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Climate change & human health: Impact & adaptation issues for New Zealand

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Adaptation to climate change is important and necessary because climate change is already happening and substantial impacts in the future are inevitable. Successful adaptation will require individual as well as collective action at the community, national and international level in order to reduce the direct and indirect impacts on health. This paper briefly summarises the likely impacts of climate change on health, globally, but focuses on adaptive measures that might be undertaken in New Zealand.

Climate change will have a wide variety of health impacts; many are predictable but some not. Higher maximum temperatures will lead to water shortages, occupational health concerns for outdoor workers, increased heat-related deaths and illnesses, and contribute to an extended range of some pest and disease vectors. In some areas, there will be increased droughts leading to forest fires, increasing hospital admissions, while in other areas more intense rainfall will lead to mudslides, flooding and contaminated water supplies. More intense weather events are likely to increase the risk of infectious disease epidemics and the erosion of low-lying and coastal land. Indirect effects of climate change, such as mental health problems, are likely to occur from economic instability and forced migration.

Adaptation policies should be as equitable as possible, because some groups in society have less knowledge and less social, human and financial capital with which to adapt. If proposed policies are considered equitable and fair, they are likely to be more generally acceptable. Because of existing socio-economic disadvantages, some groups will require special consideration and deliberate support by local and central government.

Both low and high carbon world scenarios require major adaptation measures in key infrastructure such as housing and the supply of drinking water and energy. But in a high-carbon world scenario, New Zealand could become a 'lifeboat' to those living in more vulnerable South Pacific countries who are displaced by the impacts of climate change, and the scale of health and social problems to be faced by New Zealanders could become considerably more serious.

1. Introduction

It has become clearer as the science of climate change has consolidated that societal adaptation to climate change will be necessary because a significant amount of climate change is inevitable (IPCC 2007, Parry et al. 2009). The exact amount of global warming 'in the pipeline' is a matter of scientific uncertainty: '…we are still left with a fair chance to hold the 2°C line, yet the race between climate dynamics and climate policy will be a close one' (Schellnhuber 2008). Human systems, and to some extent the natural systems on which they depend, must adapt in response to the present and future effects of climate change (Rogeli et al. 2009).

Successful adaptation may be possible if people take collective responsibility for this problem, but it will require major changes in policy, as well as cultural and behavioural change (Chapman & Boston 2007, Lorenzoni et al. 2007). It will also require ongoing efforts to ensure the adaptation burden does not become too large. However, many people think that the risks from climate change are still uncertain, mostly in the future and more likely to affect people in other countries (Rathzel & Uzzell 2009). Along with a disregard for future generations, these are all factors that lead people to discount the risks and the need for action sooner rather than later (Swim et al. 2009).

Some of the major impacts of climate change are likely to be on population health (Hales & Woodward 2006). A recent review concluded that climate change is potentially the biggest global health threat of the 21st century (Costello et al. 2009). Higher maximum temperatures will lead to increased heat-related deaths and illnesses and contribute to an extended range of some pest and disease vectors. In some areas, there will be increased severity and frequency of droughts leading to forest fires; in other areas more intense rainfall will lead to slope instability, flooding and contaminated water supplies. More intense, large-scale cyclones will increase the risk of infectious disease epidemics (e.g., via damaging water supplies and sewerage systems) and cause the erosion of low-lying and coastal land through storm surges. Indirect effects of climate change will occur from economic instability, loss of livelihoods and forced migrations.

A range of policies based on early indications of change and the precautionary principle in relation to future change is essential if communities are to protect their health and well-being in the face of climate change. The structure of social systems underpinning population health and adaptive capacity, and the interaction between the vulnerability and resilience of individuals, families and communities and regions, is of crucial importance. "Prevention is better than cure", so we need to make strenuous efforts in both mitigation and adaptation, if we wish to avoid major health impacts.

Politically and socially, adaptation to climate change requires that we recognise social inequalities and the related ethical issues of who will benefit from particular policies. Adaptation policies should be as equitable as possible, because some groups in society have less knowledge and less social, human and financial capital with which to adapt. Indeed, there is some UK evidence that if the actions proposed by these policies were equitable and fair, more people would be more likely to adopt them (Darier & Schule 1999). Clearly, some groups will require special consideration and deliberate support by local and central government.

The rest of this paper is structured as follows. We begin with consideration of the projections of climate change effects, focusing in particular on infectious disease and flooding impacts, probably the two areas of greatest direct health impact. We then turn to indirect effects on health, drawing out the implications of socio-economic impacts. The rest of the paper considers adaptation at different scales, starting with adaptation at the micro level and working up, through the community level, cities, the national level and lastly to global level adaptation issues.

2. Projection of climate change effects

Projections of future climate change come from past observation, observed interventions and modelling. The NIWA models, outlined by Reisinger et al. (2010) detail the potential effects of two climate change scenarios. The first is the 2°C scenario, the "rapidly decarbonising world" scenario, in which there are local effects of heat and air pollution and an extended range of vector-borne infectious diseases. The second is the 4°C scenario, the "high carbon world" scenario, in which there will be a substantial increase in all these effects. The 4°C scenario is now starting to look increasingly likely (Ramanathan & Feng 2008, Rogelj et al. 2009, WBGU 2009). There are already major direct and indirect impacts globally, including in the Pacific, which are beginning to involve considerable social disruption and, potentially, migration (Oxfam 2009). While both these scenarios call for major adaptation measures in key infrastructure such as housing and the supply of drinking water and energy, in the more extreme scenario, New Zealand becomes a 'lifeboat' to those living in more vulnerable countries that are displaced by the impacts of climate change, and the scale of health and social problems New Zealand will have to face becomes considerably more serious (Hales & Woodward 2006).

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In the rapidly decarbonising world scenario, it is possible to estimate health impacts. We already know that in Auckland and Christchurch a small number of heat-related deaths occur annually in people aged over 65, and the incidence of these heat-related deaths is likely to increase (McMichael et al. 2003, Hennessy et al. 2007). Core body temperature is approximately 37°C in all human beings and it requires only a relatively small change to higher or lower temperatures around this optimum before health is affected (Parsons 2003, Kovats & Hajat 2008). Currently, in New Zealand there are around 1600 excess winter deaths, largely due to respiratory and coronary conditions. Warmer temperatures from climate change may reduce the number of the very old and the very young dying in winter (Davie et al. 2007).

Because people in New Zealand increasingly understand that cold, damp winter weather is bad for their health, the prospect of rising temperatures may reduce their concerns around climate change. This belief may then become another barrier to changing their behaviour to mitigate climate change and supporting appropriate government actions to do likewise.

We should be aware of the potential for surprises: the European heat-waves in 2003 were estimated to have killed 70 000 people, but no epidemiological models predicted this scale of mortality before the event (Hales & Woodward 2006, Gosling et al. 2007). Apart from heat-related deaths, there are other possible harmful health effects from increasing temperatures. For example, there is growing awareness that there are likely to be serious non-fatal effects from heat stress in outdoor workers, particularly if they have prolonged exposure to higher temperatures without breaks and without opportunities to rehydrate (Kjellstrom 2009).

The combination of warmer temperatures and increased rainfall variability is likely to increase the intensity and frequency of food-borne and water-borne diseases. Several studies have found relationships between temperature and food poisoning, as well as between temperature and specific enteric diseases (Bentham & Langford 2001, Kovats et al. 2005, Hashizume et al. 2007). A European study found that temperature influenced transmission of salmonellosis infection in about a third (35%) of all cases of this enteric disease (Kovats et al. 2004). This association between temperature and salmonellosis has also been found in Australia (D'Souza et al. 2004, Zhang et al. 2007). A recent New Zealand study found a similar association, namely, that a 1°C increase in monthly average ambient temperature was associated with a 15% increase in salmonellosis notifications within the same month (Britton et al. in press). Diarrheal disease in the Pacific islands is also sensitive to both temperature and extremes of rainfall (Singh et al. 2001).

European studies have shown that higher temperatures increase the amount of allergen-producing pollens, potentially leading to exacerbation of asthma symptoms (van Vliet et al. 2002). Higher temperatures and lower rainfall worsen droughts, in turn increasing the risk of forest fires and dust-storms, both of which increase the likelihood of hospital admissions from respiratory and cardiovascular conditions (Emanual 2000, Motta et al. 2005). There is potential for synergistic impacts from higher temperatures on the current respiratory and coronary impacts of photochemical smog (Dickerson et al. 1997, Bernard et al. 2001) and fine particulate matter (Ebi & McGregor 2008).

Higher temperatures are already having an impact on water supplies in many places. Increased variability of rainfall affects the supply of water for drinking as well as for agriculture and horticulture. In New Zealand, areas with higher socio-economic deprivation have a poorer quality of reticulated water (Hales et al. 2003). So we would expect that, as a result of climate change, any competition for dwindling supplies would particularly affect the already socially and economically disadvantaged. Climate projections suggest that there will be a reduction in rainfall and more frequent dry conditions in the north and east of the North Island and most of the east coast of the South Island, which is likely to have an impact on agriculture and forestry and exacerbate regional inequalities (Mullan et al. 2005, MfE 2008). It could also affect household water supplies in dry periods. Currently, 11 of 73 local authorities in New Zealand have water metering systems that meter and charge for water supplied to households (Hide 2009). Unless there is a policy developed to ensure that households have a right to a minimum amount of water at no charge, water charging could further increase inequalities and infectious diseases that are influenced by hygiene levels (e.g., skin infections and gastrointestinal infections). Indeed, minimum access to water to allow hand-washing and general cleanliness can be considered a basic public good that helps protect the whole community from infectious disease spread.

3. Infectious diseases

There is a major concern about the impact of climate change on infectious diseases (Crump et al. 2001). Warmer temperatures and increased rainfall variability are likely to increase food-borne and water-borne diseases. Infectious agents, such as protozoa, bacteria and viruses, and vector organisms, such as mosquitoes, ticks and sandflies, have no thermostatic mechanisms, so reproduction and survival rates are strongly affected by temperature levels and fluctuations.

In terms of vector-borne diseases, parts of the North Island may become suitable for breeding the mosquitoes that are a competent major dengue vector. But while much of New Zealand will become receptive to other less-efficient vector species, the risk of dengue in New Zealand may remain below the temperature threshold for local transmission even beyond 2050, under both scenarios, unless of course these scenarios turn out to underestimate future temperature increases (Hales et al. 2002). Competent mosquito vectors for Ross River virus are already established in New Zealand (McMichael et al. 2003) and a study in Australia found a relationship between high levels of rainfall and outbreaks of Ross River virus infection (Woodruff et al. 2002). Consequently, there may also be potential for climate change to lead to outbreaks of Ross River virus infection in New Zealand.

There has been a rise in tuberculosis globally and nationally. The incidence of tuberculosis in Tuvalu (295 per 100 000 per year) and Kiribati (372 per 100 000 per year)[1] is at least an order of magnitude higher than the rates of tuberculosis in New Zealand (7 per 100 000 per year) (Lim et al. 2009). We know that population movement increases the transmission of tuberculosis, but the main risk factor requiring rapid societal and housing adaptation is crowding in households (Baker et al. 2008). Recent reports have estimated that by 2050, in just three low-lying Pacific atolls, all with strong political and social links to New Zealand, about 235 000 people in the Republic of Kiribati, 20 000 people on Tuvalu and 800 people on Tokelau will likely be at high risk of climate change-related migration. This is because these islands are extremely vulnerable to the projected changes in sea level because of their small size, low elevation above sea level, lack of resources, population pressures and insecure water, food and financial situations (Mimura et al. 2007, Britton 2009).

Families that are forced by the consequences of climate change to leave their island homes are likely to form a pattern of chain migration to New Zealand (Pene et al. 2009). Unless New Zealand recognises the need to rapidly build extended-family houses, or generally increase the supply of low-income family housing to accommodate these immigrants, we are likely to see an increase of overcrowding in state houses and other low income houses. This could dramatically increase the risk of a number of infectious diseases for which crowding is a risk factor (Baker et al. 2000).

[1] WHO 2008: Core Health Indicators. Available from: http://www.who.int/whosis/database/core/core_select.cfm (accessed 9 December 2009)

4. Flooding

Flooding from extreme weather events and the effect on water catchment areas is already a key civil defence issue and a regional water and land management issue in New Zealand. Adaptation to more flooding will require increased work throughout catchments, such as stop-banks to minimise flooding, planting trees, retiring farmland on unstable hill country, and restricting, as well as re-locating, housing developments.

Coastal flooding is likely to be one of the most dramatic consequences of climate change globally, and perhaps for New Zealand as well. Current estimates of the number of people at risk globally from flooding by sea level rise and coastal storm surges vary from 600 million to 1.2 billion (Wilbanks et al. 2007). According to mid-range IPCC climate scenarios, based on a 40 cm rise in sea level by the 2080s, there could be 200 million affected (Patz et al. 2005). Since the Fourth Assessment Report by the IPCC, however, estimates for sea level rise have been increasing, with some research suggesting a risk of 1.5-2 m by 2100 (Richardson et al. 2009).

The impact of Hurricane Katrina on New Orleans (USA) provided a tragic example of the possible consequences of extreme weather events and cumulative socio-economic disadvantage. Several structural factors in this situation meant that low-income African-American people were most affected: they lived in the residentially segregated, low-lying areas; there was little public transport available for evacuation; the levees were poorly maintained; there was endemic corruption and no functional emergency plan; and generally there was poor policy implementation (Kates et al. 2006).

As Sen (1999) has highlighted, inherent capabilities as well as ability to function in society are important for health. Those with higher incomes and wealth, as well as social and cultural capital, have many more resources available to them through their networks. It is important that adaptive responses, such as health and housing protection and provision during and after extreme events, should not increase health inequalities. The deaths from drowning and destruction caused by Hurricane Katrina and the mass evacuations led to a doubling of mental health problems among the survivors, particularly in those who were already vulnerable through not having partners (Kessler et al. 2006). In contrast, there were *lower* rates of suicide ideation than before the disaster, with this being associated with increased closeness to loved ones, developing faith in one's own abilities to rebuild one's life, increased spiritual or religious feeling, and finding deeper meaning and purpose in life. This pattern of differing mental health responses graphically illustrates the variable adaptive capacity of communities and population and highlights the concept of individual and community resilience.

The fate of New Orleans also highlights the precarious location of many settlements in relation to the availability of secure freshwater supplies, as well as the location of many towns and cities in relation to river flooding. Apart from freshwater and adequate food supplies, other essential infrastructure for maintaining health and saving lives following extreme events includes electricity supply, transport and telecommunications.

Government policies to ensure that water and energy infrastructure and systems work well during extreme events need to consider equity as well as efficiency. Concerns about extreme events having a repeated

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impact on certain locations, and the difficulty of maintaining hygiene and contagion controls, mean that in some cases whole towns, or even parts of cities, may need to be relocated. For example, in New Zealand, the small far north town of Kaeo has been flooded several times in recent years and questions have been raised as to whether its location is sustainable. But given low income levels and less disposable income for private insurance in such towns, government assistance is likely to be needed to facilitate such major adaptation.

5. Indirect impacts on health from socio-economic effects of climate change

There are also likely to be indirect impacts on health from climate change, through multiple economic consequences and environmental problems, such as disruption to food and water supplies, which could lead to civil conflict. While New Zealand is less likely to be affected by these consequences than elsewhere in the world, we are already seeing the consequences of uncertainties arising from an economic recession, possibly interacting with people's future planning taking into account climate change, which may have led to more migrants coming to New Zealand in 2009 than in the previous five years.[2]

Mental health issues, as mentioned above, have been shown to follow environmental disasters. Mental health problems ranging from depression to suicide can arise from a range of effects associated with climate change, such as prolonged drought and the economic losses that follow. For migrants, who have to leave their homes, there is a deep sense of cultural loss as well as the stresses that come from forced relocation (Oxfam 2009).

6. Adaptation at an individual level

People living in remote communities are likely to be at increased risk due to their isolation and poor access to services. There is a clear relationship between flooding, drought and fire, leading in some cases to suicide, and severe mental health impacts in rural communities

[2] http://www.stats.govt.nz/~/media/Statistics/Browse%20for%20stats/IntTravelAndMigration/HOTPAug09/InternationalTravelAndMigrationAug09HOTP.ashx (accessed 9 December 2009)

(Smith et al. 1990, Fritze et al. 2008). These extreme weather events are likely to be increased by climate change as the 2008 fires in the state of Victoria and projections by CSIRO suggest (Hennessy et al. 2006).

Clearly, not all populations have equal access to material resources and services. For example, households with low income and little or no wealth are more likely to be less educated and therefore are less able to make contingency plans. The very young and old, sole parents with children and those with chronic illnesses and disabilities are all likely to be similarly disadvantaged. Indeed, those living in socio-economically disadvantaged, residentially segregated areas, where there is less public transport and fewer people who own or have access to cars, are likely to be particularly at risk from climate change impacts.

We know from the work of Paul Slovic and colleagues that those who are vulnerable are understandably more risk averse than those with more material resources and may be more attached to riskier places where they can access resources through local networks (Slovic 1987). By contrast, those with more economic power are more likely to be risk-takers, because they are better resourced to cope (Flynn et al. 1987). Furthermore, Douglas & Wildavsky (1982) asserted that people, acting within social groups, downplay certain risks and emphasise others as a means of maintaining and controlling the group. As an illustration, when Slovic wrote his seminal article in 1987, the only risk factor related in any way to climate change that he included among a long list of risks was "coal burning (pollution)" and this was positioned as a "known risk" with a low "dread factor".

Taking appropriate individual action is more difficult than it might seem. It has been shown that in the area of consumption patterns and energy efficiency, people frequently misinterpret the actual causes of actions that mitigate or increase climate change (Nolan et al. 2008). However, consideration of co-benefits associated with mitigation actions could potentially provide powerful incentives to change individual behaviour. For example, walking, cycling and taking public transport could be presented in social marketing campaigns as being less a sacrifice of time and convenience, and more an opportunity to socialise, keep fit and do one's bit towards having a smaller carbon footprint. Likewise, eating a low-meat or vegetarian diet could be presented as a way of reducing coronary and cancer risks, as well as lowering one's carbon footprint associated with food production emissions (Costello et al. 2009). Recent work highlights that about 7% of national emissions (at least for the USA) could be achieved from a range of household level measures "with little or no reduction in household well-being" (Dietz et al. 2009). Indeed, many of these household measures would save householders money in the long term.

7. Adaptation at a community level

Because of its many local features, including the need to engage local communities, a critical path to better adaptation is from local government action (including by regional councils). For example, some adaptation requires a range of infrastructure investments, including even the progressive modification of urban form, although planning lags make the latter a slow process (Chapman 2008). Intensifying housing can, for example, reduce the vulnerability of dispersed communities and at the same time help build social capital that links together different social and ethnic groups, while reducing car dependence and energy use (Kennedy et al. 2009). This could have a variety of health and environmental (mitigation) advantages.

Councils have a key role to play through their planning processes for infrastructure development, such as Long-Term Council and Community Plans and Regional Land Transport Programmes, and their roles under the Resource Management Act. They also have key roles in the management of the 'three' waters, fresh-water, storm-water and waste-water. In all these areas, spending decisions can strongly influence community choices and adaptation options. Councils can also support civil society organisations including NGOs undertaking mitigation, adaptation and resilience building in their local communities. One example of this sort of organisation is the 'transition towns' movement, which is focused on local solutions to issues such as peak oil and climate change. However, it is unclear whether this movement will increase or decrease inequalities in resilience and preparedness in low-income communities, as it appears to be largely a middle-class initiative in New Zealand. Many of these potential local government actions to adapt to climate change can be supported by central government actions. These include ensuring greater legislative powers for local government and allowing local government to improve its resourcing (e.g., by raising revenue from petrol and other taxes).

8. Adapting cities

Most New Zealanders (85%) live in cities; however, most of our cities do not have high density housing and apartments and have instead developed large sprawling suburbs. Urban sprawl increases carbon emissions – a mitigation issue – but may also increase people's everyday vulnerability to extreme weather events, as more transport infrastructure per person is needed for more distributed populations.

Urban design and planning is beginning to incorporate climate change adaptation considerations (Ruth & Coelho 2007, Kirshen et al. 2008). Most attention so far seems to have focused on dealing with storm-water run-off and urban heat island effects in urban areas. Temperatures in large urban areas can be between 5 and 11°C higher than their surrounding rural environs, because heat from the sun absorbed by urban building materials during the day is slowly released back into the urban atmosphere at night (Patz et al. 2005). Ways to reduce the heat island effect include increasing the number of trees on streets, the area of parks, roof-top gardens and reducing new roads and other hard and artificial surfaces such as parking lots. Passive cooling of buildings, through good design and construction and the painting white of some surfaces (especially roofing), can also reduce heating. Regarding storm-water, rooftop water collection can reduce run-off risks, as can ground-level features such as replacement of hard surfaces by pervious paving and having well vegetated swales (i.e., low lying areas of vegetated land which can hold run-off). Reducing the risk of storm-water incursion into sewerage systems also has clear health benefits, especially if existing capacity is otherwise at risk of being over-whelmed, with sewage-contaminated overflows into back gardens, streets, streams, rivers and harbours. The latter may have particular importance for Māori, in terms of protecting traditional marine food sources such as shellfish.

At the community level, enhanced social networks can provide closer monitoring of, and assistance to, vulnerable people and populations in times of need. Mixed land-use urban planning can foster socio-

economically and ethnically integrated suburbs and strengthen 'weak ties', the social contacts that can provide people with new information that they are less likely to gather from close friends and family (Granovetter 1983). These social contacts are important to prevent deaths in extreme weather. As was evident in recent overseas heat waves, lack of trust can keep people locked in over-heated rooms (Klinenberg 2002).

9. Adaptation at a national level

National efforts to adapt to climate change to ensure that the social, economic and environmental determinants of population health do not move in an adverse direction will require a major reconsideration of many existing policies. An analysis of recent New Zealand Government initiatives suggests that policies across a range of areas show little forward progress and a number of retrogressive actions (Wilson et al. 2009). A lack of progress on mitigation has the longer-term effect of making adaptation more difficult.

The policy approach of emphasising co-benefits to human health and social and economic well-being seems to hold the most hope for policies that encourage both mitigation and adaptation. For example, improved urban design will have benefits for social capital and mental health, providing adaptive capacity and resilience as well as increasing the eco-efficiency of living in the city (Hales et al. 2007).

Similarly, there are demonstrable multiple benefits from retrofitting houses to make them more energy efficient, in terms of health and education outcomes, and energy savings (Chapman et al. 2009). Raising standards in the Building Code so that houses are better able to withstand extreme winds and rain is also likely to lower the relatively high level of excess winter deaths in New Zealand (Telfar Barnard et al. 2008).

In anticipation of an increase in climate change-related migration, there is a case for greater provision of extended family housing for families who are likely to come to New Zealand through chain migration (Pene et al. 2009). Some of this new housing stock needs to be social housing. Research on social housing tenants has shown that when tenants from the private rental market are moved into social housing their rate of hospitalisation reduces significantly; this indicates an improvement in their health and a saving for the taxpayer (Baker et al. 2009).

While many of these changes require central government level actions, they may also involve a re-balancing of power with local government, even a shift in power to the latter, as discussed earlier in this paper.

10. Adaptation at a global level

If a high carbon world eventuates (as projected in the higher carbon and higher temperature scenario earlier in the paper) it will intensify many population health problems. However, with complex systems we cannot simply extrapolate existing quantitative models of health impact, so that it is more difficult to specify adaptive measures. It seems likely that the flow-through effects of global social dislocation under this scenario will be important and major social and health impacts on New Zealand could be expected, especially through the impact of increased climate change-related migration and global economic and social insecurity, even if some of the more worrying possible developments are avoided (Dyer 2008).

Some authors have called for dramatic global solutions requiring global government decisions to over-ride national considerations, as national adaptation measures are likely to be increasingly ineffective, especially in poorer countries. Some have suggested that global imperatives will require New Zealand cities to become rapidly intensified to restrict urban sprawl and enable more intensified agriculture (Vince 2009). Yet others have argued that we need to optimise land use globally in order to maintain adequate food supplies and exchange migration rights and food security in return for protection of "terrestrial commons" (Müller et al. in press). However, this would present major governance challenges, and it is not clear that we are equipped to do this in the limited time available before major impacts occur. As Vaclav Smil has argued, "[e]ffective planetary management is far beyond our intellectual and social capabilities [although] …we are doing it anyway" (Smil 2002). Such proposals would require a major rethinking of the requirements of economic development and climate adaptation, to balance individual rights with the survival of whole human populations (Sen 1999).

11. Conclusion

Planned adaptation to climate change, driven by the need to sustain economic development, health and well-being in the face of potentially major disruptions to critical natural systems, is essential for New Zealand. Fortunately, well managed adaptation can potentially make substantial positive contributions to the health and social and economic well-being of the whole population. Fundamentally, there are many co-benefits to health of moving to a low-carbon economy and one of the biggest is the reduction of the future burden of adaptation. Meanwhile, a major aim must be to improve the resilience of vulnerable communities.

There are many adverse direct and indirect health effects of climate change already apparent, and with substantial climate change already 'in the pipeline', greater effects will become apparent over time. Maintaining population health in the face of these major changes must be a central aim of adaptation policy. This will be a stretch even in a rapidly decarbonising world, but will present profound and unprecedented challenges if a high carbon world eventuates. The direct health effects may be largely driven by extreme weather events, but globally the indirect effects flowing from forced migration and economic and political uncertainty are likely to have a greater impact on health over time, by acting on the broader determinants of health. Factors such as the indirect impact of acidification of oceans affecting food supplies remain as yet imponderable, but of increasing concern.

The high carbon world scenario is likely to involve major global social disruption, which will bring further risks of infectious diseases and other impacts on health. However, we cannot extrapolate health impacts in a simple linear fashion as we cannot as yet delineate, let alone quantify, all the threats to health that will arise from a rapidly changing climate system.

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