New Zealand Association of Scientists discussion paper

Climate change

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1. Introduction

1.1 A shift in the debate

Over the last half-decade or so the debate on climate change has shifted from discussions of whether or not it is real and anthropogenic in nature, to questions around its likely impacts, and mitigation of and adaptation to, those impacts. It is now clear that many Kyoto Protocol signatories, including New Zealand, are unlikely to meet their emission reduction targets over the First Commitment Period (2008–2012) without purchasing emission reduction units on the international market. Domestic carbon dioxide emissions are still increasing and are now over 30% greater[1] than those of 1990. Consequently, New Zealand will probably fail to reduce to the levels of that year, and looks certain to bear an emissions deficit of more than $500 million over the First Commitment Period. However, notwithstanding the present inability of many nations to meet the established targets, the Kyoto Protocol remains a vital first step towards responsible behaviour that ultimately will enhance the quality of life of future generations.

The Climate Change and Governance Conference, held at Te Papa, Wellington, in March 2006, provided a necessary forum for international concern about an issue of paramount importance. It also succeeded in placing New Zealand at centre stage in the international debate, and demonstrated that New Zealand is a nation that can play a significant part in the big geopolitical issues. Given the overwhelming preponderance of scientific opinion, the conference left those of us who attended in little doubt that climate change is real, and raised awareness that anthropogenic emissions are at least a partial cause. Now, at the beginning of the third millennium, the international community must take meaningful steps to limit the release, and mitigate the effects, of carbon dioxide and other harmful emissions through both technology and policy approaches, and develop a continuing capacity to adapt to climate change and its associated variability and instability.

In 2005 the globally averaged concentration of atmospheric carbon dioxide (the main contributor to the Earth's enhanced greenhouse effect) was about 380 parts per million (ppm). In the same year the concentration of atmospheric methane (the second most significant contributor to the Earth's enhanced greenhouse effect) was about 1.8 ppm. Though a high per capita emitter, New Zealand produces only about 0.2% of the world's greenhouse gases, so that even a major reduction in our emissions would make little difference to the global emissions budget. However, this fact is no reason for failing to act as a good global citizen. Mitigating climate change requires substantive reductions in global greenhouse gas emissions, both through minimising the world's dependence on fossil fuels and through the adoption of alternative energy sources. As a signatory to the Kyoto Protocol, New Zealand is now poised to make significant contributions to addressing climate change through meaningful engagement in the ongoing policy debate, but also through its excellent science.

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The views articulated in this article are not necessarily those of my employer, The Royal Society of New Zealand.

1.2 Objections to climate-change science?

1.2.1 Climate change as just one global problem?

At present, a small, but vocal, minority remains unconvinced of anthropogenic climate change. We must consider their objections carefully because they remind us of the necessity for robust science. Others see the proposed measures to reduce emissions and to adapt to climate change as unwise uses of scarce resources when issues of terrorism, warfare, malnutrition, infant mortality, poverty, disease and energy security apparently present much more urgent demands.

1.2.2 Global carbon dioxide concentration measurements

A commonly raised objection is that historic (prior to 1950) globally averaged carbon dioxide and methane concentration figures were based on sparse, unrepresentative and unreliable ice core data, and that present-day measurements are biased, mostly having been taken over the oceans. In fact, records taken at remote sites, such as the Antarctic, are reliable because of the integration of gas concentrations due to atmospheric mixing (David Lowe, pers. comm.). Problems can occur if measurements are taken close to cities or adjacent to grain fields.

The European Project for Ice Coring in Antarctica (EPICA) has provided an ice core that extends the carbon dioxide record back about 650 000 years[2], some 210 000 years longer than the Vostok record[3], which also provided valuable greenhouse gas information. The atmospheric carbon dioxide concentration is now about 36% greater than the pre-industrial (1750 AD) value of about 280 ppm, and possibly is higher than at any time over the last 20 million years[4]. Although the relative positions of the sun and the earth are thought to be the major driver of ice age cycles, the new core indicates a stable relationship between carbon dioxide, methane and Antarctic climate. For example, it shows that the concentrations of both gases were lower during relatively mild warm periods than during the hotter warm periods of the last 400 000 years.

1.2.3 Global methane concentration measurements

Natural sources of methane are mostly biogenic (processes occurring in anaerobic environments, particularly in wetlands). Ice core measurements show that atmospheric methane has more than doubled since industrialisation and, during the last ice age, was less than half the pre-industrialisation concentration[5].

Atmospheric methane absorbs terrestrial infra-red radiation that would otherwise radiate into space. It is about 21 times more effective at warming the atmosphere than carbon dioxide by weight. Its short atmospheric chemical half-life (5–12 years), and potency in absorbing infra-red, suggests that we can make real progress on climate change over the near term by addressing methane emissions[6]. The historic record indicates that methane is present in greater concentrations than at any previous time over the last 400 000 years[7]. The global average methane concentrations have increased 150% since 1750, but the overall rate of growth has slowed over the last decade. Atmospheric methane remained at a steady concentration (1.75 ppm) between 1999 and 2002[8]. The reason for relative stability since 1999 is unclear, but isotopic analysis suggests that is unlikely to be due to draining of wetlands (David Lowe, pers. comm.).

1.2.4 The unknown role of water vapour and aerosols in global warming

A common objection is that the aggregate greenhouse effect of atmospheric water vapour and clouds remains unclear, and could be much greater than that of atmospheric carbon dioxide. Water vapour has a greater greenhouse effect than any other gas, including carbon dioxide, so that variations in atmospheric moisture content can be highly important. As the earth warms, ocean water evaporates, enhancing the warming effect. However, some of the vapour turns to cloud, reflecting the sun's radiation back into space, but also trapping heat. The net effect of additional water vapour and clouds increases warming, and recent work indicates that clouds could have a very powerful warming effect[9].

1.2.5 Global average surface temperature record

Objections to the globally averaged surface temperature record centre on the absence of a representative statistical sample of surface temperature measurements (taken on weather stations and ships), on the reliability of those records, that the existing records indicate a fall in temperature between 1940 and 1976, and that the average temperature has not risen since 1998. IPCC global temperature data[10] (based on thermometer measurements) do indicate a negative departure from the 1961–1990 average between 1940 and 1976 (possibly relating to the shading effects of industrial aerosols during that period). However, IPCC data also reveal a temperature maximum between 1930 and 1940 (possibly resulting from solar effects[11]), and warming is very clear from about 1970 onward, amounting to approximately 0.5°C from that year and to approximately 0.8°C from the mid-nineteenth century onward. Such temperature increases are dramatic and could have major negative effects on economies, world agriculture, physical environments and on ecosystems. They are particularly worrying because fossil fuels remain relatively cheap and available energy sources, and we continue to emit carbon dioxide in increasing amounts.

There is a concern that temperature measurements could have been biased by the development of towns and cities near the sites where temperatures are measured, as built environments retain more heat than rural areas. However, when the historic temperature record is separated into a set taken in calm weather and another in windy weather, no significant difference emerges[12], even though warming effects due to nearby cities should be more pronounced in calm conditions, when wind cannot dissipate the heat. Thus, the proximity of towns and cities probably has no significant effect on the historic temperature record.

However, while scientists have a high level of confidence that global mean temperatures were higher during the last decades of the twentieth century than previously[13], less confidence can be placed on data from 900 AD to 1600 AD (for which some historic observational records exist) and particularly on data prior to about 900 AD. Scientists recognise that proxy records of past temperatures, based on dendrochronology and the isotopic composition of snow, stalactites and corals (and even hard-to-calibrate historic data, such as the dates of grape harvests, diary records of frosts and heat-waves, and sea-ice-free periods in harbours), are more uncertain than instrumental observations. Careful averaging of proxy records to produce global or hemispheric records is required, and sophisticated data-reduction methods (such as principal components analysis) are used on regional records prior to incorporation within the global record.

1.2.6 Lower atmosphere temperature records

Until now, satellite and balloon measurements had suggested net cooling of the lower atmosphere (troposphere), a result at odds with the notion of global warming**.** However, recent work that corrects for errors deriving from satellite drift (leading to variations in the time of day in which temperature measurements have been taken) have now shown that the troposphere is warming, and earlier approaches indicating cooling are now considered erroneous[14].

1.2.7 Solar cycles and volcanic eruptions

Solar cycles influence the amount of radiation reaching the Earth, and might account for some warming. Further, volcanic eruptions of variable frequency, and associated airborne particles that shade and cool the earth for a year or more, may have influenced the record significantly. Solar activity, and related variation in radiation, may account for cool periods, such as the Little Ice Age (roughly from 1500 AD to 1850 AD), and for warm periods, such as the Medieval Warm Period (around 1000 AD). However, variations in solar energy flux alone cannot explain the 0.5°C warming seen over the last 30 years and must derive from variations in inputs to albedo-related phenomena[11]. Possibly, natural effects alone would have led to cooling[15].

1.2.8 The unknown importance of feedbacks

Several feedbacks, not yet incorporated in climate models, could be important. Monbiot[16] argues that feedbacks could 'spiral out of control' if the earth warms by more than two degrees. For example, as polar ice melts, the revealed surface absorbs more heat, thus accelerating warming. Release of methane frozen within Siberian permafrost and the ocean floor also could have major warming effects, and termination of Arctic ice formation would affect ocean currents and even disrupt the Gulf Stream.

Feedbacks that potentially could cool the earth include a reduced capacity of the oceans to absorb heat as the surface warms, and the shading effect of certain pollutants, such as sulphate particles that produce acid rain. However, aerosols are transient in the atmosphere, so that current efforts to reduce pollution could actually give rise to further warming.

1.2.9 The evidence is overwhelming

Thus, most or all of the standard objections have been answered to a large extent, and it is now widely accepted that the earth is indeed warming at a significant rate. For example, Mears & Wentz estimate current global warming at 1.9°C per century, while Christy estimates warming at about 1.2°C per century[17]. Thus, the overwhelming majority of scientists now accept that anthropogenic climate change is real[18], that it is an issue of grave concern, and that many nations are not yet taking sufficient measures to deal with the problem. Indeed, the Copenhagen Consensus[19], which seeks to identify priorities for the advancement of human welfare, is based partly on the contention that present investments in climate change and other geopolitical issues are insufficient to address the central problems. In addition, there are concerns about the cost impacts of Kyoto that fall disproportionately on developing economies within the Kyoto framework, such as India, Bangladesh and China. Potentially, such nations could bear significant emissions reduction costs while still at low levels of economic development and with low per capita emissions.

2. Responding to climate change

2.1 A probable international response to climate change

As the First Commitment Period approaches, it is possible that the US will eventually commit to an emissions cap and that the major developing nations, such as China and India, will agree to caps substantially higher than their 1990 base levels in return for technological and financial assistance (e.g. in retrofitting of carbon dioxide capture and storage technology). The developed world can take a major step forward in curbing global emissions by providing technological assistance to developing industrial countries to build their economies without significant emissions.

Technological innovation and adoption will be driven by the advanced industrial economies, and they will adopt higher environmental standards. Existing economic instruments, such as emissions trading, will be augmented by regulated technical standards and other mechanisms designed to reduce both the use of fossil fuels and the extent to which carbon transfer is embodied in products and services. However, it is quite possible that international agreement on binding emissions caps beyond 2012 will not be reached. If not, nations that reduce their net emissions may act against those that do not, possibly by using technical standards as market access conditions or by imposing import tariffs on non-complying nations.

Global emission reductions on a scale that will lead to stable and acceptable atmospheric concentrations are achievable only through major policy and behavioural changes on the part of the major emitters: USA, Europe, Japan and the developing economies of China, India and Brazil, whose emissions are growing rapidly. Already, behavioural change has begun in Europe, and Japan, Canada, Scandanavia and the European Union states are investing heavily in emission reduction initiatives. In 2006, the State of California passed the California Global Warming Solutions Act[20], which requires major industrial polluters to reduce emissions by 25% by the year 2020. Stern[21] argues that stabilising total greenhouse gas concentrations between 500 and 550 parts per million will require a 75% reduction in carbon emissions from the global power sector, widespread adoption of low-emission transport, major increases in energy efficiency, advances in non-energy emissions, such as agricultural and industrial processes and deforestation, so that by 2050 total emissions per unit of GDP must be 25% of current international levels or less. In 2003 a British Government White Paper[22] committed the United Kingdom (UK) to a 60% reduction in carbon dioxide and other greenhouse gas emission levels by the year 2050, and in 2006 the UK's Tyndall Centre suggested that cuts of 80% are necessary[23].

Eventually, the international community must address direct causality between demographics and concomitant energy consumption and greenhouse gas emissions. Energy demand increases in tandem with population growth and, over the long term, addressing climate change may require constraints on population growth, as well as moves towards the provision of electricity based on renewable sources, such as hydro, geothermal, solar, tidal and wind energy. China is already taking early steps towards the increased use of renewables, and has made substantial investments in wind farms, aiming to produce 30 GW of wind power by 2020[24] (only about 2% of its projected annual electrical energy consumption for that year, but growing in significance thereafter as the relative costs of wind power reduce). Already, significant progress has been made in the development of tidal turbines, and Sir David King, Chief Scientist for the United Kingdom, has stated his belief that tidal energy can meet a significant fraction of the future energy needs of the United Kingdom[25]. Scotland's Marine Energy Group estimates the potential future contribution of tidal power to Scotland's energy consumption at fully ten per cent[26].

2.2 Climate change as scientific and technological opportunity

Given the high probability of increased climatic instability and associated economic and environmental impacts, ideally the global response should be articulated as one of technological and economic opportunity, rather than of economic penalty. If carbon capture and storage technology does not prove feasible, then the use of coal for electricity generation and oil for transport fuels must be reduced or eliminated in favour of low emission energy sources. However, if carbon capture works and proves cost-effective, then emissions from coal-fired electricity generation could fall by up to 95%, thus producing even lower emissions than geothermal power. Stern[21] argues that carbon capture and storage technologies could allow the continued use of fossil fuels, so that in 2050 these could still make up half of global energy sources.

Alternative energy sources will probably include established or emerging technologies, such as hydro, geothermal, wind, tidal power and nuclear fission, but ongoing advances in energy production and efficiency may prove to be highly important. Likely sources also include new generation technologies, such as marine and bio-energy (e.g. cost-efficient production of ethanol from ligno-cellulosic biomass), photovoltaics, and hybrid vehicles that plug in and feed back to the national grid. Renewable electricity can replace coal-fired power generation, though hydrogen fuel cell technology will have significant levels of embodied carbon if derived from fossil fuels, and will require renewable electricity for the extraction of hydrogen from water if it is to make a viable contribution.

Nuclear fusion may be very difficult to achieve, and for the moment there are genuine concerns about both the long term safety and the cost-effectiveness of nuclear fission. Much research is needed before we can be sure of the long run reliability of nuclear plant and infrastructure. However, major international research programmes, such as the International Thermonuclear Reactor (ITER) joint international research and development Tokamak project[27], will determine the potential of nuclear fusion for the supply of energy to national grids. ITER is to be constructed in Cadarache, in the South of France, a joint project between the European Union, Japan, China, India, the Republic of Korea, the Russian Federation and the USA. If fusion proves technically successful, affordable and safe, then eventually we stand to gain practically unlimited, emission-free electrical energy for the foreseeable future.

2.3 Generating wider economic benefits

Over the next few decades, the world's climate change response should encourage wider environmental and socio-economic benefits, such as investment in energy-efficient construction and manufacturing, growth in renewable energy businesses, growth of forestry industries, reduced reliance on oil, technical standards that seek to reduce embodied energy in goods and services, and enhanced sustainability of land and water resources. Many nations are already adopting such approaches, and business communities around the world are seeking assurances of long term certainty in emissions policies that affect their own commercial performance and long-run viability.

However, the international community can only afford to aim for wider socio-economic benefits because the world is still at an early stage in the development and understanding of climate change. Global warming may lead to soil loss, desertification and over-grazing, deforestation, disruption of the Gulf Stream and other thermo-haline currents, ocean acidification and associated impacts on marine ecosystems, melting of ice caps (leading to reduction in reflectivity and concomitant increase in energy absorption and acceleration of warming), sea-level rise and other major irreversible changes. In turn, these changes may lead to agricultural and environmental problems (including crop failures), disrupted energy demand and supply, coastal erosion and flooding events, storm damage, disruption of industries and the establishment of new pathways for disease (including malaria) and pest incursion. Stern[21] believes that inaction could lead to the loss of at least five per cent of global GDP annually, and possibly up to 20%.

Responsible precautionary action is already crucial, even in the absence of full scientific certainty of climate change and its implications. A century from now, the problem may have become very pervasive indeed, exceeding even our most pessimistic projections, and already one estimate puts the number of deaths from the effects of climate change at 160 000 annually[25]. If the international community does not make serious efforts to mitigate and adapt, then many people may die or suffer extreme hardship because of loss of arable land, increased frequency and severity of droughts or increased incidence of pests and diseases, and the costs of protecting cities and coastal infrastructure will mount steadily.

2.4 New Zealand's response

New Zealand must now accept the fact that its climate change measures may retard economic growth over the short term, though the impact of mitigation could be surprisingly small. For example, Dodds estimates the effect on economic growth in Australia as a drop from 2.2% to 2.1% per annum[28], while Stern[21] estimates that it will cost only around 1% of the world's GDP to stabilise greenhouse concentrations at between 500 ppm and 550 ppm. In fact, we could even see direct economic advantage in adapting our economy to climate change. California's Climate Action Team has determined that global warming emissions reduction could increase income to California by more than $4 billion and create 83 000 new jobs[29] from innovative technologies, reduced reliance on fossil fuel imports and because of new income flows to firms that reduce their emissions. California's response to climate change is a very important example of how a modern industrialised state can lead by example, and California is now having a major influence on the policies of other states within the USA.

New Zealand is rapidly achieving consensus on potential solutions, but failure to realise the required level of consensus could result in enduring inconsistencies between energy, land use and climate change policy, resulting partly from continuing ideological opposition to certain forms of Government intervention (e.g. Government involvement in forest growing, technical regulation of vehicle emissions and energy-efficient building standards). Today, it has become increasingly important that all nations recognise the economic transformation, business and sustainable development opportunities potentially on offer within the Kyoto framework and beyond.

As a small economy, New Zealand is unlikely to contribute significantly to the international climate change response, except in policy leadership, in a few niche science and technology applications, and in the provision of necessary palaeo-climate research and land-based and ocean-based observations. Therefore, we must be informed by the policy responses of the big emitters and those with the economic and technological capability to address the issues meaningfully. However, while New Zealand's science and technology capacity is limited, we can influence other nations for the greater good, partly by relying on a profile that is credible within the international community because of our contributions to human rights, nuclear and conservation issues. We can assume leadership in aspects of climate-change research in which we already have a competitive advantage. The Hon. Simon Upton, Chair of the International Round Table on Sustainable Development, has pointed out that our enteric methane programme is a leading programme in its field[30]. Though the future impacts of this programme and related research on global emissions are unpredictable, such programmes can only enhance New Zealand's scientific profile and credibility as a negotiating partner. This outstanding programme, and others (for example, in animal and plant genetics and soil science), deserve to be recognised and promoted as premier examples of New Zealand's high quality niche research base.

New Zealand can also assume a leadership position in forward-looking land use policy. Government may have a significant role to play in the future development of forestry, supporting afforestation and reforestation and encouraging forest biodiversity. There is real potential for enhanced management and control of soil erosion and flood events, and we can improve water quality and nutrient management on farms, optimising the use of fertilisers and other agrichemicals and reducing nitrogen application on New Zealand's soils.

3. New Zealand's climate-change policy design

Several key principles could underpin New Zealand's ongoing policy response, taking due account of our small economy and low investment in research, science and technology, but also taking advantage of our international credibility as environmentally conscious and prepared to articulate a balanced position on political issues.

3.1 Support excellent climate-change research

Climate change is one area of international concern in which we need integration of first-class economics, policy and science. Much of the required science is both expensive and challenging, and the international community must ensure that the climate-change science effort is well resourced and that domestic and international policy is predicated firmly on excellent science. New Zealand undertakes research in many areas that pertain directly to climate change, such as our bio-physical work on Antarctica and the Southern Ocean (e.g. freshwater flows driving Southern Ocean heat transport). We support programmes in enteric methane (AgResearch), livestock performance (AgResearch, Livestock Improvement Corporation, Dexcel, Canesis, Massey and Lincoln Universities), atmospheric physics (including air quality monitoring and climate modelling – NIWA, Victoria, Auckland, Canterbury and Otago Universities), marine and terrestrial ecosystems (Landcare Research, AgResearch, and several universities), marine and terrestrial physics and chemistry (NIWA, GNS and several universities), soil science (Landcare Research and several universities), forestry (Scion Research and Canterbury University) and environmental research (NIWA and several universities), and in the economics of possible climate-change policies (Motu Research, Landcare Research, and several universities). The excellent work carried out within these areas deserves ongoing commitment from Government, so that New Zealand continues to play its part and commands respect for its profile in climate-change research.

Growing for Good[31] (a 2004 report from New Zealand's Parliamentary Commissioner for the Environment) states that a broad, systemic approach is necessary for the achievement of sustainable farming (see section 3.3.2), including education, strategy development and implementation, and new research, science and technology. Specifically, New Zealand's research community can address a wide range of relevant bio-physical and socio-economic problems, including new farm management systems, integrated catchment management systems, soil ecosystems, water quality and abstraction, the impacts of farming intensification, the impacts of land use change (in particular, the impact of new systems on soils not yet used for such systems), the impacts of pollution and animal waste, improved nutrient management (including more efficient application of fertilisers and other agrichemicals), embodied energy in products and services, and the impacts on agriculture of, and adaptation to, long term climate change. Additionally, economics and social research could provide new and relevant understandings of rural communities and around the supply chain drivers that lead to farming intensification and increased environmental impact (e.g. the impact of domestic and international supermarket chains on New Zealand farming systems and behaviours, the dynamics of domestic and international markets, and the behaviours of processors, exporters and other stakeholders).

New Zealand should support greater investment in energy-related research that coheres with our science and technology capabilities and potential commercial opportunities in areas such as hydro and micro-hydro generation, wind power, geothermal, co-generation using wood waste, low-emission bio-fuels, and energy-efficient building and construction. Our investments could prove particularly effective if incentives are provided for energy generation at the level of the small farm and family dwelling. Above all, currency with overseas research (especially with advances in carbon capture and storage) will be crucial. New Zealand could also benefit substantially from the acquisition of a cross-government Geospatial Information Systems capability that supports necessary policy and research relating to biosecurity, civil defence and emergency management, agriculture and the environment.

3.2 Harmonise climate-change policy with energy policy

3.2.1 Take meaningful action

Agreement on climate-change policy by our political parties is critical, but some mitigation measures could be electorally challenging and unpalatable for certain influential sectors. However, failure to meet our commitment to reduce emissions will have serious financial implications and must be taken very seriously.

Naturally, governments must initiate stepwise, measured climate-change initiatives that minimise economic impacts over the short term. However, there is a great risk that governments around the world focus on short term, relatively minor palliatives**.** To make the necessary progress, New Zealand must direct attention at coal-fired thermal power stations and transport fuels – the big emitters of fossil carbon. Coal-powered generation should be progressively and rapidly eliminated and, simultaneously, carbon capture and storage technology developed and adopted widely. Having stopped burning coal ourselves, we must then consider the ethics of continuing to export coal for others to burn.

Government's proposal[32] to require oil companies to introduce a minimum of 3.4% bio-fuels into transport fuels by 2012 is a significant political first step but will have minor impact on emissions. This very low proportion should be increased substantially in the future. Substitution of small, efficient vehicles and diversion of freight onto an electrified rail system (supported by non-carbon generation) would be good starting points, consistent with a policy of taxing polluters while subsidising compliers. Registration fees related to vehicle engine size or directly to emissions, paid for by higher fuel taxes, would help. Introducing taxes on air travel and long distance road freight in order to subsidize rail and sea transport would reduce fuel use and road congestion, while lower road speeds would reduce both fuel use and the accident rate. Making public transport more efficient, cheaper (with respect to private transport) and more user-friendly could persuade many people to leave their cars at home. Rewards for using low emission vehicles in general and encouraging acceptance of hybrid vehicles, and ultimately of battery-powered vehicles, would be useful. Improved insulation and solar water heating on new buildings would increase comfort and reduce energy use.

From a long-term perspective, agriculturally-induced releases of methane and nitrous oxide are less important issues than carbon dioxide. Both methane and nitrous oxide are greenhouse gases, but both are transient in the atmosphere (methane reverts to bio-carbon dioxide and nitrous oxide to nitrogen). New Zealand's emissions of both gases are increasing because of continuing intensification of farming, particularly dairying. Intensification of agriculture proceeds unabated, partly because the costs of atmospheric and water pollution are externalised. Internalizing these costs could make much dairying unprofitable and would have severe political costs, but it is highly important that New Zealand finds new ways of curbing agricultural emissions without reducing profitability significantly.

Forests remove significant amounts of carbon dioxide. However, when felled and processed, some of the carbon is re-released. Permanent forest absorbs carbon dioxide while growing, but a mature forest can be almost carbon-neutral. Planting trees is beneficial in many respects, but forestry provides only a partial solution to the carbon problem. The most effective long term solution is either a massive reduction in the use of fossil carbon or the development of carbon capture and storage, and ultimately all nations must aspire to one or other of these objectives.

3.2.2 Government's 2006 draft policy proposals

Government's 2006 draft policy proposals[33–35] focus on necessary, first step measures as New Zealand moves towards low emissions electricity, low carbon transport, power and heat, sustainable technologies and effective emissions pricing. The proposed options include emissions trading (including cap and trade), a charge on carbon dioxide from electricity generation and industrial heat, incentives (including capacity grants, subsidies, guaranteed prices and tariffs), new obligations around renewables, and project, regulatory and voluntary measures. Each of the adopted measures will be evaluated in respect of environmental effectiveness, cost effectiveness, price impacts, ease of implementation and compatibility with long term emissions pricing. The proposed policies demonstrate New Zealand's genuine commitment to mitigating climate change through the adoption of transitional measures through to 2012.

3.2.3 Address peak oil and deal with externalities

The International Energy Agency (IEA) estimates that, in the absence of major changes in consumption patterns, by 2030 the world's energy needs would be more than 50% greater than those of today[36]. Fossil fuels would continue to dominate energy supplies and would probably account for more than 80% of the likely increase in energy demand. The use of certain renewables, including geothermal, solar and wind, would probably grow more rapidly than other sources, but would still account for only 2% of primary energy demand. The IEA also estimates that the world is likely to need about 2800 new power plants over the next three decades. On current technology, most of them will emit large amounts of carbon dioxide over several further decades. Thus, without major behavioural change, carbon dioxide emissions will continue to rise, and irreversible climate change will become very probable.

It is clear that New Zealand's climate-change policy must harmonise with energy policy in order to achieve the desired reductions. New Zealand's carbon dioxide emissions per unit of power generated are very low by comparison to those of other developed nations, and some 70% of our electricity is derived from renewable sources, mainly hydro and some geothermal and wind. Government's Sustainable Development Programme of Action[37] identifies the energy challenges and opportunities facing New Zealand, and discusses possible future directions for policy development. It also identifies energy as a critical area for action, given that energy supply and demand have significant economic, social and environmental impacts. An inevitable peak in oil production is of great concern, requiring immediate consideration of alternative fuel sources. A second concern is the generation of negative externalities, including direct environmental impacts and global climate change. If we are to achieve true social, economic and environmental sustainability, our future energy systems must be priced fairly and efficiently, reflecting current and projected scarcity or abundance of energy resources and the relative production and distribution costs, and exert minimal environmental impact.

3.2.4 Engage actively in the agreed economic measures

Regulated technical standards and emissions trading (a market that stimulates the removal of carbon and establishes limits on emissions at the level of the firm; firms or industries that reduce their pollution receive credits which they can then sell to net polluters), perhaps based on the European Union model, will go quite some way to addressing Kyoto, and will help to delay the pernicious effects of climate change by a few years. In conjunction with emissions trading, steadily reducing emissions caps will provide necessary incentives to hold atmospheric carbon dioxide concentrations at acceptable levels. Related measures, such as citizen entitlements, could also encourage low emission behaviours by rewarding individuals who pollute less and penalising those who exceed their entitlements. Careful analysis is required in order to determine the optimum deployment of trading, carbon taxes (which can be used to subsidise renewable generation), citizen entitlements and other economic measures.

Over the short term, New Zealand may be well advised in not imposing a carbon tax, partly because of the unfavourable market distortion that could occur if one nation does so when as yet most of its trading partners do not. However, the long run effects of market distortion could prove much less costly than the impacts of protectionism and damage to our national brand, and for this reason New Zealand may have a strong incentive to advocate carbon taxes. Economic measures, such as taxes and incentives, are often effective in moderating the behaviours of industries and nations, and discouraging emitters using differential taxes may eventually prove to be an effective way of moving them towards low carbon activity. In 2002, Government announced the introduction in 2007 of a revenue-neutral tax on petrol, diesel, coal and gas, and on carbon-emitting industrial processes, such as cement manufacture. At that time the economic impact on an average household from higher cost electricity, petrol and other fuels was estimated at only four dollars per week. However, in 2005 the idea was discarded on advice that the proposed tax would fail to reduce emissions to the required extent and that New Zealand could achieve substantive reductions through forestry, wind generation and other means. The decision not to proceed with the tax may have been based on sound considerations of its likely effectiveness in reducing emissions and the probable negative effects of market distortion, but what will be the consequences for humanity a century from now if every nation adopts constrained measures, thinking primarily of maximising present wealth rather than of the future welfare of the world?

3.2.5 Assess all costs and benefits

Proposals to reduce carbon dioxide emissions require comprehensive and detailed analysis. Nuclear power is emission-free, but we must consider energy use in the mining and processing of uranium, and in the construction and eventual decommissioning of the plant. Bio-fuels appear attractive, but a US analysis of all inputs (farm machinery and fuel, fertilizer manufacture, agricultural chemicals, irrigation, crop transport, fuel production and transport etc) showed that the substitution of both bio-diesel[38] and bio-ethanol[39] transport fuels can be net carbon-emission processes. Even wind turbines embody considerable carbon costs, including steel and cement manufacture and site preparation.

3.2.6 Develop an adaptation strategy

Adaptation to global warming and climate instability must occur on a national or regional basis, according to local bio-geophysical conditions and the structure of the affected economies. Adaptation is already under way in other countries. For example, the Thames Barrier was constructed in order to minimise flood risk to the city of London from flooding of the Thames river (a single event estimated potentially to cause thirty billion pounds in damage), and has already been used with far greater frequency than originally anticipated[25].

Irrespective of the measures adopted by other nations, New Zealand must develop a considered adaptation strategy, addressing possible impacts on agriculture, the physical environment, ecosystems, industries and public health, increasing resources significantly to civil defence and emergency management and hazard warning systems. This strategy should guide our response over several decades and should not be limited to the First Commitment Period or subsequent implementations. For example, the United Kingdom has instituted a foresight process for addressing fluvial flooding, coastal erosion and defence issues, and has adopted a thirty year to eighty year purview[25]. Similarly, New Zealand's adaptation strategy should be pursued over a period of several decades.

3.2.7 Provide enduring commitment

The long-term nature of climate change now requires long-term investment. Meaningful progress on climate change will require the ongoing commitment of diverse constituencies, which themselves may stand to gain from the new technological and commercial opportunities on offer. Industries that potentially can contribute and benefit include manufacturers of wind turbines, micro-hydro, solar power and other plant and their suppliers; service providers of low carbon materials; design, building and construction businesses that can exploit new opportunities in building energy efficiency; white-ware and appliance manufacturers that can also achieve advances in energy efficiency; farmers who earn rents from wind turbines on their properties and who use less fertiliser through enhanced nutrient management; and farmers, foresters and processors with opportunities in bio-energy. In addition, opportunities will emerge for new investment institutions and schemes for the creation and distribution of renewable energy, but will require policy stability over several decades so that governments and businesses can have confidence in making long-term investment decisions.

3.3 Harmonise climate-change policy with environmental policy

3.3.1 Work towards sustainable economic development

Sustainable development is development that recognises the inevitable interplay between human beings, the biophysical environment and natural resources, and that attempts to find appropriate uses of land, water and biological resources through innovative scientific, technological and economic mechanisms. Economic mechanisms that may help to achieve sustainable development include legislation and regulation, taxes, subsidies and property rights.

Central to a successful international climate-change response will be sustainable economic development that enables future generations to inherit a world with a functional, life-giving biophysical environment. Responsible nations will implement change in which the exploitation of resources, technological development and human capital, labour and other institutional policies are directed towards the needs of future generations. Sustainable economic development will also recognise that a degree of continuing environmental impact is inevitable if humankind is to live beyond subsistence level. However, true sustainable development will only be achievable if responsible behaviour is encouraged actively, consumption patterns moderated, and the creation of undesirable externalities discouraged.

3.3.2 Work towards sustainable agriculture

The pressing environmental issues for New Zealand include sustainable management and use of water, waste management, sustainable use of our marine resources, air quality, energy efficiency and ecosystems management. Addressing such issues will be vital for a healthy environment and for economic prosperity. The Resource Management Act 1991 governs our management of the environment, including air, water, soil, biodiversity, the coastal environment, noise, subdivision and land use planning. Other relevant legislation includes the Energy Efficiency and Conservation Act 2000, and the Environment Act 1986. It is evident that our future climate-change policies must take full account of environmental externalities and cohere with established environmental policy.

Growing for Good[30] discusses recent trends across New Zealand's dairying, horticulture, sheep, beef and viticulture industries, and concludes that our natural capital is under considerable pressure. For example, between 1994 and 2002 the number of dairy cows increased by over 30%, whereas the land area used for dairying increased by only 10%. In that period, synthetic fertilizer application across all agricultural industries increased by over 20% and, in particular, the amount of nitrogen applied on agricultural land more than doubled[40]. Thus, New Zealand's waterways and lakes are becoming nutrient-enriched and degraded from excess nitrogen, animal waste and eroded sediment, and agricultural nitrous oxide and methane now make up about half of New Zealand's total emissions (see section 3.2.2). *Growing for Good* notes that many of our key export markets in Europe and Asia may not accept products sourced from farms that pollute the environment. The report recommends dialogue around a new vision for the future of farming; the establishment of a pan-sector agency to articulate and implement the vision; immediate action to remedy pollution from farms, to manage the use of nitrogen fertilisers, and to deal with contamination of waterways; and more research into sustainable farming systems, integrated catchment management and soils.

A key challenge is the development and adoption of sustainable farming systems that maintain and enhance New Zealand's natural capital. We now recognise that sound environmental behaviours, including water and soil management, appropriate agrichemical and energy use and waste disposal, are crucial for the future of agriculture. Sustainable farming practices will reduce direct environmental impact and help to maintain international market access by enhancing New Zealand's profile as an environmentally-conscious nation and trading partner. Most importantly, sustainable farming will contribute directly to our climate-change response by reducing the embodied energy within agricultural goods and services, through increased animal productivity and concomitant reduction in methane emissions, and lower nitrogen emissions from soils because of efficient fertilizer application.

4. Conclusions

Human-induced climate change is a reality. However, New Zealand enjoys advantages that potentially can assure strong economic performance as Kyoto and later agreements impact on the major emitters. Enlightened and integrated measures, that take account of New Zealand's potential for renewable energy and that build on strong domestic and international research, science and technology, will ensure that New Zealand continues to prosper, retains a clean environment, plays an active role, and is perceived as a credible trading partner.

The international community must now accept the overwhelming preponderance of scientific evidence that points to continually increasing concentrations of atmospheric greenhouse gases and associated climate change. In decades to come, it may be our children, or more probably the children of the third world, who pay the price for inaction on the part of our generation. We must remember our responsibilities, not only to each other, but also to the wider world of which we are a part. It must now be the humanitarian within us that dictates the course of our future actions, and ours must be the actions of the sentient and concerned global citizen, placing the welfare of the present and future world securely above our own selfish ambitions.

Recommendations

1. Provide ongoing support to New Zealand's climate change and related environmental research.
2. Provide ongoing support to policy around sustainable economic development and sustainable agriculture.
3. Develop climate-change policy that generates wider economic and environmental benefits over the medium term; thereafter focus primarily on eliminating emissions through both technology and policy approaches.
4. Adopt and adapt overseas technology, such as carbon capture and storage.
5. Maintain open dialogue on the merits of carbon taxes as one means of encouraging low carbon behaviour and generating revenues which can support the development of renewable energy sources.
6. Attempt to influence the international community to behave as good global citizens, seeking to reduce greenhouse gas emissions and other environmental externalities by adopting low emission behaviours and new technologies.
7. Develop a cross-Government Geospatial Information Systems capability to underpin policy and research around biosecurity, civil defence and emergency management, agriculture and the environment.

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