern New Zealand) was “a principle reason for the 1998 recession”.

Climate change is likely to lead to changing patterns of land-use. These will have implications for infrastructure, labour requirements (demand and supply), and regional council policies on protecting soil, water and biodiversity resources. Adaptation will also be desirable in order to take advantage of new horticultural opportunities, and increases in the length of the growing season.

An additional issue for New Zealand under a non-mitigation future is that the projected changes in sea-level rise (and also the projected likelihood of more intense tropical cyclones) are expected to lead to substantial stresses on the low-lying small island states to our north – under some scenarios rendering some islands eventually uninhabitable.

Given the projected impacts of unmitigated climate change on New Zealand, and the likely international pressures on our trade if other countries agree to global mitigation policies but we do not, we recommend New Zealand implements a mitigation approach consistent with international policy developments.

We now consider the implications for New Zealand if international negotiations do lead to substantial global mitigation through abatement of emissions. As described in our “global perspective” discussion, even under the most stringent international mitigation policies, global temperature rises of the order of 2°C appear likely. Figure 2 indicates that adaptation would be needed even under such a stringent mitigation scenario to manage risks to the most vulnerable sectors and regions within New Zealand, particularly water supply, coastal communities and natural ecosystems, but also for agriculture and forestry.

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[35] Ministry of Agriculture and Forestry (2000). Situation and Outlook for New Zealand Agriculture and Forestry.

[36] Wratt et al, 2006: New Zealand Climate Change – Water and Adaptation. In: “Confronting Climate Change- Critical Issues for New Zealand. Victoria University Press, Wellington.

[37] Bucckle et al, 2002: A structural VAR model of the New Zea;land Business Cycle. Working Paper 02/06, New Zealand Treasury, Wellington.

We conclude that from both international and the national perspectives, mitigation and adaptation policies and actions are essential. Agricultural and horticultural enterprises can develop approaches to both mitigation and adaptation, through changing within-farm practices and soil management in particular. Options include:

Mitigation:

- sequestering carbon in soil
- reduction of methane and nitrous oxide emissions
- afforestation of marginal agricultural land

Adaptation:

- higher soil organic matter leading to greater water holding capacity and hence less need for irrigation
- more nitrogen mineralization leading to less fertiliser application and less resulting degradation in water quality
- improved water harvesting and management

We also note that studies in larger economies suggest that flow-on effects from impacts occurring outside their own boundaries are potentially as large as or larger than the direct effects occurring inside their boundaries. For New Zealand these flow-on effects include both the impacts of potential international policies on fuel process and trade, and the impacts of climate changes themselves on production in other countries and on regional stability resulting e.g. from loss of sustainability in Pacific Island countries. (Some small Pacific Island nations are very vulnerable to potential combined effects of sea level rise and storm surge from more intense tropical cyclones [38], and to impacts on coral reefs and associated ecosystems from increasing ocean temperatures and ocean acidification). Adaptation to flow-on effects arising from outside of New Zealand will be necessary.

TOR 7: Consider the case for increasing resources devoted to New Zealand-specific climate change research.

Under T.O.R, 6 we have argued the need for both mitigation and adaptation approaches to climate change for New Zealand. As noted in the National Party pre-election climate change policy statement, “good science is essential to quality decision making”. Our members are undertaking critical research on both adaptation-relevant and mitigation-relevant topics, largely funded through the Foundation for Research, Science and Technology (FRST), the Pastoral Greenhouse Gas Research Consortium (PGGRC)(an industry/government partnership), and MAF. The individual submissions from some of our members (GNS Science, Landcare Research, Scion, Victoria University) provide their views on specific areas where they consider more research investment to be desirable.

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[38] Dupont, A.; Pearman, G. (2006). Heating up the planet: Climate Change and security. Lowy Institute Paper No 12 (http://www.lowyinstitute.org/Publication.asp?pid=391).

The members of the New Zealand Climate Change Centre between them possess a wide range of knowledge and expertise in climate change. Our members would be pleased to work together on any specific national assessments on scientific and technical issues related to climate change which are required. Such national assessments have been undertaken in other countries (and were carried out in New Zealand in the early 1980s). They would require some financial resources to cover the time of expert participants.

Our members would also be pleased to work collaboratively with and support government agencies in identifying strategic research opportunities and gaps. This would provide early identification of significant new issues and developments from a scientific perspective, and identify the resources (including scientific capacity) and the international linkages that would be required to address them. This could help agencies such as FRST, Ministry of Research, Science and Technology (MoRST) and MAF develop investment plans and strategic research priorities.

We consider that at a minimum, maintaining at least the current level of Research, Science & Technology (RS & T) is critical to New Zealand, for clearly no other country will do work for us that lies at the core of our national interests. New Zealand's credibility in international fora and our ability to identify and develop the most cost-effective responses to climate change depends on a credible and internationally recognised research, science and technology effort

TOR 9: Consider the need for any additional regulatory interventions to combat climate change if a price mechanism (an ETS or a tax) is introduced.

Our members are not experts in the field of government laws and regulations, so we have not provided detailed submissions on this item. Nevertheless, while the focus of this review is on the emissions trading scheme and/or other mechanisms to address reductions in climate change emissions, we have pointed out under T.O.R. 6 that New Zealand should address adaptation as well as mitigation. Further consideration may be needed of government mechanisms to facilitate adaptation.

TOR 10: Consider the timing of introduction of any New Zealand measures, with particular reference to the outcome of the December 2009 Copenhagen meeting, the position of the United States, and the timetable for decisions and their implementation by the Australian government.

It is explained in the IPCC Synthesis Report that early mitigation actions would avoid further locking in carbon intensive infrastructure and reduce climate change and associated adaptation needs. One of the highlighted conclusions is: *"Many impacts can be reduced, delayed or avoided by mitigation. Mitigation efforts and investments over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation levels. Delayed emission reductions* *significantly constrain the opportunities to achieve lower stabilisation levels and increase the risk of more severe climate change impacts*[39]*."*

We are not experts on progress with negotiations on agreements to follow the first Kyoto commitment period, and the positions and timetables of the United States and Australian Governments. Nevertheless, we do see strong scientific and technical reasons for progressing quickly with mitigation. Our members do and will help by providing supporting science to New Zealand's negotiators. We submit that New Zealand should encourage international agreement to get significant emissions reductions underway as quickly as possible, and should match the timing and scale of its own measures to fit with this.

[39] Section 5: The Long-term Perspective, in Summary for Policymakers, IPCC Fourth Assessment Synthesis Report, IPCC 2007.

APPENDIX

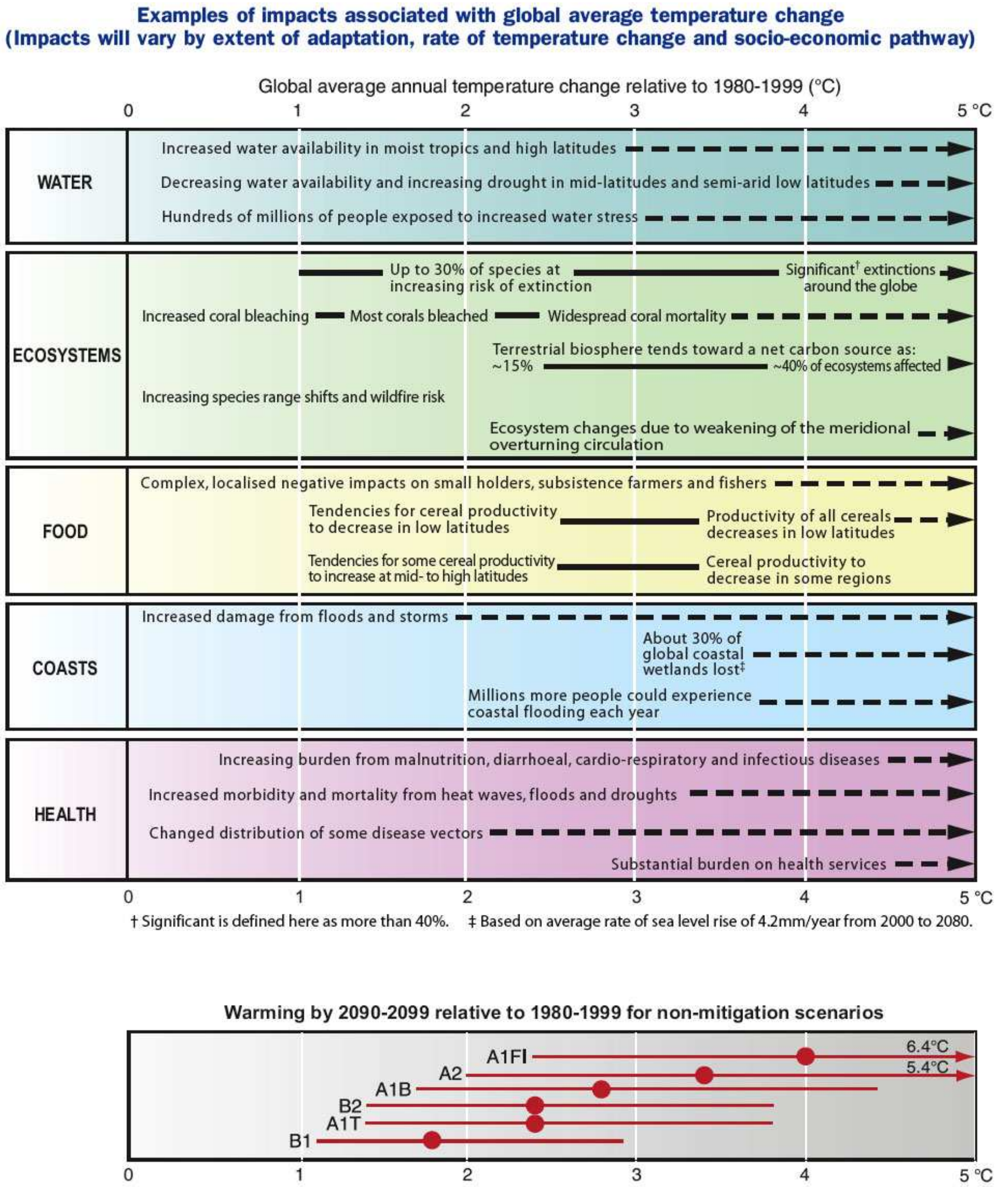

Figure SPM.7. Examples of impacts associated with projected global average surface warming. ***Upper panel:*** *Illustrative examples of global impacts projected for climate changes (and sea level and atmospheric CO_2 where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. The black lines link impacts; broken-line arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left-hand side of text indicates the approximate level of warming that is associated with the onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. Confidence levels for all statements are high.* ***Lower panel:*** *Dots and bars indicate the best estimate and likely ranges of warming assessed for the six SRES marker scenarios for 2090-2099 relative to 1980-1999. {Figure 3.6}*

Figure A1: Impacts Associated With Various Levels of Global Average Temperature Change[40]

[40] Figure SPM 7, Summary for Policymakers, Synthesis Report, IPCC Fourth Assessment (2007).