

# **Climate Change in Hamilton City, New Zealand: Sectoral Impacts and Governmental Response**

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# Climate Change in Hamilton City, New Zealand: Sectoral Impacts and Governmental Response

*Rebecca Gasper and Andrew Blohm*

## 1. Introduction

This case study focuses on climate change impacts in Hamilton City in the North Island of New Zealand. Hamilton is the largest inland city in New Zealand, and has been growing rapidly in area and population size over the past decade in the context of a changing climate. Several recent studies have analyzed the current and future impacts of climate change on the city and its residents. Hamilton can serve as an important model for understanding climate change in cities because of the availability of information about local manifestations of change, and because of the governmental response to the resulting challenges.

### 1.1. Key Issues

The Hamilton case study reveals several important climate change impacts on urban infrastructure and human welfare including the following systems: water demand and treatment, public health, transportation, energy—including transmission infrastructure as well as future energy demand—and air quality.

In addition to providing information about the sector-specific impacts of climate change in Hamilton, three key lessons emerge that may contain broader significance for other cities across the globe. First, the possible international significance of forced migration due to climate is evident in this region of the world, where citizens of neighboring small island states may need to relocate to New Zealand in the face of sea level rise and associated impacts. Second, the relevance of the integrated, and perhaps cumulative, nature of climate change impacts in cities was revealed through a study modeling the effects of physical changes on infrastructure, transportation, energy and water systems in Hamilton. Finally, the response of national and local government illustrates the importance of adaptation measures in climate policy and the great potential for use of collaboration and partnerships to confront –and perhaps even take advantage of—climate change effects.

### 1.2. Case study organization

The case study first provides brief background on the global and regional contexts, including information on the demographic and climatic characteristics of Hamilton. Next, climate change impacts are discussed including current and anticipated physical changes and resulting impacts on the following systems: water supply and treatment, transportation, energy, air quality and public health. Many of the projections of the impacts are derived from the Phase I report of a government-sponsored study on Climate Change's Long-Term Impacts on New Zealand Infrastructure (CLINZI)<sup>1</sup>, a joint modeling study conducted by the New Zealand Centre for Ecological Economics (NZCEE) and the Center for Integrative Environmental Research (CIER). Additional local considerations including relevant social concerns and the integrated nature of impacts are also discussed. The report details the response of local and

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<sup>1</sup> Jollands et al., 2006

national government to climate change issues and concludes by highlighting the important lessons learned from the case.

## 2. Background

This section of the case study reviews the global, regional and local contexts, featuring those characteristics of Hamilton that may be of particular importance for city planning in response to climate change impacts.

### 2.1. General information and demography

New Zealand is a country in the southwest Pacific Ocean comprised of two islands. Hamilton City is located in the North Island adjacent to the Waikato River 126 km from Auckland, New Zealand's largest city (Figure 1). The city is a major service center of the greater Waikato region, one of the primary producers of Maize in the country.

Like other regions of the world, New Zealand has been experiencing growth in its urban areas. In 2009, over half of the national population resided in the four largest cities – Auckland, Hamilton, Wellington, and Christchurch. Hamilton's population size has grown steadily over the past decade to an estimated 140,700 residents over 9,400 hectares in 2009. Its population's 1.5 per cent growth rate between 2006 and 2009 makes it the third fastest growing city in the nation<sup>2</sup>.

**Figure 1: Map showing Hamilton, New Zealand**



*Source: Jolland et al. 2006*

<sup>2</sup> New Zealand Statistics, 2009

The New Zealand census bureau anticipates continued growth, projecting 26% growth in the Waikato region in 2026 compared to 2001.

## **2.2. Regional and local climate**

New Zealand's location primarily in the southern hemisphere results in temperature-moderating westerly airflow patterns. Equally important contributors to local climate are large mountain ranges in the South Island, which produce strong west-east rainfall and temperature gradients.

Taken together, these atmospheric features of New Zealand have led to a heterogeneous and diverse environment<sup>3</sup>. There is high spatial variation in soil and vegetation type within and among regions of the country, forming microclimates that range from temperate grasslands to subtropical forest. The natural climatic variation is an important consideration for the country when dealing with climate change currently and in the future. Local-level analyses should be used in tandem with broad projections for planners to prepare for change. City officials and managers should also consider that the natural variability of the climate may be exacerbated by increased variability in weather patterns as the planet warms.

## **2.3. Local air quality**

Air quality in Hamilton is relatively good with respect to national indicators focused on carbon monoxide, ozone, lead and nitrogen dioxide<sup>4</sup>. High wind speeds in the region do not facilitate the accumulation of heavy pollution, and most of these pollutants do not present local hazards. The main concern for the region is suspended particulate matter (PM-10) that results from burning of local fires and heating fuel. Within the past five years, Hamilton has fallen within "good" to "acceptable" range for PM-10 levels according to the national legal standards on air quality. Because emissions of PM-10 are associated primarily with heating, it is possible that future air temperature changes will influence local air quality.

## **2.4. City infrastructure**

Hamilton is New Zealand's highest export region, handling 20 per cent of all export activity<sup>5</sup>. The city's proximity to two major seaports and two international airports facilitates its role in trade and other social and economic activity. As with other major cities, this role depends on the reliability of its transportation infrastructure. It is therefore important to understand and prepare for any climate changes that may impact the function of the many highways, tunnels and railways throughout the city.

The energy infrastructure for Hamilton is particularly robust. The system has enough supply capacity to meet energy demand under future climate scenarios as well as expected growth in energy demand as a result of population increases. Further, as the region already experiences high winds, transmission infrastructure such as substations are located indoors and most cables underground, increasing the reliability of transmission. However, energy infrastructure in the recent past has fallen victim to extreme weather events including floods and high winds. In 2004, as a result of a strong windstorm outside design capacities, a transmission link

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<sup>3</sup> Kenny et al., 1995

<sup>4</sup> Smith, J., 2006, pp. 9-15

<sup>5</sup> New Zealand Statistics, 2006

was cut for three days between the north and south island creating economic and social disruptions<sup>6</sup>.

### **3. Climate change impacts**

This section of the report describes current and anticipated physical climate changes on New Zealand and Hamilton, and projected impacts on city infrastructure and public health.

#### **3.1. Current and projected physical changes in Hamilton**

Climate change throughout New Zealand has been occurring throughout the 20th century. Air temperatures have increased 0.4-0.7 degrees Celsius since 1950, sea level has risen 70mm and alpine snow mass has decreased<sup>7</sup>. In general, winters have been warmer and diurnal temperature ranges have decreased due to minimum temperatures rising much faster than maximum temperatures<sup>8</sup>. Climate change has resulted in about 10 fewer days per year below freezing and an additional two days per year with temperatures above 30 degrees Celsius<sup>9</sup>.

Within 70-100 years, temperatures could rise as high as four degrees Celsius in the North Island and by three degrees Celsius in the South Island<sup>10</sup>, with average IPCC model projections of an additional degree of warming in the Hamilton region by 2050 compared to average temperatures between 1980 and 1999; Figure 2 below.

Frost days are expected to occur less frequently in the North Island. Precipitation changes will likely be highly variable, with heavy precipitation events occurring more frequently and drought risk growing in the eastern parts of the country<sup>11</sup>. Flooding and storms are expected to increase in frequency throughout the country, and tropical cyclones will form more often in the North.

In the Waikato region, climate models predict uniform warming with slightly drier summers, although there is variation among model results. Summer water deficits are likely to increase over the next century, with increased drought severity in north-central Waikato. The Waikato region overall will become increasingly tropical<sup>12</sup>, with average temperatures increasing 0.2-1.3 degrees Celsius by the 2030s and up to four degrees Celsius by 2080<sup>13</sup>.

Modeling projections for regional precipitation are varied, although most predict annual increases in rainfall. The IPCC projects changes from -4 to 14 per cent by 2030 and -6 to 26

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<sup>6</sup> Joallands et al., 2006

<sup>7</sup> Wratt et al., 2004

<sup>8</sup> Walther et al., 2002

<sup>9</sup> Plummer et al., 1999

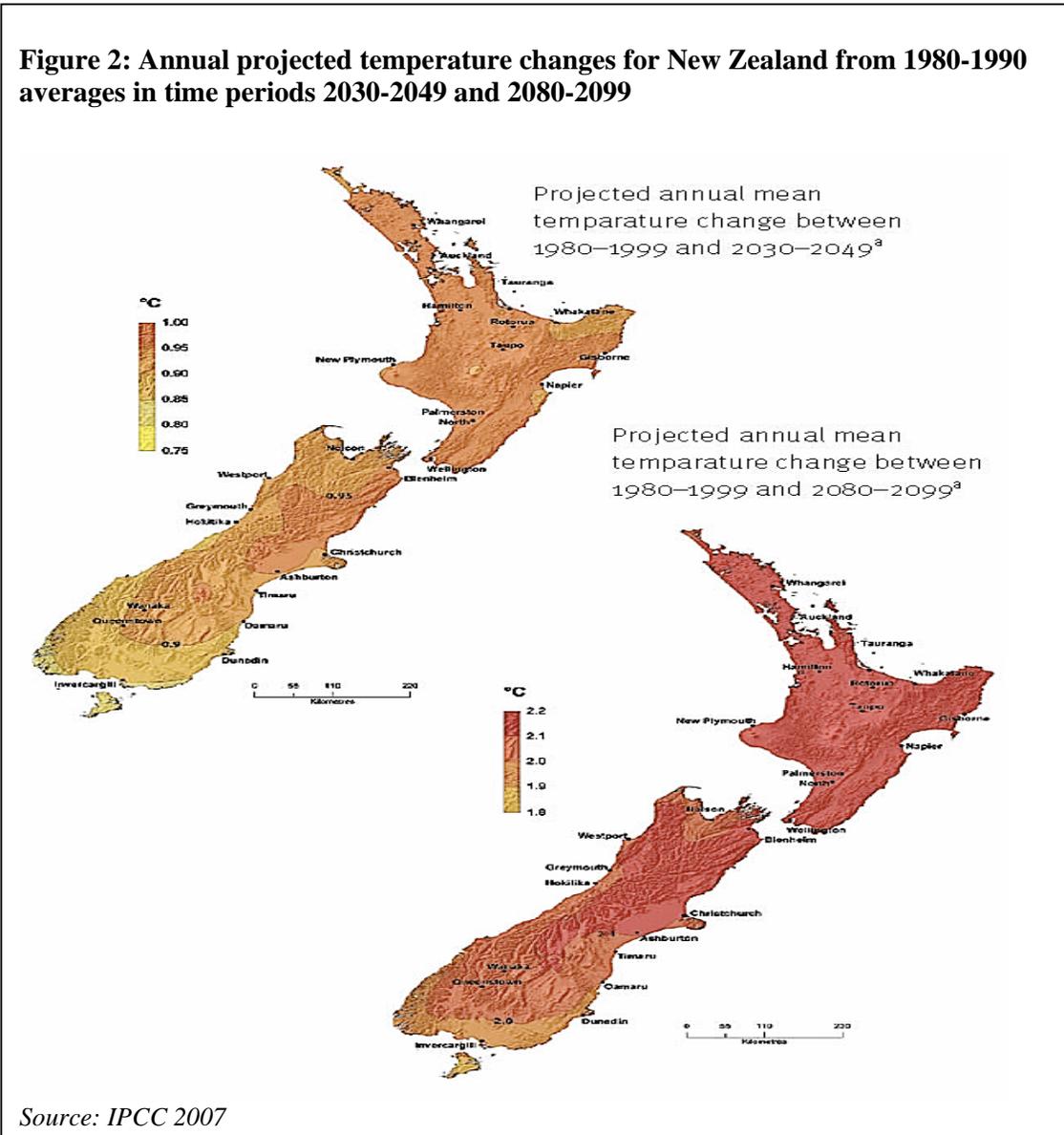
<sup>10</sup> Jollands et al., 2006

<sup>11</sup> Wratt et al., 2004

<sup>12</sup> Sinclair, 2001

<sup>13</sup> IPCC, 2007, pp 515

per cent by 2080<sup>14</sup>. Increased probability of severe storms and heavier rain is associated with more severe inland flooding and more storm surges in coastal areas<sup>15</sup>.



<sup>14</sup> IPCC, 2007, pp 515

<sup>15</sup> Sinclair, 2001

## **3.2. Impacts on infrastructure and services**

This section of the case study documents expected impacts on primary components of the infrastructure of Hamilton.

### **3.2.1. Structural infrastructure damage**

Heavy precipitation events are likely to become more frequent and more severe as climate change continues to occur. These events may result in more frequent flooding from the nearby Waikato River, causing damage to residential and commercial infrastructure. At the same time, warming temperature and more frequent droughts will likely cause reduced river levels between heavy rainfalls. As a result, more landslides and greater surface erosion may occur<sup>16</sup>, causing frequent disturbance of river sediments and decreased protection from levees<sup>17</sup>. Increased damage is likely for buildings, roads, bridges and other transit structures, energy services and communications.

### **3.2.2. Transportation**

Climate change impacts are likely to compromise the integrity of transportation infrastructure throughout the city. Increased precipitation and high winds cause landslides and debris accumulation that damage roads, rail and bridges. Prolonged rain and intense heat results in cracks and buckles along paved roads and railroads, which result in the need for repairs.

There have been few studies documenting the costs of these repairs under climate change scenarios. However, the CLINZI study found that climate change is expected to significantly impact road repair costs over the next 25 years. Depending on the projected precipitation changes and the seasonal distribution of those changes, road repair costs may range from a 4 per cent decrease to a 9 per cent increase from 2006 costs<sup>18</sup>. At the upper bound, this may only translate to a USD 2000–3000 cost increase, but the results of the study suggest the need for city planners to update aging infrastructure and to identify potential weaknesses on roadways and other transportation methods to avoid greater costs in the future.

Hamilton's position in the midst of a primary export center of New Zealand amplifies the importance of its transportation sector for regional economic activity. Moreover, most residents rely on private transportation to get to work. When major roads and bridges are impeded or under repair, local business may suffer, trade may be disrupted and economic activity may decline.

### **3.2.3. Water treatment and supply**

The city of Hamilton uses a single water treatment facility that draws water from the Waikato River. City planners must consider whether future demand increases for water in a warmer climate will exceed the supply capacity.

The CLINZI model showed that population size rather than climate is the primary determinant of water system stresses, and that Hamilton's system is generally robust to climate impacts<sup>19</sup>.

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<sup>16</sup> Dymond et al., 2006

<sup>17</sup> IPCC, 2007, pp 510

<sup>18</sup> Jollands et al., 2006

<sup>19</sup> Jollands et al., 2006

Hamilton's storage capacity appears capable of meeting demand even under warming conditions and local population growth projections from 2006.

Although population is the primary determinant of aggregate water demand, climate variables do significantly impact per capita water consumption. Short-term supply shortages have been predicted to occur in 2030 with 30-40 per cent probability. The IPCC also predicts water security issues in the North Island in general, which may affect Hamilton indirectly through local competition for Waikato River resources<sup>20</sup>. Long-term water management plans therefore ought to account for the interacting effects of population growth and climate change<sup>21</sup>, and for potential regional concerns.

Intense precipitation, high temperatures and few annual frost days can increase water turbidity, which makes water more difficult and costly to clean. Modeling projections for the Hamilton water supply predict increases in turbidity, but not to the extent that treatment costs would increase significantly. Still, city planners should consider these potential changes when making capital investment decisions to reduce future costs. Factors influencing water treatment costs other than turbidity need to be investigated further before conclusions can be drawn on costs of water treatment in the future.

#### **3.2.4. Energy**

As in other urban centers around the world, the energy supply infrastructure in Hamilton and the greater Waikato region is necessary to maintain core city functions including health care services, economic activity, clean water supply, and comfort in homes. In Hamilton, most of the residential energy demand is for heating homes.

Climate change can influence energy systems by affecting demand either through reduced heating needs or increased cooling needs. On the other hand, infrastructure damage to energy infrastructure could restrict supply when the grid is damaged by storms or strong wind. Extremely high temperatures can also cause failures of electricity conductor systems.

Evidence from the CLINZI study suggests Hamilton City's physical electricity supply infrastructure is able to cope with mean climate change impacts. While demand for electricity in summer months in particular is expected to increase, heating demand during the winter is very likely to decrease. Even in the summer when electricity demand is high, modeling results show that it is unlikely to exceed supply capacity<sup>22</sup>. Moreover, local temperature predictions under all IPCC scenarios do not exceed threshold temperatures for grid failure, and thus service interruptions due to climate change are unlikely in the future. Overall, the Hamilton City electricity infrastructure distribution system appears to be robust to average expected climate change impacts, with physical infrastructure that is well specified and designed to accommodate growing loads and severe weather events.

Still, a potential source of vulnerability for the energy supply system overall lies in the lack of data regarding other energy services in the city. To adequately prepare for future needs, the city should collect data on gas petroleum services and also disaggregated energy data so that vulnerabilities of particular sectors are not obscured by use of aggregated data.

Climate change impacts in this area provide a somewhat unique opportunity for Hamilton to expand its energy portfolio, even perhaps to transition to cleaner sources. The city may have

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<sup>20</sup> IPCC, 2007, pp 50

<sup>21</sup> Ruth et al., 2006

<sup>22</sup> Jollands et al., 2006

the opportunity to take advantage of expanded capacity for hydroelectric power generation from increased winter rains in the Waikato catchment and intensified river flows from snow pack melt<sup>23</sup>. Also, increased winds could allow for expansion of a renewable wind energy system.

### **3.2.5. Air quality**

According to CLINZI modeling results, although increased energy use for cooling during summer months may result in slightly higher greenhouse gas emissions, climate change is unlikely to cause a reduction in local air quality. Stable weather conditions allow air pollutants to increase in concentration and pose serious health risks, especially during air inversions. To the extent that climate change reduces these periods of stability with more frequent extreme events, wind gusts, increased variability of precipitation, and windier conditions overall, future conditions may actually reduce local concentration of air pollution<sup>24</sup>.

Additionally, the need for home heating is likely to decline with average winter temperatures, which will alleviate the impacts of Hamilton's greatest air quality threat (PM10) and other pollutants emitted from heating sources. Domestic housing standards such as insulation and double-glazed windows could create further opportunities to reduce heating costs and pollution.

Air quality is also influenced by local traffic creating smog. Congestion caused by roadway disruption could lead to short-term hazardous air quality conditions as climate change results in the need for more frequent repairs. These effects may also be compounded by increasing use of roadways as population growth and development continues to occur.

## **3.3. Impacts on public health**

Rising levels of greenhouse gases have the potential to accelerate destruction of stratospheric ozone increasing the risks of skin cancer for New Zealand residents. As greenhouse gases trap warm air closer to the surface of the earth, the upper layers of the atmosphere begin to cool, resulting in the destruction of ozone by CFCs. With the destruction of ozone comes increased risk of skin cancer as a result of more UV radiation passing through to the earth's surface. A study conducted in the United States suggested that CFC depletion of the ozone layer could subsequently increase skin cancer rates by as much as 5-20 per cent.<sup>25,26</sup>. New Zealand residents have fair skin and tend to spend significant time outdoors, which may make them particularly vulnerable to skin cancer.

CLINZI model results, however, indicated that heat-related mortality, respiratory problems and skin diseases are not likely to increase in Hamilton as a result of climate change. However, this could be a function of societal adaptation through improvements in healthcare and technology, a trend that will need to continue into the future to reduce the potential for increased skin cancer rates.

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<sup>23</sup> Wratt et al., 2004

<sup>24</sup> Jollands et al., 2006

<sup>25</sup> Woodward et al., 2001

<sup>26</sup> Slaper et al., 1996

Water- and vector-borne diseases may also impact human health as the warming climate favors pathogenic range expansion and increases the life cycle of disease-bearing organisms. The New Zealand Ministry for the Environment is concerned that heavy rains may disperse pathogens such as cryptosporidiosis into water supplies overwhelming current water treatment practices. Dengue, a mosquito borne disease, has been a problem throughout most of the south Pacific outside of New Zealand. Climate change has the potential to create ecological niches for the development of new disease vectors. Warming temperatures decrease the development time for insects and expand their range of favorable environment. Mosquito range expansion may increase the regional incidence of dengue<sup>27</sup>. A high percentage of New Zealand residents are considered at risk of this disease due to changes in environmental conditions, expanding mosquito habitat, accidental mosquito introduction and the large percentage of residents with no protective antibodies<sup>28</sup>.

### **3.4. Social implications of change**

Migration from low-lying islands of the Asia-Pacific region to New Zealand and Australia due to sea level rise and related impacts is possible within the next century<sup>29</sup>. The government of Tuvalu, located on a low-lying atoll with a mean height of approximately two meters, has negotiated migration rights for nearly all of its citizenry to New Zealand. Climate change impacts including sea level rise and salt water inundation place communities in atolls such as Tuvalu at extreme risk. As a result of climate change impacts and migration agreements in place we can expect to see increasing immigration into New Zealand, potentially straining existing infrastructures in urban areas such as Hamilton. Tuvalu, listed as a least developed country by the United Nations, has a population of just 9,000. Still, other at-risk atolls including Tokelau, a dependent territory of New Zealand, will contribute migrants as well<sup>30</sup>. Therefore, population growth in cities throughout these countries may be higher than anticipated due to immigration. Most of the indigenous population of New Zealand is located in cities and climate change impacts may affect these residents differently as they may not have the same access to information and resources as other sectors of the population<sup>31</sup>.

### **3.5. Integrated nature of impacts**

It is important for city planners using projections and model results for decision-making to consider that impacts in one sector, even if they seem relatively mild, may negatively impact other parts of city infrastructure. Population growth and its associated demands for resources and space could also exacerbate issues associated with climate change. The IPCC warns, for example, that projected coastal population growth and development across New Zealand could intensify the effects of sea level rise by 2030<sup>32</sup>.

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<sup>27</sup> Woodward et al., 1998

<sup>28</sup> Maguire, T., 1994

<sup>29</sup> Woodward et al., 2001

<sup>30</sup> Barnett and Adger, 2003

<sup>31</sup> IPCC, 2007, pp 522

<sup>32</sup> IPCC, 2007, pp 50

The CLINZI study examined integrated impacts in Hamilton and found that impacts of climate change on one infrastructure system in many cases will also negatively impact other infrastructure systems (Table 1). The energy system has the widest range of indirect impacts followed by the transport system. General public health and air quality appear to be most susceptible to impacts in other sectors.

These interactions are important because they may generate nonlinear cumulative impacts. For example, climate change effects were found to have little impact on water demand and future water shortages. However, energy supply, water quality decline from severe weather events, and other impacts can also add to water supply stress. If these conjunctive impacts were also considered with direct climate change impacts on water demand, it is possible that the impact of climate change as a whole would be significant.

<b>Table 1: Matrix of integrated climate change effects in Hamilton City, New Zealand</b>					
	Water	Transportation	Energy	Air quality	Public health
Water	Little impact on aggregate demand, possible increase in turbidity and treatment costs	NA	Possible increase in energy use for water treatment due to turbidity increases	NA	Little impact on water demand potential for health impacts if water supply disrupted by extreme events
Transportation	NA	Possible increase in road repair costs, resulting in potential congestion increases	NA	Increased trips likely due to population pressure, increasing traffic-based air pollutants	Increased emissions from traffic may have health impacts
Energy	Disruption of electricity supply could disrupt water supply and treatment	Disruption of electricity supply could disrupt traffic signals during extreme weather events	Reduced electricity demand for heating and reduced use of wood-burning stoves likely	Potential reduced emissions due to reduced heating	Disruption of electricity could disrupt public health provision
Air quality	NA	NA	NA	Little impact from gradual climate change on air quality	Potential decrease in emissions-related health problems
Public health	NA	NA	NA	NA	Little direct impact from gradual climate change on public health
<i>Source: Adapted from Jollands et al. 2006</i>					

## **4. Preparing for climate change**

New Zealand's government has acknowledged the information gathered by the scientific community regarding climate change, and has accepted a role in both mitigation and adaptation efforts from local to global levels.

### **4.1. National and local governance**

The Ministry for the Environment mandated commissioned research institutions to use the best possible science to gather information about the regional and local effects of climate change across the country. Using this information, the national government devised broad legislation and strategies for sustainability practices, transportation planning, industrial and domestic energy efficiency standards and coastal development policies. The Ministry mandates a role for local governance in implementing these policies, and provides guidebooks for local government to assist these efforts. National and local governments work together to plan emergency response strategies, to develop insurance schemes to protect citizens from health problems and property damage that may increase as a result of climate change, to inventory emissions and to identify educational or training needs for the public.

District and regional councils are charged with developing plans that address city planning and community mobilization to reduce emissions and to adapt to inevitable change specific to their region. Adaptation at the local level will likely include managing development in the private sector, managing expansion of urban areas, as well as infrastructure and communications planning. For example, the Tauranga City Council, located along the Western Bay of Plenty is mainly concerned with flooding impacts and damages. Local government here considers climate change when making any investment decision or technological changes to the storm water drainage or water treatment systems. Land use plans for the next 50 years have also been updated to include considerations of increased precipitation intensity. Napier City, which has more coastal development than Tauranga City, is concerned mainly with erosion and sea level rise. Local government here is focused on a new risk-based planning approach to reduce further development and to limit erosion trends<sup>33</sup>.

### **4.2. Planning in the Hamilton City region**

Local governments will need to adaptively manage issues such as water allocation for irrigation, erosion control, water supply and management, pest management, and a range of other issues likely to be impacted by climate change. Consequently, like other cities in New Zealand, the Hamilton City Council and the regional Environment Waikato have developed plans to reflect local challenges. A water campaign in the Waikato region educates the public about potential water supply and contamination issues and encourages domestic practices to conserve water. Local government is also reviewing the status of underground pipes that supply water to households, identifying and repairing leaks to improve the efficiency of the system.

The City of Hamilton prepared a five-phase Local Action Plan that involves: (1) conducting a greenhouse gas inventory and forecast; (2) setting emission reduction targets; (3) developing a specific action plan for industry and domestic sectors; (4) implementing the action plan; and

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<sup>33</sup> Ministry for the Environment, 2008

(5) monitoring achievements. The emissions audit was completed in 2001 and identified the city's greenhouse gas output by sector. Hamilton City then set a reduction target to stabilize emissions to 2001 levels by 2020, and to slow the rate of emissions from corporate activities to 11 per cent below 2001 levels by 2010<sup>34</sup>.

### **4.3. Preparing for migration**

New Zealand and Australia are both involved in discussions on migration from disappearing islands in the South Pacific. New Zealand has already agreed to establish a labor program to accept residents of the Pacific archipelago Tuvalu, which stands to see catastrophic flooding damages and saltwater intrusion within the next century even under the best-case sea level rise scenarios<sup>35</sup>. Although these global discussions have not yet translated into local policies, there is likely to be activity in the major cities of New Zealand to confront additional population rise if and when immigration becomes a reality.

## **5. Conclusion**

Hamilton City is in a generally good position to face climate change, with relatively few threatening risk factors and high adaptive capacity in most respects. Modeling projections indicate that the water, healthcare, and energy systems in the city are relatively robust to climate change and that infrastructure capacity is not likely to be exceeded in either case by changes in demand under warming scenarios. Good governance in Hamilton helps to reduce the city's vulnerability to those risk factors it does face, with policy action plans in development and implementation phases for many climate change associated issues. Table 2 summarizes sector-specific impact predictions and corresponding policy measures.

Still, these projections highlight the importance of interacting vulnerabilities (see Table 1).

CLINZI projections are broadly consistent with other studies that have shown that while individual climate change impacts in New Zealand are expected to be relatively small, these changes are likely to serve as threat multipliers, exacerbating existing and future vulnerabilities (e.g. population growth). Taken together, modeling results for Hamilton suggest that while direct impacts of climate change are potentially minor, indirect impacts could be substantial for urban areas. The energy sector has far-reaching implications for other aspects of welfare in Hamilton. Although this sector alone is robust to climate change, even slight negative impacts could prove to exacerbate impacts in other sectors (e.g. transportation). It is also important to consider that climate change scenarios tested in modeling predictions are gradual. If unanticipated rapid changes occur, impacts may be more severe than expected.

The relative security of each sector also clearly depends on the degree of warming. The IPCC developed a gradient of vulnerability for New Zealand for each sector based on the degree of warming from 1990 levels. Water security in New Zealand has the lowest coping range, such that greater than 2 degrees Celsius of warming exceeds adaptive capacity<sup>36</sup>. Although studies indicate that Hamilton has enough water supply to meet demand even under warming scenarios, short-term shortages may occur in tandem with competing demands from

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<sup>34</sup> Hamilton City Council, 2006

<sup>35</sup> Patel, 2006

<sup>36</sup> IPCC, 2007, pp 510

surrounding water-stressed agricultural areas. When considering Hamilton within its regional context, planners should be prepared for potential future shortages.

New Zealand presents important lessons to other countries with regards to climate change planning. Even though the country faces perhaps relatively fewer challenges than other nations, its government is still implementing policy approaches for preparedness. The national government places a clear emphasis on forward-thinking adaptation policies, accepting the inevitability of some degree of change. By integrating climate change considerations into land use planning and infrastructure investment now, the country (and the city of Hamilton) could limit future damages and costs. Understanding sectoral impacts now allows local planners to find creative ways to take advantage of physical climate changes and to even seek benefits to change by investing in hydroelectric power or wind energy, for example.

**Table 2: Summary of expected climate change impacts in Hamilton, New Zealand and resulting national and local policy responses**

Sector	Expected impacts	Existing policy responses
Transportation	Significant structural damage and disruption likely within the next 25 years	Introduction of a fuel tax Urban planning to reduce sprawl and limit congestion on roadways Investment in a national program to update and expand efficient public transportation options
Water	Local water supply robust to aggregate demand increases, although short-term and regional water shortages may occur	Regional campaign to increase efficiency of water use and to educate the public about water issues
Energy	Electricity supply and infrastructure likely to cope with future demand loads, although structural damage from storms is possible Reduced energy demand in winter likely Increased water flows for hydroelectric power likely	Climate considerations incorporated into energy infrastructure plans and investment decisions Energy-efficiency standards implemented for corporate buildings Federal funding for R&D into clean and renewable energy technologies
Air quality	Less winter heating may lead to reduction of PM10 concentrations Windier conditions may improve local air quality	Continual monitoring of local sector-specific emissions National air quality standards for major pollutants
Public health	Increased incidence of skin cancer possible, but uncertain Risk of contamination of water sources with infectious disease Increased risk of mosquito-borne disease	Plans to expand health coverage through private-public partnerships and collaboration among levels of government Climate-related considerations incorporated into water supply and treatment plans

The formation of partnerships among national, regional and local government and between the private and public sectors has helped both the country's and city's preparation efforts. The necessary collaboration among disciplines and the systems approach to urban infrastructure concerns leaves the door open to tackle multiple problems at one time (e.g. development and adaptation to climate change). Top-down legislation is designed to allow each region to focus on their specific vulnerabilities and tailor policy accordingly. Private and public sectors are collaborating to develop comprehensive insurance schemes and to reinforce transit infrastructure. The success of these efforts will be tested as changes continue to occur, but it is certain that New Zealand's efforts to combine programs and forge partnerships between the public, private and nongovernmental sectors have the potential to address environmental, social and economic problems and to provide a guide to other nations and their cities.

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