AECOM Imagine it. Delivered.

Auckland Economy Climate Change Risk Assessment
21-Aug-2020

Auckland Economy Climate Change Risk Assessment

Quality Information

Document	Auckland Economy Climate Change Risk Assessment
Ref	p:\606x\60633984\400_technical\433_report\final report and summary slides\1.4 auckland economy ccra_final tech report_20200821_clean.docx
Date	21-Aug-2020
Prepared by	Danielle Clarke, James O'Donnell, Sarah Lindberg
Reviewed by	Victoria Chantra, Will Symons

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
1	Draft	Client review	Victoria Chantra	
2	Final	For issue	Victoria Chantra	

Limitations

AECOM New Zealand Limited (AECOM) prepared this report pursuant to the terms of engagement agreed between AECOM and the ATEED dated 05 June 2020.

This report was prepared exclusively for the client and purpose identified in the terms of engagement referred to above. No responsibility is accepted for any use of any part of this report for any other purpose or by any third party. This report was prepared with the usual care and thoroughness exercised by the consulting profession, using practices and standards applicable at the time it was prepared. No other warranty, express or implied, is made as to the professional advice included in this report. Where this report indicates that information has been provided to AECOM by third parties, AECOM has not undertaken any independent verification of this information except as expressly stated in the report. AECOM assumes no liability for any inaccuracies or omissions in such information.

This report was prepared between 22 June 2020 and 22 August 2020 and is based on the conditions encountered and information reviewed at the time of preparation. AECOM disclaims responsibility for any changes that may have occurred subsequently. This report should be read in full. Caution must be taken when considering the conclusions expressed in this report because significant uncertainty remains due to the inherent complexities involved in analysing the past climate and variables typically encountered when modelling future climate change. AECOM cannot guarantee the accuracy of the

climate observations and projections described in this report and is not responsible for any third party's reliance upon on this information.

This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners. Except as required by law, no third party may use or rely on this report unless such use or reliance has been authorised in writing by AECOM. Before granting any such authorisation, AECOM may require the third party to execute reliance letters in a form (or forms) prescribed by them.

To the extent permitted by law, and unless otherwise expressly agreed in writing, AECOM expressly disclaims and excludes liability for any loss, damage, cost or expense suffered by any third party resulting from the use of, or reliance on, any information contained in this report. AECOM does not admit that any action, liability or claim may exist or be available to any third party. Third parties are responsible for independently making their own inquiries and seeking their own professional advice in relation to their particular requirements and proposed use of this report.

Table of Contents

Executive Summary

AECOM delivered this preliminary Auckland Economic Climate Change Risk Assessment (CCRA) for ATEED to explore the implications of climate change related risks and opportunities for economic recovery from COVID-19. This CCRA adds to the knowledge of climate change risks already identified by Auckland Council. It considers both risks and opportunities arising from physical climate change hazards and from the transition to a low carbon economy. This assessment has focused on four key sectors and associated subsectors within Auckland's economy: construction, food and beverage, visitor economy and screen. The food and beverage sector covers the manufacturing, supply chain, food technology, wholesale, agriculture, horticulture and viticulture subsectors. The construction sector covers the infrastructure, residential and non-residential subsectors. The screen sector covers the film sector infrastructure and filming locations subsectors. The visitor economy sector covers the tourism, business and major events and international education subsectors.

Key physical risks across each of the four sectors have been outlined below.

Sector	Risks
Food and beverage	Water supplies are reduced disrupted or contaminated – this risk was rated moderate for manufacturing and the primary sectors in 2040 and major for horticulture and viticulture in 2110. Reduction in outputs from livestock and crop production due to changing seasonality – this risk was rated minor for the primary sectors in 2040 and major for horticulture and viticulture in 2110. Assets such as crops and livestock, are damaged or destroyed – this risk was rated minor for the primary sectors in 2040 and major for horticulture in 2110.
Construction	Partially constructed buildings and infrastructure, construction sites and equipment are damaged or destroyed. This risk was rated minor in 2040 for all subsectors rising to moderate/Major in 2110. Maritime infrastructure and maritime transportation assets are damaged or destroyed disrupting the construction sector supply chain. This risk was rated minor in 2040 rising to moderate in 2110. Changes to seasonality and average climatic conditions which result in failure of buildings and infrastructure to meet or maintain the level of service expected by owners or end users. This was rated Minor in 2040 rising to moderate in 2110 for the residential and non-residential subsectors.
Screen	Large scale ecosystem change. This risk was rated minor in 2040, rising to moderate in 2110. Built assets, such as studios, that are necessary for service provision are damaged or destroyed. This risk was rated minor in 2040, and increases to moderate in 2110. Flights to and from Auckland International Airport are disrupted. This risk was rated insignificant in 2040, rising to moderate in 2110.
Visitor Economy	Flights to and from Auckland International Airport are disrupted. This risk is rated minor in 2040, rising to major in 2110. Large scale ecosystem change. This risk was rated minor in 2040, rising to moderate in 2110. Built assets and Māori cultural heritage sites, that are necessary for service provision are damaged or destroyed. This risk was rated minor in 2040 and increases to moderate in 2110.

In contrast to physical risks, transitional risks and opportunities arise from the process of adjustment towards a low-carbon economy. Depending on the nature, speed, and focus of change required, transition risks may pose varying levels of financial and reputational risk or opportunities to organisations and across sectors. Using a defined transition scenario the following potential transitional risks were identified across the four sectors:

- Increased costs of transporting input materials across the sectors due to increasing fuel costs
- Higher electricity costs causing reductions in demand, or reductions in profit margins
- Increased costs of inputs to production due to price on carbon
- Additional capital outlays required for fuel switching and energy efficiency retrofits in response to policy, regulation, consumer demand or market signals, stressing balance sheets and cash flows
- Stranded assets: Investments see their economic life curtailed due to technological, regulatory and/or market changes, stressing balance sheets
- New costs of compliance associated with carbon-related regulation such as the Task Force of Climate-related Financial Disclosures (TCFD) causing reductions in profit margins via increased operating costs
- Reputational risk if skills required to transition, or prosper from the transition, are not present in the labour market
- Increased risks from wildfires due to afforestation efforts
- Reduction in the competitiveness of exports if other markets do not take action to reduce emissions; and
- Increased Directors and Officers (D&O) liability insurance costs.

The severity of each transition risk depends on the characteristics of each particular sector and the sector's resultant sensitivity to each identified risk. For example, the transitional risk of higher electricity costs depends on the energy intensity of the production of a good or service, the ability of the business to absorb costs or to pass costs on to consumers, and the sensitivity of consumers to changes in price. This will be different for each sector.

There are transitional opportunities that relate to all sectors including: increasing demand for locally produced goods and services (as imports increase in relative price due to higher transportation costs); the ability to expand into new markets through the provision of low-carbon goods and services; access to new financial products (such as green bonds) to support business growth; and development of onsite electricity generation/microgrids (which may increase resilience to disruption to external energy network shocks).

Results from both the physical and transitional risk assessments provide ATEED with an understanding of the implications of climate change related risks and opportunities. This understanding can support both ATEED and Auckland Council incorporate measures into economic recovery planning while also addressing climate-related risks and opportunities

1.0 Introduction

1.1 Context and audience

Warming of the climate system, driven by anthropogenic greenhouse gas emissions, is unequivocal (IPCC, 2019). The world has already experienced significant climatic changes due to emissions from the combustion of fossil fuels and land-use change. Auckland is already experiencing climate change impacts. Over the past century, Auckland's mean annual temperature has increased by approximately 1.6 °C and sea levels have risen by approximately 16 centimetres over the past 100 years. If global emissions continue to rise, sea levels are projected to continue to rise by up to one metre by the end of this century. Auckland Council has recently adopted Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan. As Te Tāruke-ā-Tāwhiri states, in a region with 3,200 kilometres of coastline, this means serious threats of coastal erosion, storm surges and flooding. Such changes are expected to continue, with far reaching consequences across all sectors of the economy and communities.

As a signatory to the Paris Agreement, New Zealand has committed to the global transition to net zero emissions, and to reaching net zero emissions sometime in the second half of this century. Auckland too has targets to reduce greenhouse gas (GHG) emissions by 50 per cent by 2030 and reach net zero GHG emissions by 2050. The most significant sources of emissions are related to transport, energy use in industry and buildings, and industrial processes. While the transition to a low carbon economy will mean dramatic change across all industries, it is recognised that emissions must decrease rapidly over the next decade and that the sooner they decline the better the physical impacts of climate change can be managed.

Risks arising from climate change can be divided into two major categories: risks related to the transition to a low carbon economy and risks related to the physical impacts of climate change (TCFD 2018). Assessments are underway to understand the broader social, economic and cultural impacts of climate change at both national and regional levels. The purpose of the recently adopted Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan is to increase Auckland's resilience to the impacts of climate change and reduce emissions that cause climate change. To support the Climate Plan, the Climate Change Risk Assessment technical report series produced by Auckland Council considered risks across a range of areas, however, there has been no specific climate change risk assessment of impacts to the region's economy.

Businesses are the backbone of the Auckland economy. They provide employment, education and training, produce a wide range of goods and services, generate investment and innovation, and contribute to social and cultural life in Auckland. Auckland's business community is made up of a diversity of business types; large businesses as well as many small and medium-sized businesses.

Small and Medium-scale Enterprises (SMEs) form a significant portion of Auckland's economy. These enterprises employ many people, and are often well-positioned to meet consumer needs. However, SME's by definition, are small in scale, with relatively limited human and financial resources. These limited resources can, but do not always, manifest in a variety of ways that can increase vulnerability to climate change, including; limited forward planning; limited capital for recovery; limited access to expertise and information; lack of influence across supply chains; and limited risk management activities. Accordingly, within each sector, SME's are likely to be more impacted by climate change than larger organisations. Sectors with a higher proportion of economic activity driven by SME's may also be more vulnerable to climate change than sectors with less SME activity.

At the time that this assessment was undertaken, New Zealand had only recently emerged from severe restrictions enforced by the New Zealand Government in response to the COVID-19 pandemic. New Zealand residents were confined to their homes from 25 March to 27 April, only allowed out to access essential services such as healthcare and to procure essential goods (Treasury, 2020a). The global response to COVID-19 has had profound economic and social implications across New Zealand. As Auckland recovers from COVID-19, there is a unique opportunity for this recovery to drive transition to a low carbon economy and to adaptation to physical climate change risks. To realise this opportunity, an understanding of risks and opportunities from climate change is required so that business can be supported and prepared for transition and build resilience to future climate risks.

It is critical that investments to stimulate the economic recovery do not lock the region into increasing emissions or greater vulnerability to future physical climate risks.

Both physical and transition risks are likely to incur costs, as well as potentially generate benefits, to the sectors considered. The wider economic implications of both physical and transition risks in terms of the region's GDP, employment, and indicators such as the consumer price index, depend on the nature of the sector and its products, as well as the physical and transition risks occurring outside the Auckland region. Whether the costs are borne by the supplier, or are passed on to the consumer, depends on the extent of competition and the ability to import goods and services. If the sector has few competitors from outside the Auckland region then they may be able to pass any costs directly onto consumers. However, if substitutes or alternatives exist in regions that are not facing the same risk, and trade is able to occur, consumers will switch to these if Auckland suppliers attempt to pass on costs. Businesses may move to other locations if the risks become too high. This assessment does not make assumptions regarding the situation outside the Auckland region, or internationally, however, this will clearly play an important role in the ultimate effect on Auckland's economy and the well-being of its people.

1.2 Purpose and Objectives

This Auckland Economy Climate Change Risk Assessment (CCRA) adds to the knowledge of climate change risks already identified by considering risks and opportunities arising from both physical climate change risks and risks arising from the transition to a low carbon economy to four sectors: construction, food and beverage, visitor economy and screen. An understanding of risks and opportunities from climate change will also support Auckland Tourism, Events and Economic Development (ATEED) and Auckland Council to integrate climate change considerations into economic recovery planning in response to COVID-19.

The objectives of the Auckland Economy CCRA were to:

- Identify and rate physical climate change risks and opportunities that may result from climate change;
- Identify risks and opportunities that may result from a transition to a low-carbon economy;
- Explore potential interactions between physical and transition risks;
- Enhance ATEED's understanding of how Small and Medium-sized Enterprises (SMEs) within each sector may be impacted differently by climate change compared with larger businesses; and
- Explore the implications of climate change related risks and opportunities for economic recovery from COVID-19 to enable the incorporation of relevant measures into economic recovery planning.

This preliminary assessment was undertaken for ATEED and was limited to risks and opportunities in relation to four priority sectors in the Auckland region. In future, further consultation with a broader audience may be undertaken to refine the assessment and expand it to other sectors.

1.3 Report overview and structure

This report consists of the following key sections:

- A summary of current and possible future climatic conditions in Auckland (Section 2.0)
- An overview of climate change risks to the four key sectors of the economy (Section 3.0)
- The consequences of these risks in relation to each relevant sector (Section (4.0)
- A summary of transition risks and opportunities for each relevant sector (Section 5.0)
- The implications of the assessment for COVID-19 recovery planning (Section (6.0); and
- An overall conclusion (Section 7.0).

1.4 Project Method

The project was undertaken in two parallel stages: Stage 1: Risk assessment and Stage 2: Review workshops with ATEED and Auckland Council. The two project stages were preceded by context setting, which established the overall objectives of the assessment and the assessment process, scope, and method. A summary of the workshop approach is outlined in Table 1. Further detail on the method, including the parameters used for the assessment is located in the *Assessment Method Statement* in **Appendix A**.

Table 1: The stages of the assessment

Stage	Objective
Context setting	• Set the context of the project; • Define the project objectives; and • Confirm the scope and the methodology.
Stage 1 – Risk assessment	• Desktop review to identify the physical climate change risks and opportunities to the four priority sectors; • Analyse and evaluate physical risks using an agreed risk framework; • Identify transition related risks and opportunities to these sectors; and • Analyse implications of findings for Auckland's economic recovery from the impacts of COVID-19.
Stage 2 – Review workshops	• Validate transition risks to the priority sectors; • Present the findings of the desktop review; and • Explore the implications of these findings for economic recovery from the impacts of COVID-19.

1.5 Limitations

- This assessment was based on publicly available information. No further modelling was undertaken for this assessment;
- Stakeholder engagement was limited to ATEED and Auckland Council personnel;
- There is a high degree of uncertainty looking out to 2110 – in general, government policies, technological and demographic change, consumer and market pressures are likely to exert a greater influence on the economic prospects of the assessed sectors than climate change;
- This assessment did not analyse the implications of cascading risks, risks that may arise outside of the Auckland region, or risks outside of the value chains within each sector.
- A single high emissions scenario, and a single transition scenario was used to assess physical climate change risks and transition risks.
- This assessment identified and rated risks. No adaptation actions were identified or assumed to be in place.

2.0 Climate change in Auckland

2.1 Auckland's current climate

The following information on Auckland's climate was sourced from Chappell (2013) and represents an average or estimated average over a 30 year period between 1981-2010.

Table 2: Auckland's current climate

Variable	Description
Temperature	The Auckland region has a relatively mild climate with few extremes of temperature. Most of the region experiences mean annual temperatures between 14°C and 16°C. The annual mean daily temperature range for Auckland is small, averaging 7.9°C. Eastern areas are generally warmer than western areas, and higher elevation regions such as the Hunua Ranges are colder, experiencing mean annual temperatures as low as 12°C.
Rainfall	Annual rainfall ranges between approximately 900 mm and 1500 mm across the region. There is a distinct seasonal distribution of rainfall; 32 per cent of annual rainfall occurs in winter months, and 20 per cent in the summer months. The average number of days each year on which 0.1 mm or more of rain is recorded varies from around 180 days in coastal areas to over 210 days in inland areas. Heavy rainfall is sporadic and occurs with thunderstorms or with the passage of depressions of tropical origin over or close to Auckland. North-easterly flows between ridges of high pressure to the east and troughs over the Tasman Sea also bring rain.
Dry spells	Dry spells – periods of fifteen days or longer with less than 1 mm of rain on any day – are common in Auckland during summer and early autumn. Dry spells last for 20 days on average, and there are usually one to two spells each year, occurring between December and March
Wind	Mean monthly wind speeds in Auckland range from 8 to 21 km/hr. Coastal areas tend to be windier than sheltered inland areas. Spring is generally the windiest season throughout the region. Auckland is experiences strong gusty westerlies which may be accompanied by thunderstorms, and rarely tornadoes. Tropical cyclones that reach Auckland and still retain hurricane force winds are very rare, however other tropical storms affect Auckland about once or twice each year, bringing heavy rain and strong easterly winds.
Frosts	Compared with many parts of the country, Auckland has a mild climate and frosts are generally light and infrequent.
Sunshine	Most of Auckland receives approximately 2000 hours of bright sunshine per year. In general, central and eastern areas receive more bright sunshine than western and southern areas of the region, and islands in the Hauraki Gulf receive even higher sunshine hours – over 2100 hours in some places.
Humidity	Relative humidity is high in all seasons throughout the region. This, combined with the warmth, gives the Auckland climate a different character to that of other areas of New Zealand.

2.2 Auckland's future climate

2.2.1 Emissions Scenario

This assessment used projections prepared for the Auckland region by Pearce (et al., 2018). This assessment used projected based upon a high emissions scenario characterised by increasing greenhouse gas emissions driven by population growth, increased use of land for agriculture, a heavy reliance on fossil fuels and a high energy intensity and low rates of technology development. Additional information on the climate change scenario is contained in **Appendix A**

2.2.2 Summary of climate projections

Under a high emissions scenario, by 2110, the Auckland region is projected to be 3.25-3.75°C warmer than at the beginning of the century. Most of Auckland is projected to experience more than 90 hot days per year (days > 25°C) and there may be approximately 12 more days with very high or extreme fire danger. The volume of annual rainfall is likely largely unchanged, but more rainfall is likely to occur in autumn, and less in spring. When rain falls, it is likely to be more intense. Most of the Auckland region will experience between 12-21 more dry days per year. Oceans will be more acidic, and sea levels will be 1.2 metres higher than the 1990s. A summary of climate change projections, and related climate hazards is contained in Table 3. Additional information on variability of projections across the Auckland region can be found in Pearce et al. (2018).

Table 3: **Climate change hazards and climate change projections**

Climate change related hazard	Baseline period[1]	Climate change projections	
		2040[2]	2110[3]
Increase in frequency, duration, and magnitude of **heatwaves**	• 19.7 hot days per year • 18.7°C mean annual temperature • 18 - 20°C median annual average daily maximum temperature • 8-13°C median annual average daily minimum temperatures	• 15-20 more hot days[4] per year • 0.75-1.00°C increase in annual mean temperature • 0.75-1.25°C increase in annual mean daily maximum temperature • 0.75-1.00°C increase in annual mean daily minimum temperature	• 70-90 more hot days per year • 3.25-3.50°C increase in annual mean temperature • 3.25-3.75°C increase in annual mean daily maximum temperature • 3.00-3.25°C increase in annual mean daily minimum temperature r
Increase in frequency of **wildfires**[5]		• 10-30 per cent increase in Seasonal Severity Rating[6] • Very High and Extreme forest fire danger increases by 40-50%	• 10-30 per cent increase in Seasonal Severity Rating • Very High and Extreme forest fire danger increases by 50-100% for the Auckland Region north of the isthmus and by 40-50% south of the isthmus
Increase in frequency and extent of **flooding**	• 7.5 heavy rain days[7] per year • annual average of the 99th percentile of daily rainfall is 48.2mm • 6-8 days with consecutive heavy rainfall days[8] per year	• 0-5 more heavy rain days per year • Increase of 5-15 per cent in the magnitude of 99th percentile daily rainfall • Increase in intensity of short duration, rare rainfall events by 14 per cent per degree of warming.	• 0-5 more heavy heavy rain days per year • increased frequency of consecutive days of heavy rainfall across the Auckland Region of about one occurrence every two years • Increase in of 10-25 per 99th percentile of daily rainfall is projected to increase by between 10-25 per cent for most of the region, with some parts of the southeast projected to experience greater than 25 per cent increase

[1] The baseline period is an average of a period of between 20 and 30 years, depending on the climate variable, centred on the year 1995.
[2] Projections are the average of the 20 year period 2031-2050
[3] Projections are the average of the 20 year period 2101-2120 0
[4] Days over 25°C
[5] Projections for wildfire are in relation to a 1980-1999 baseline and are for the 20 year periods centred on 2050 and 2080.
[6] Seasonal Severity Rating (SSR) is a seasonal average of the Daily Severity Rating (DSR), which captures the effects of both wind and fuel dryness on potential fire intensity, and therefore control difficulty and the amount of work required to suppress a fire.
[7] Days where rainfall is above 25 mm.
[8] Consecutive days that experience above 40 mm per day

Climate change related hazard	Baseline period[1]	Climate change projections	
		2040[2]	2110[3]
		• Increase in intensity of long duration rainfall events by 5-6 per cent per degree of warming.	
Increase in **coastal inundation**		• Increase by 0.3 metres[9]	• Increase by1.2 meters[10]
Less frequent but more intense **storms**	• 18.6 windy days[11] per year • 9 cyclones every 10 years	Two fewer windy days per year	Three to four fewer windy days per year Increase in intensity and reduction of frequency of tropical cyclones
More frequent and intense **drought**	• PED[12] is 225 mm–375 mm per year • 237 dry days[13] per year in Auckland	60-100 mm increase in PED 3-9 more dry days per year Annual relative humidity increases by 1 per cent	100–140 mm increase in PED 12-21 dry days per year Annual relative humidity decreases by up to 2 per cent for the majority of the region
Changes to **seasonality**	• Few frosts each year across most of the region. More frosts in high elevation and northwest regions		• 0 frosts across the isthmus and eastern areas of Auckland. Few frosts per year in high elevation areas, and the northwest of the region • Spring arrives earlier, winters are shorter and summers longer • Spring becoming drier and autumn becoming wetter

[9] By 2045 (Golubiewski et al, 2019)
[10] By 2100 (Golubiewski et al, 2019)
[11] A day with daily mean wind speed of 10 m/s or more
[12] Potential evapotranspiration deficit (PED) is the gap between water demand and water availability.
[13] Days with less than 1 mm of rainfall

3.0 Physical climate change risks

This section outlines key physical climate change risks that have the potential to arise across the Auckland region over the coming century. These risks are likely to impact different sectors in slightly different ways. This section provides a broad overview of the risks while the consequences of these risks to each subsector are explored in further detail in Section 4.0.

3.1 Maritime infrastructure and maritime transport assets are damaged or destroyed

- Damage to port, ferry, marina and mooring infrastructure due to storm surges, waves and increased corrosion due to sea level rise.
- Disruption of sea-based activities due to storm events.

The Auckland region has benefited greatly from its extensive access to the coast; the Auckland Port is a hub of international and coastal maritime trade; ferry services have increased the mobility of residents within urban Auckland and between Auckland's islands; and marinas and docks support a vibrant pleasure-craft leisure sector.

Climate change is likely to impact port, ferry, marina and mooring infrastructure and the activities they support. Coastal transportation assets are, in general, more sensitive to extreme events, such as storm surges and waves, heavy rain and wind events and heatwaves, than to incremental changes in mean climatic factors. However, sea level rise, and increased destructiveness of storm surges and waves can damage coastal infrastructure as a result of inundation, or increasing corrosion in the inter-tidal splash zone, requiring additional maintenance funding and engineering upgrades (UNECE, 2013; UNECE, 2015).

3.2 Information and Communication Technology systems are disrupted

- Damage to towers, wires and fibre, exchanges, underground pits, data centres and cable landing stations due to high winds, flooding, and coastal inundation.

New Zealand's businesses rely on information and communications technology (ICT), such as the internet and telephone networks to connect to customers, communicate, manage operations, improve productivity, and develop new and exciting products. Businesses in New Zealand have relied on ICT services for some time. In 2008, 91 per cent of New Zealand's businesses had broadband access, 60 percent had a web presence, 74 per cent used the internet to place orders, and 42 per cent used the internet to receive orders (Statistics New Zealand, 2009). The importance of ICT to businesses continues to grow. Since 2011, monthly data consumption, a proxy for the importance of ICT, has grown by 61 per cent per annum (MBIE, 2017). Now 98 per cent of 'economically significant firms' have websites, 44 per cent of these firms receive more than 10 per cent of sales via the internet. Having a reliable and stable internet connection Auckland-wide is of paramount importance now that working from home has become commonplace at many workplaces around the region.

Some telecommunications infrastructure - towers, wires and fibre, exchanges, underground pits, data centres and cable landing stations - are at risk from high winds, floods and coastal inundation (CSIRO, 2007) or loss of power. Increased extreme rainfall events and storm surges in the Auckland region have the potential to lead to the flooding of telecommunications exchange stations. Mobile telecommunications towers may be adversely affected by an increase in wind events. These hazards have the potential to cause damage and may lead to increases in the cost of telecommunications supply due to an intensified infrastructure maintenance regime. These impacts can flow through to business via increasing costs, lower performance, or disruption.

ICT infrastructure in New Zealand is well regulated through the Telecommunications Act 2001, and the Telecommunications (New Regulatory Framework) Amendment Bill 2017, increases the likelihood that risks to ICT infrastructures will be managed over the 21st century. More importantly, critical components of ICT systems are designed to 'fail over' to the remaining sites if one fails, and main exchanges and cell sites have back-up power systems (New Zealand Lifelines Council, 2017).

Accordingly, the climate related disruptions are likely to be infrequent and short-lived even by the end of the century.

3.3 Electricity supplies are disrupted

- Damage to transmission lines, structures, and substations due to storm events, wildfires, flooding and coastal inundation.

A survey of 77 SME's in Auckland found that 96 per cent of businesses are unable to operate without electricity (Shaikh, 2018). Power outages, even those of a relatively short induration can be disruptive and costly for businesses. In 2018 the North Island of New Zealand experienced 66 power outages which had an average duration of 4.5 hours. These outages each affected on average 6,026 people (EATON, 2019).

Climate change may increase the risk of electricity supply due to more intense storm events, wildfires, flooding and coastal inundation. These hazards can damage above ground transmission lines, reduce the stability of structures, or inundate substations and other infrastructure (CSIRO, 2007). Weather and tree-related incidents, which in 2018 accounted for one third of disruptions, could drive additional disruptions throughout the century (EATON, 2019). As the majority of Auckland's power is hydroelectric, water shortages across New Zealand may also impact hydro-based power production (The Pacific Institute, 2009). In addition to disruption, these hazards may also increase the costs of electricity.

There is a high degree of adaptive capacity within the electricity network, and resilience is influenced by strong regulation. In general, investment in transmission and distribution services is governed by the Commerce Commission and other parts of the supply chain are governed by the Electricity Authority, and both regulators have statutory objectives to promote reliability.

3.4 Road networks are damaged or destroyed

- Damage to roads due to flooding and coastal inundation.

Auckland's population relies upon more than 7,000 kms of road to move people and goods more than 8.3 billion kilometres each year (Auckland Transport, 2018). The road network allows 74 per cent of people to commute to work in private vehicles (Richard Paling Consulting, n.d.), and for a large proportion of economic activity to take place. Climate change related hazards, particularly sea level rise and flood events may cause temporary or permanent damage to the road network.

A small proportion of Auckland's total road network is exposed to sea level rise, as shown in Table 4. Over the 21st century, inundation of roads is likely to occur more frequently, to more of the road network. In 2011 a storm coincided with a high tide which caused submerged lanes on Auckland's northern motorway (Chappell, 2013). Given there is only one main highway in Auckland, events such as these do have the potential to substantially impact the road network.

Table 4: Exposure of roads in Auckland to sea level rise (Paulik et al., 2020)

Sea level rise	Exposure of roads (km)
0 m	48
0.1 m	55
0.2 m	62
0.3 m	71
0.4m	80
0.5 m	90
0.6 m	100
0.7 m	112
0.8 m	124

Sea level rise	Exposure of roads (km)
0.9 m	137
1.0 m	149
1.1 m	163
1.2 m	176

Flooding can also damage road networks, or interrupt travel. Paulik et al. (2019) found that, at present, 1,259 km of Auckland's roads lie within area prone to flooding. Both Paulik et al. (2019) and Auckland Transport, (2018) have noted that the risk of flooding is increasing due to urbanisation, which adds pressure to drainage systems, as well as climate change.

Auckland Transport has started assessing the vulnerability of network infrastructure to climate change and sea level rise (Auckland Transport, 2018) and is in the process of developing a resilience action plan that aims to allow people to get to their destinations and for businesses to move freight, even in difficult conditions. However, the length of road per person in New Zealand is one of the highest in the world (Learnz, nd)[14], which could pose a constraint to the funding of adaptation (MfE, in press)[15].

3.5 Flights to and from Auckland International Airport are disrupted

- Damage to Airport runways, and electrical infrastructure due to flooding and coastal inundation.
- Disruption of flights due to high-wind events.

Auckland Airport is the busiest airport in New Zealand, with almost 21 million passengers in the year ended January 2020 (Auckland Airport, 2020). It is one of New Zealand's most important infrastructure assets directly providing thousands of jobs for the region, as well as supporting New Zealand's tourism sector, international education and business events. The airport is also crucial for freight movement. In 2013 it accounted for $13 billion in annual freight movements (Insight Economics, 2014).[16]

Auckland Airport however, is both exposed and sensitive to a range of climatic hazards. These include flooding and sea level rise, which can cause temporary or permanent inundation of runways and taxiways, loss of ground transport access, and inundation of electrical infrastructure. Higher temperatures can cause heat damage to infrastructure and increase cooling requirements. While changes in wind direction which may increase crosswinds and cause implications for capacity, and change noise distribution (AECOM, 2019; Williams, 2016; International Civil Aviation Organization, 2016). These hazards have the potential to cause disruptions to airport services or increase costs of air travel due to intensified maintenance requirements, or high capital expenditure retrofits. These impacts can flow through to business via increasing costs for importing and exporting, additional costs for prospective customers, or costs associated with increased disruption.

Auckland Airport has a high capacity to manage the risks posed by climate change, as the benefits of adaptation are likely to be internalised, and the costs of adaptation are likely to be minor relative to the value of the airport. Without adaptation, sea level rise may lead to major impairments to airport functionality by 2110.

[14] Learnz. (nd). New Zealand Roads. http://www.learnz.org.nz/memorialpark134/bg-standard-f/new-zealand-roads.
[15] NCCRA Learnz. (nd). New Zealand Roads. http://www.learnz.org.nz/memorialpark134/bg-standard-f/new-zealand-roads
Auckland Airport. (2020). January 2020 (Updated) Monthly traffic update
Insight Economics. (2014). Estimating the Regional Economic Importance of Auckland Airport. Prepared for Auckland International Airport Limited
[16] file:///C:/Users/james.odonnell/Downloads/EconomicImportanceofAucklandAirport.pdf Estimating the Regional Economic Importance of Auckland Airport

3.6 Water supplies are reduced, disrupted or contaminated

- Reduction and contamination of urban and rural water supplies due to drought, flooding, and changes to evapotranspiration.

Water is a key input to many sectors of Auckland's economy. Climate change related hazards, such as drought, changes to humidity and evaporation, and changes to rainfall regimes have the potential to reduce supplies of water and lead to contamination of freshwater resources.

Due to increased humidity, an increase in the number of annual dry days, increased rainfall variability and increased PED, Auckland is expected to become more drought-prone in the future (refer Section 2.2) (Pearce et al, 2018). An increasing incidence of drought will reduce the availability of water for both residential and commercial purposes (Ministry for the Environment, 2004). Businesses are more likely to face increased costs resulting from the increasing variability in water availability. The recent drought in Auckland has highlighted just how vulnerable Auckland's water supplies are; this year Auckland experienced the worst drought in 25 years and faces city-wide water restrictions.

The risk of water contamination is likely to increase under current climate projections. Heavy rainfall events can cause pollution and fertiliser to runoff into rivers and streams, resulting in contamination via pathogens such as giardia, cryptosporidium and campylobacter (Royal Society, 2017; Eyles et al, 2003) and eutrophication.

Despite these changes, Auckland's proximity to the Waikato River, a reliable and significant water source means it would be unlikely Auckland businesses will face severe water constraints in the long-term. However, they will likely face increased costs and may be affected by short-term water restrictions.

The majority of primary production systems are outside of the rural urban boundary and therefore rely on either local or on-farm water catchment systems, which may include consented takes from bores and streams. These systems are not affected by regional water restrictions but will be affected by reductions in rainfall variability as this could reduce localised supply.

3.7 Built assets that are necessary for service provision are damaged or destroyed

- Damage to built assets due to flooding, coastal inundation, wildfire, storms, erosion and drought.

All sectors of Auckland's economy rely upon built assets[17], whether they are offices, factories, warehouses, university campuses, barns, commercial buildings, or huts along a walking trail. Coastal inundation and flooding have the potential to cause significant impacts to Auckland's built assets. Other hazards such as wildfire, storms, erosion and drought may also damage built assets.

Analysis by Paulik et al. (2020) revealed that 1,790 buildings in Auckland are, at present, exposed to a 100-year extreme sea-level flood event. By 2110, with 1.2 m of sea level rise, the number of buildings exposed is projected to quadruple to 7,296. The replacement values of these assets increases in parallel to exceed $5 billion, as shown in Table 5.

Table 5: Exposure of buildings in Auckland to sea level rise (Paulik et al., 2020)

Sea level rise	Number of exposed buildings	Replacement value of exposed buildings (NZ$ million)
0 m	1,790	607
0.1 m	2,047	726
0.2 m	2,360	900
0.3 m	2,719	1,212
0.4 m	3,061	1,377

[17] For the purpose of this risk assessment, the built environment has been disaggregated to allow for a more nuanced understanding of risk across the economy. 'Built physical assets' is taken to mean all assets across the Auckland region that are not related to transport (e.g. roads, rail, ports, airports), or lifeline infrastructure (e.g. electricity, water, ICT).

Sea level rise	Number of exposed buildings	Replacement value of exposed buildings (NZ$ million)
0.5 m	3,420	1,646
0.6 m	3,831	1,851
0.7 m	4,316	2,173
0.8 m	4,820	2,622
0.9 m	5,371	3,225
1.0 m	5,921	3,828
1.1 m	6,559	4,801
1.2 m	7,296	5,323

Low-lying coastal areas, including parts of the Central Business District, eastern bays (e.g. Mission Bay), Onehunga, Mangere Bridge, Devonport, and Helensville are the most vulnerable to coastal inundation (Pearce et al., 2018). Across Auckland, sea level rise will increase the nuisance caused by smaller and more frequent flooding events, and cause higher magnitude impacts from larger low frequency events.

Built assets are also at risk from flooding caused by extreme rainfall events. Paulik (2019) found that 48,167 buildings, with a replacement value of $27.6 billion are located within a flood hazard area. Climate change may increase flooding risk, as rainfall events become more intense, however there is considerable uncertainty about projections for future flood risk.

3.8 Assets such as construction sites, crops and livestock, are damaged or destroyed

- Damage to construction sites, crops and livestock due to floods, storms and wildfire.

Some sectors of Auckland's economy depend upon assets that are seasonal, such as certain crops, or produce assets that are highly exposed to climatic elements during their production, such as buildings and infrastructure under construction or repair. The temporary and unfinished nature of these assets may increase their vulnerability to wildfire, floods, and storms. Businesses that use or produce these assets already plan for many of these risks. For example, the construction sector is accustomed to working in inclement weather, and may businesses across the construction and food and beverage sector insure construction sites and crops and livestock respectively. The increasing frequency and intensity of climate change hazards may increase costs of insurance, or increase risks to personnel, and render current actions to reduce exposure and sensitivity insufficient.

3.9 Disruptions to systems that are sensitive to seasonality and changes in climatic parameters

- Changes to the timing and characteristics of Auckland’s seasons, due to changes in climatic means.

The seasons exert a strong influence on a number of sectors of Auckland’s economy. For example, they influence heating and cooling requirements, determine when it is best to plant and harvest crops, and influence tourist behaviour. As Auckland’s climate continues to change, it is projected that spring will arrive earlier, winters will be shorter, and summers longer. Changes in seasonality are driven by multiple climate variables (Pearce et al, 2018). The Auckland region faces risks to sector productivity and output due to gradual loss of production from increased rainfall variability, warming temperatures, increased PED and increased humidity (Pearce et al, 2018). Both the primary production and tourism sectors are particularly vulnerable to changes to seasonality and average climatic parameters.

3.10 Large scale ecosystem change

- Changes to, or degradation of New Zealand's ecosystems due to pests and diseases, coastal inundation, and changes in climatic means.

Healthy ecosystems and rich biodiversity are fundamental to life on our planet, and directly support several sectors of Auckland's economy. Much of New Zealand's biodiversity and ecosystems face stresses from population pressures, land-use change and fragmentation, and pests and diseases. Climate change is projected to add to the stresses these ecosystems face. For example, sea level rise will inundate many of Auckland's coastal ecosystems, and erode beaches and cliffs (Fernandez & Golubiewsksi, 2019); warmer temperatures are likely to increase the incidence of pests and diseases, placing additional pressure on ecosystems (McGlone and Walker, 2011), and a changing climate may also impact upon species distribution although evidence that explores the implications of climate change on Auckland's ecosystems is limited.

3.11 People are exposed to environmental hazards

- Risks to the health and safety of workers and customers due to wildfire, floods, heatwaves, droughts and storms.

All sectors of Auckland's economy rely upon healthy, safe and productive workers, and businesses must be able to assure the safety of customers. There are many climate change related hazards that already pose risks to the welfare of employees and customers across Auckland, including wildfire, floods, heatwaves, droughts and storms (Jones et al., 2014). These events do not generally lead to many deaths, and there is limited evidence to suggest that deaths or injury will substantially increase over the 21st century (MfE, 2020).

Some climate change related hazards have the potential to cause illness or reduce welfare and productivity. For example, an increase in average temperatures will extend the suitability of climate for exotic vectors, encouraging their migration and subsequent transmission of disease (Derraik and Slaney, 2007). Higher temperatures also have the potential to reduce labour productivity, however in the near-term it is unlikely that New Zealand will lose working hours to heat stress (International Labour Organization, 2019).

4.0 Sector consequences

4.1 Overview of sector consequences

This section describes the consequences of the physical risks identified in Section 3.0 for each priority sector. Each priority sector is addressed separately beginning with an overview of the sector, description of sector characteristics followed by a summary of the key physical risks to the sector. Each expression of consequence includes:

- A description of how the risk relates to the sector.
- A description of the consequences of that risk on the sector
- A risk rating table and confidence rating.

Risks were rated in accordance with the risk framework presented in **Appendix A**. The framework accounts for both the likelihood of the occurrence of a hazard, or series of hazards that give rise to the risk, and the scale and intensity of the impact of the risk. Risks are a function of the number of businesses exposed within a subsector, or the percentage of economic activity exposed within the subsector, and the severity of the consequences that stem from the exposure. A level of confidence in the risk ratings based on the literature reviewed is also provided for each risk rating. See **Appendix A** for further detail.

Table 6: The applicability of risks to the four sectors of Auckland's economy assessed

Risk	Food and Beverage	Construction	Screen	Visitor Economy
Maritime infrastructure and maritime transport assets are damaged or destroyed	X		X	X
Information and Communication Technology systems are disrupted	X		X	X
Electricity supplies are disrupted	X		X	X
Road networks are damaged or destroyed	X	X	X	X
Flights to and from Auckland International Airport are disrupted	X		X	X
Water supplies are reduced, disrupted or contaminated	X	X	X	X
Built assets that are necessary for service provision are damaged or destroyed	X	X	X	X
Assets, such as construction sites, crops and livestock, are damage or destroyed	X	X		
Disruptions to systems that are sensitive to seasonality and changes in climatic parameters	X	X	X	X
Large scale ecosystem change	X		X	X
People are exposed to environmental hazards	X	X	X	X

4.2 Food and Beverage

4.2.1 Sector overview

The Food and Beverage Sector in this report is comprised of the following subsectors: manufacturing, wholesale, food technology, supply chain, horticulture, viticulture and agriculture. Table 7 below outlines the definition and geographical spread of each of the five subsectors.

Table 7: Food and beverage subsectors

Food/beverage subsector	Definition	Geographic locations
Manufacturing	This sector includes the five subcategories (M.E Consulting, 2019): Meat and meat product manufacturing; Seafood processing; Dairy product manufacturing; Fruit, oil, cereal, bakery and other food product manufacturing (called other food product manufacturing); and Beverage manufacturing.	Auckland is home to 23 per cent of national food and beverage manufacturing employees and 30 per cent of national F&B manufacturing businesses (M.E Consulting, 2019). Most manufacturing occurs in South Auckland (M.E Consulting, 2019).
Wholesale	Wholesalers includes both large and small distributors who sell products to retailers. We have included farmers markets within this definition.	There are four main wholesalers in Auckland who dominate the Northern region produce trade; T&G Global, Fresh Direct, Market Gardeners and Freshmax. All are based in Mt Wellington.[18] Farmers' markets are widespread across the region.
Food technology	Food Bowl is an open access facility available to support food and beverage companies in Auckland This facility allows companies to undertake research and design, pilot processes and commercial runs of food and beverage products. (New Zealand Food Innovation Network, 2020).	FoodBowl is based in Mangere (New Zealand Food Innovation Network, 2020). FoodBowl has been the only physical asset assessed for the food technology sector. Larger companies may have their own in-house facilities.
Supply chain	Includes both linear domestic infrastructure (roads) and infrastructure used for supply of imports/exports (sea and air).	Auckland Airport is located in Mangere, South Auckland. Auckland's main commercial port is located in Auckland CBD.
Agriculture	This sector includes dairy and beef and sheep livestock industries.	Spread throughout per-urban and rural areas of Auckland

[18] Based on personal communications with industry professionals.

Food/beverage subsector	Definition	Geographic locations
Horticulture	Auckland's main horticultural produce includes onions, potatoes, kiwifruit, lettuce, broccoli, wine grapes, cabbage, olives, cauliflower, pumpkin, carrots, avocados and strawberries (Auckland Plan, 2019).	Franklin in the south has the majority of Auckland's quality soils and a significant proportion of Auckland's horticultural produce is grown here (Deloitte, 2018).
Viticulture	Wine both grown and processed in Auckland.	There are over 100 vineyards in Auckland. The main wine-growing regions are in Matakana, Kumeū, Clevedon and Waiheke Island (Auckland Plan, 2020). Although 20 per cent of New Zealand wineries are in Auckland, only 1 per cent of hectares of grapes are grown in Auckland (Coriolis, 2017).

4.2.2 Characteristics of the Auckland's food and beverage sector

In 2015 the food and beverage sector generated $3,245 million for the Auckland economy, which is 4 per cent of Auckland's total gross domestic production (Infometrics, 2015a). The Auckland region accounts for the largest number of food and beverage businesses compared to all other regions in New Zealand (Infometrics, 2015a). The number of businesses in the sector is an indicator of economic health, and the number of business units in the food and beverage sector is growing faster than the rate of growth of other business units across the entire Auckland economy (Infometrics, 2015a).

Businesses within the food and beverage sector are larger than the average business size within Auckland (Infometrics, 2015a).[19] However, based on data between 2010-2015, business size within this sector is decreasing. The average number of employees in each food and beverage business decreased from 11.6 employees in 2010 to 10.7 in 2015. Smaller businesses are less resilient to economic shocks, and decreasing business size within the sector may decrease sector resilience.

Despite the large number of businesses, the sector only employs a small proportion of the total workforce in Auckland. In 2015 the sector employed just 3.6 per cent of the total Auckland workforce (Infometrics, 2015a). The sector experiences lower productivity than Auckland's economy as a whole (using Gross Domestic Product (GDP) per full-time equivalent (FTE) as an indicator of labour productivity). GDP per FTE decreased by 0.2 per cent per annum between 2010-2015 in the food and beverage sector compared to growth of 0.6 per cent GDP per FTE per annum across the total economy (Infometrics, 2015a).

In terms of demographics, employees in this sector are most likely to be male, older, without higher qualifications and non-Māori or Pasifika[20] (Infometrics, 2015a). Employees working in this sector in Auckland are predominantly born in New Zealand (56.7 per cent of the total workforce, with the second highest category of employees comping from Asia (16.2 per cent)) (Infometrics, 2015a). However, within the primary sector, there is an increasing proportion of migrant workers especially within the horticulture and viticulture sectors (Sriramaratnam, 2008).

[19] Based on the number of employees.
[20] The source report doesn't specify ethnicity of workers but rather excludes these two ethnic groups (Māori and Pasifika).

4.2.3 Overview of most significant risks and consequences for the food and beverage sector

Auckland's Food and Beverage sector faces risks to built assets (such as factories and warehouses) and key infrastructure assets (such as roading and ICT infrastructure). These assets are necessary for primary production, manufacturing, food technology, wholesale and supply chains. Risks to these assets may affect primary production in addition to movement of goods (and to a lesser extent, labour). The horticulture, agriculture and viticulture subsectors (primary sectors[21]) may predominantly be affected through changes to environmental conditions, extreme weather events and sea level rise which may reduce primary production outputs. An increasing incidence of the invasion of pests, diseases and weed species may increase input costs for primary producers, and contamination and/or disruption of water supplies may pose additional hazards to both the primary production and manufacturing subsectors. Changes to environmental conditions also pose hazards to workers, particularly those working in outdoors in the primary sectors.

The three most significant physical risks to the food and beverage sector have been identified as:

- Water supplies are reduced disrupted or contaminated – this risk was rated moderate for the primary sectors in 2040 and major for horticulture and viticulture in the primary sectors in 2110.
- Reduction in outputs from livestock and crop production due to changing seasonality – this risk was rated minor for the primary sectors in 2040 and major for horticulture and viticulture in 2110.
- Assets such as crops and livestock, are damaged or destroyed – this risk was rated minor for the primary sectors in 2040 and major for horticulture in 2110.

Projections indicate there are future growth opportunities for New Zealand's food and beverage sector. Asia is the largest destination region for food and beverage exports, and growth in these markets is projected to increase (Coriolis, 2019). New Zealand is facing increasing demand for food products due to its high-quality brand. This is due to New Zealand's clean and green image, which is supported by a primary sector which is relatively free of pests and diseases that are seen in other countries (Coriolis, 2019). The swift elimination of COVID-19 in New Zealand compared to the global impacts is only likely to enhance this image. Market shifts by 2050 project that the majority of exports will be consumer-ready processed food and beverage products (Coriolis, 2019). To take advantage of this economic opportunity, the sector will need to ensure it is resilient to the impacts of climate change.

4.2.4 Maritime infrastructure and maritime transport assets are damaged or destroyed

Maritime infrastructure and maritime transport assets for this sector include ports and port assets associated with sea freighting food and beverage products. These assets may face damage from extreme weather events such as storms. More permanent damage may be caused by sea level rise. Damage to coastal assets used to export food and beverage products may, depending on the severity of the damage, limit or disrupt Auckland's ability to export produce.

Sea freight is the most common type of export transport used to import and export goods (Statistics New Zealand, 2016).[22] Nationally, approximately 98 per cent of dairy, 95 per cent of meat, 90 per cent of fruit and nuts, 100 per cent of beverages, 63 per cent of fish and 80 per cent of miscellaneous edible preparations[23] are sent by sea freight; the remaining percentages for all these subcategories are sent by air (Statistics New Zealand, 2018).

In addition to exporters, manufacturers that rely on imported goods as manufacturing inputs may also be constrained in their ability to supply outputs, unless they are able to find a comparable local substitute in both price and quality.

The food and beverage sector generates significant revenue from exporting primary and manufactured products. Damage to coastal assets that are crucial for export processes may either reduce or eliminate the revenue streams of exporters, which may have flow-on impacts for producers,

[21] Excludes forestry.
[22] Based on data between 2005-2015.
[23] Tea/coffee.

manufacturers and wholesalers who sell directly to exporters. New Zealand has a strong reputation internationally for high quality food and beverage exports and future economic projections indicate that income from food and beverage export earnings is likely to continue to increase (Corilois, 2019). To take advantage of this projected growth it is important that export infrastructure is resilient to climate change.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Maritime infrastructure and maritime transport assets are damaged or destroyed				
Manufacturing	Insignificant	Minor	Minor	Limited agreement, limited evidence
Supply Chain	Minor	Minor	Minor	
Food Tech	Insignificant	Minor	Insignificant	
Wholesale	Insignificant	Insignificant	Insignificant	
Agriculture	Insignificant	Insignificant	Insignificant	
Horticulture	Insignificant	Insignificant	Insignificant	
Viticulture	Insignificant	Insignificant	Insignificant	

4.2.5 Information and Communication Technology systems are disrupted

ICT systems are a crucial inputs to modern businesses, both within the primary sector and across the manufacturing, supply chain, food technology and wholesale sub-sectors. These systems allow data to be stored and recorded and communications to be sent between various stakeholders across the sector. The ICT sector may face disruption from increased rainfall and extreme weather events. Disruption to ICT systems may reduce overall efficiency of the sector.

As modern manufacturing processes become increasingly automated, this increases the sector's reliance on ICT systems (Ministry of Business, Innovation and Employment, 2018). The manufacturing subsector may face disruptions to manufacturing processes that rely on ICT systems, which may reduce manufactured outputs.

If ICT systems are disrupted, the supply chain subsector may face delays to the processing of orders and routine commerce activities, which may in turn affect export efficiency and subsequent returns.

The food technology subsector may face infrequent disruptions to operations, and storage and communication of data, which, depending on the severity of the disruption, may hinder sector innovation.

The wholesale subsector may also face infrequent disruptions to the processing of orders and routine commerce activities, which may affect sector revenue.

In the primary sectors, farm automation is increasing the output of agriculture, horticulture and viticulture systems (MBIE, 2019). ICT disruptions may provide constraints on the ability to monitor field conditions and collect and track production output data, which reduces production system efficiency.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Information and Communication Technology systems are disrupted				
Manufacturing	Insignificant	Insignificant	Minor	Limited agreement, limited evidence
Supply Chain	Insignificant	Insignificant	Minor	
Food Tech	Insignificant	Insignificant	Minor	
Wholesale	Insignificant	Insignificant	Minor	
Agriculture	Insignificant	Insignificant	Insignificant	
Horticulture	Insignificant	Insignificant	Insignificant	
Viticulture	Insignificant	Insignificant	Insignificant	

4.2.6 Electricity supplies are disrupted

Although electricity is an important input into this sector, it is not the main energy source across either the manufacturing or the primary sectors. The main energy source for manufacturing is process heat and the main energy source for farming systems is diesel (Fitzgerald, n.d). Nevertheless, all subsector activities within this sector rely upon a stable electricity supply. Supply may be disrupted by extreme weather events. Disruptions to electricity supplies across the manufacturing, food technology, wholesale and primary sectors may impact key processes associated with processing, innovating and growing. This may in turn cause decreases in subsector efficiency and decreases in resultant outputs.

Food and beverage production is an energy-intensive sector. Approximately 30 per cent of New Zealand's primary energy is associated with food production processes (Fitzgerald et al, n.d). This 30 per cent is relatively equally proportioned between growing, processing and distributing food to consumers (Fitzgerald et al, n.d). Productivity is increasing across the sector, which increases the sector's energy requirements (Fitzgerald et al, n.d).

Food and beverage manufacturing is also energy-intensive. The food and beverage manufacturing industries consume 10 per cent of New Zealand's primary energy, and dairy and meat processing sectors consume 70 per cent of this 10 per cent. The majority of energy in food and beverage manufacturing is used for process heat which is largely supplied by fossil fuels such as reticulated gas (Fitzgerald et al, n.d). However, there are likely to be key manufacturing processes that rely on electricity – without electricity as an input such processes may fail, resulting in overall processing/manufacturing delays. The manufacturing process is essentially a system of various subcomponents, and electric outages/disruptions have the potential to halt all manufacturing processes until repaired.

Disruptions to electricity supplies may interfere with the ability of the food technology sector to engage in routine activities, such as recording data on computer systems and using lighting to undertake testing and trials in laboratories. Frequent or prolonged disruptions may impede innovation. For the wholesale sector, goods requiring refrigeration may perish in the absence of generators or backup power.

Electricity is the second most consumed energy source on farming systems, with diesel having the highest level of on-farm consumption (Fitzgerald et al, n.d).[24] Diesel is typically stored on site, either above or below ground. Consumption of electricity and diesel in primary production systems is increasing while consumption of petrol and natural gas remains relatively stable (Fitzgerald et al, n.d). As with manufacturing, the vulnerability of the primary production subsectors depends on whether key

[24] Based on a summary of several primary production energy use profiles.

processes rely on electricity. For dairy systems, milking sheds typically rely on electricity and any temporary disruption to electricity supplies may constrain milk production outputs. Depending on the length of electricity outages, there is also a risk of spoiling agricultural products that require refrigeration, especially during the summer months.

For the horticulture subsector, electricity supply disruption could affect producers' ability to maintain/store crops due to disruption to air conditioning units and refrigeration rooms. Electricity disruptions may also result in a failure to maintain appropriate temperatures in greenhouses. It is evident that some local producers use natural gas to heat their greenhouses; there is insufficient data available to discern whether this is common practice across Auckland and whether some greenhouses run off electricity (NZ Hot House, 2018). For the viticulture subsector, electricity disruption can result in potential disruption to air conditioning units and cool rooms used to maintain and store grapes.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Electricity supplies are disrupted				
Manufacturing	Insignificant	Insignificant	Minor	Limited agreement, limited evidence
Supply Chain	Insignificant	Insignificant	Insignificant	
Food Tech	Insignificant	Insignificant	Minor	
Wholesale	Insignificant	Insignificant	Minor	
Agriculture	Insignificant	Insignificant	Insignificant	
Horticulture	Insignificant	Insignificant	Insignificant	
Viticulture	Insignificant	Insignificant	Insignificant	

4.2.7 Road networks are damaged or destroyed

Approximately 1 per cent of roads in Auckland are exposed to 1 metre of sea level rise and 5 per cent of roads are exposed to 3 metres of sea level rise (Golubiewski et al, 2019). Although this is a low percentage, past storm events have damaged Auckland's road network. In 2011 a storm coincided with a high tide which resulted in Auckland's northern motorway having submerged lanes (Chappell, 2012).[25] Damage or destruction to main highways can impact domestic supply chains. If businesses have to reroute to use alternative local roads, these routes may be less direct and more prone to congestion than state highways, leading to slower transportation times. Damage to state highways may result in delays to the transport of both food and beverage products and inputs necessary for activity within each subsector.

Damage to road networks may place constraints on both the manufacturing and supply chain subsectors to efficiently transport inputs to manufacturing plants and outputs to distribution facilities and across domestic and international supply chains. Auckland's proximity to both the international airport and port are key to supporting the largest manufacturing sector in New Zealand (ATEED, 2020). This proximity also facilitates efficient domestic and international supply. Additional costs associated with disruption and re-routing may reduce the efficiency of these subsectors.

For the food technology subsector, disrupted domestic distribution may impact upon inputs needed for innovation, which may vary depending on the product being tested or trialled. However, in contrast to manufacturing, as only small amounts of inputs are needed, disruption to this subsector is likely to be limited.

[25] This is the Auckland Climate NIWA report filed in future_plans_projections

In relation to the wholesale subsector, the majority of wholesalers are based in Mount Wellington, in South Auckland, at the nexus of both the southern motorway and roads leading to the south and east of Southern Auckland. If any of this key roading infrastructure is damaged or destroyed due to climate hazards, the wholesale sector may face potential constraints on the ability to connect consumers to products.

For the primary production subsectors (agriculture, horticulture and viticulture) damage or disruption to road networks may result in supply chain impacts – both upstream and downstream. Upstream, primary producers may face short-term delays in obtaining raw inputs necessary for production. This could include fertiliser use, livestock feed and labour supply. Downstream, meat, milk, crops and wine may face delays in connecting to manufacturers and/or wholesalers.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Road networks are damaged or destroyed				
Manufacturing	Insignificant	Insignificant	Moderate	Limited agreement, limited evidence
Supply Chain	Insignificant	Minor	Moderate	
Food Tech	Insignificant	Insignificant	Insignificant	
Wholesale	Insignificant	Insignificant	Minor	
Agriculture	Insignificant	Minor	Minor	
Horticulture	Insignificant	Minor	Minor	
Viticulture	Insignificant	Minor	Minor	

4.2.8 Flights to and from Auckland International Airport are disrupted

The food and beverage sector relies on Auckland International Airport for shipping goods by air freight in addition transporting labour resources from abroad. Disruptions to airport services from extreme weather events can lead to highly perishable foods spoiling, which may lead to reduced sales. Disruptions may also temporarily prevent workers from entering New Zealand.

Only a small proportion of food and beverage exports are sent by air freight: 2 per cent of dairy, 5 per cent of meat, 10 per cent of fruit and nuts and 27 per cent of fish (Statistics New Zealand, 2018). It is possible for the majority of New Zealand's food and beverage exports to be sent via sea freight in chilled or frozen form rather than sending goods via air freight. However, this is not possible for some perishable products, such as fresh milk, which is air-freighted directly to China. For these products, local markets would need to be found (potentially flooding the local market and disrupting the domestic market). The export sector may lose income from high value perishable food and beverage products that are typically air freighted (Infometrics, 2015b).

The primary sectors may face labour constraints if flights to and from Auckland airport are disrupted longer-term. Based on 2013 data, one fifth of new entrants to the primary industries workforce comprised of temporary migrants, and the vast majority (35 per cent) of these migrants went into the horticulture sector (Ministry for Primary industries, 2019). Both the horticulture and viticulture sectors

in particular rely on seasonal labour to ensure crops are either picked, packed and/or pruned at the end of each growing season (Sriramaratnam, 2008).

Subsector	Risk rating			Confidence
	Present	2040	2110	
Flights to and from Auckland International Airport are disrupted				
Manufacturing	-	-	-	Limited agreement, limited evidence
Supply Chain	Insignificant	Insignificant	Moderate	
Food Tech	-	-	-	
Wholesale	-	-	-	
Agriculture	Insignificant	Insignificant	Minor	
Horticulture	Insignificant	Insignificant	Minor	
Viticulture	Insignificant	Insignificant	Minor	

4.2.9 Water supplies are reduced, disrupted or contaminated

The primary sector is expected to face reduced water availability, as indicated under the drought and water variability projections. Within this sector, the most severe consequences from water reduction and contamination may be experienced by the primary sector. Under the *Resource Management Act 1991* water is not allocated strategically, but rather on a first-come-first served basis – there is no water safeguarded for food production (Deloitte, 2018). Without any prioritisation among users, food producers at both 2040 and 2110 may likely face water shortages and/or increased water costs due to associated scarcity, increasing the overall food production costs for producers (Deloitte, 2018).

Water is crucial to food production systems. Many primary industries are sensitive to changes in rainfall and seasonal variability (Cradock-Henry and Fountain, 2019). Livestock, horticulture and viticulture industries use water as a key input to their production processes and future water constraints may have downstream implications on these production systems. Food production systems are likely to use their own water sources which means that if such sources become contaminated, food producers may need to purchase temporary uncontaminated water, adding additional costs to production. These costs may likely be passed on to wholesalers, manufacturers and consumers. Both water shortages and contaminated water supplies can affect livestock health, causing diseases such as leptospirosis, which reduces milk production and in extreme cases can lead to livestock death (Dairy NZ, n.d). New Zealand livestock farming systems rely on rainfall to grow pasture to feed their herds (Cradock-Henry and Fountain, 2019). If there is insufficient water to grow pasture, producers may need to purchase feed which may increase input costs. In the horticultural subsector, water is used for growing the plants, fighting frosts and processing the output to take it to market (Deloitte, 2018).

Inconsistent weather conditions impact upon food production; the reliability of water supply for vegetable crops during growth periods is very important to ensure quality as well as yield (Deloitte, 2018). The horticultural subsector in Auckland is typically comprised of family-owned and multi-cultural businesses (Deloitte, 2018). Current competition for water is one of the many reasons why growers are moving out of Auckland to ensure the profitability of their businesses (Deloitte, 2018).

Water is crucial to growing high-quality wine (Ministry of Agriculture and Forestry, 2009). Vineyards need water for irrigation, sanitation and cleaning (Gabzdylova et al, 2009). Presently, the south-eastern areas of Waiheke Island and north-eastern areas of Auckland have the lowest levels of rainfall in the region (Chappell, 2013 - based on a 30-year period between 1981-2010). Both these areas are key viticulture regions. Waiheke Island is not connected to Auckland's water infrastructure system.

When water shortages occur on the island, water has to be shipped in from the mainland, which causes additional costs for viticulture producers.

Soil runoff can also affect the health and quality of surrounding waterways, as surrounding waterways receive both sediment and nutrient run-off (MPI, 2020). A 1997 study on erosion and sediment in the Pukekohe region found that although erosion occurs locally, within paddocks, little of this sediment is transported downstream to larger waterways such as the Manukau Harbour (Basher et al, 1997). However, with climate projections demonstrating an increasing incidence of heavy rainfall, the sediment load may travel further, contaminating larger streams and harbours and placing additional pressure on water sources.

In the manufacturing sector, water is used for a range of processes including material processing, cooling and washing and cleaning (Pacific Institute, 2009). Assuming that the costs of water may increase during times of scarcity, this may result in increased costs to food and beverage production, which in turn would be passed onto consumers. The consequences of contaminated water supplies would impact upon the ability to manufacture food and beverage products. Alternative water sources could be procured at high cost assuming that cost may be exacerbated during times of scarcity. The risk of contamination is generally low for those business attached to the municipal supply. There is minimal water involved in supply chain management, food technology and wholesale subsectors hence the consequences of water scarcity for these subsectors may be much less severe than manufacturing.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Water supplies are reduced, disrupted or contaminated				
Manufacturing	Insignificant	Minor	Moderate	Limited agreement, medium evidence
Supply Chain	-	-	-	
Food Tech	-	-	-	
Wholesale	-	-	-	
Agriculture	Minor	Moderate	Moderate	
Horticulture	Minor	Moderate	Major	
Viticulture	Minor	Moderate	Major	

4.2.10 Built assets that are necessary for service provision are damaged or destroyed

Built assets within the food and beverage sector include buildings, factories, warehouses, milking sheds, packing equipment, dams and irrigation systems. Extreme weather events such as storms, floods and heavy rainfall can damage infrastructure that is crucial to all subsectors. Damage to built physical assets from extreme weather events can delay economic activity and increase repair and maintenance costs to asset owners. Slow-onset sea level rise can also damage built physical assets by resulting in the permanent destruction of sites.

For the supply chain subsector, both warehouses and cool stores are necessary for service provision. Damage to these built physical assets may cause products in these facilities to perish and may result in reduced storage facilities available. Warehouses and cool stores are also key built physical assets for the wholesale sector. Damage to warehouses and cool stores from extreme weather events may cause products in these facilities to perish and may result in reduced storage facilities available.

For the manufacturing subsector built physical assets necessary for service provision include manufacturing plants used to process primary food into secondary products. Damage to these by extreme weather events may affect sector productivity by causing delays and subsequent decreases in the output of secondary products. Damage to built physical assets for both the wholesale and

manufacturing section may be unable to meet retail demand, which may in turn increase consumer prices due to supply shortages (Deloitte, 2018). Small wholesalers include farmers markets. Farmers markets are predominantly held outdoors in Auckland. These markets may be more exposed to extreme weather events which may make outdoor markets unviable during warmer months. Small, niche food producers depend on produce markets for their livelihoods (Bell and Beaston, 2008). Closure of these markets may result in the closure of small food-producing businesses.

FoodBowl is the only type of built physical asset considered for the food technology sector. Its purpose is to provide facilities to foster development of innovative processed food and beverage products and it has space and equipment for hire (Coriolis, 2019). Damage to this asset from extreme weather events may place constraints on innovation, as small and medium-sized businesses may be unable to use this facility to engage in experiments and trials of new food and beverage products.

For the primary production subsector, damage to key primary sector inputs necessary for service provision may constrain producers' ability on the ability to produce primary outputs. Damage to dams and irrigation systems may constrain the ability of food producers to provide water to livestock, crops and grapes respectively. Damage to milking sheds, pens and buildings key for livestock and crop housing/storage which may cause short-term disruption to the ability to raise livestock and process and pack crops.

By 2040 and 2110 the intensity of storms is projected to increase (specifically wind speed and rain rates) and more intense storms pose a higher risk to key infrastructure (Pearce et al, 2018). Based on these projections, it is unclear whether storms may increase in an intensity significant enough to damage key infrastructure. Poorer quality infrastructure is likely to be less resilient to extreme weather events, increasing the infrastructure's vulnerability. No research was available on the quality of this sector's infrastructure quality.

While extreme weather events may cause temporary damage to all key infrastructure involved in any of the food and beverage sectors listed gradual sea level rise and coastal inundation resulting from extreme weather events may result in the permanent destruction of sites, which may render economic activity unviable among any of these subsectors.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Built assets that are necessary for service provision are damaged or destroyed				
Manufacturing	Insignificant	Minor	Minor	Medium agreement, limited evidence
Supply Chain	Insignificant	Minor	Minor	
Food Tech	Insignificant	Minor	Minor	
Wholesale	Insignificant	Insignificant	Insignificant	
Agriculture	Insignificant	Insignificant	Insignificant	
Horticulture	Insignificant	Insignificant	Insignificant	
Viticulture	Insignificant	Insignificant	Insignificant	

4.2.11 Construction sites, crops and livestock are damaged or destroyed

Crops, livestock and soil are considered temporary outdoor assets within the food and beverage sector. All of these assets may be affected by erosion and extreme weather events. Erosion affects the productivity of land as it removes topsoil, which is the most nutrient-dense component of soil (MPI, 2020). Primary producers may face reductions in productivity from increased soil erosion due to reduced growth of pasture and crops. Although erosion is a natural process, extreme weather events, drier conditions and farming practices all increase the rate of erosion (MPI, 2020).

Crops, livestock and soil may also be exposed to extreme weather events, such as storms, drought, hail and floods and severe rainfall. Severe rainfall can exacerbate soil erosion, reducing the productivity of the soil (MPI, 2020). Storms, droughts, hail and floods can cause injury to livestock and damage to crops. Depending on the severity and magnitude of the extreme weather event, producers may lose significant numbers of livestock or entire crop seasons.

The agricultural subsector can be impacted by erosion due to a reduction in topsoil which may reduce the amount of pasture grown in farming systems. Reduced pasture decreases the amount of feed available for livestock and may require producers to purchase additional feed as an input. The impacts of extreme weather events can also lead to injury or death of livestock. In 2017, producers in Clevedon, a rural town in South Auckland, lost entire livestock herds due to rising flood waters (Hurley, 2017).

The horticulture subsector may also face reduced productivity from soil erosion. Horticultural production in particular requires continual disruption to the soil, including deep ripping and various phases of hoeing, which makes the soil more vulnerable to erosion (Basher et al, 1997). Producers experiencing high levels of soil erosion may have reduced crop outputs which may in turn affect producers' profitability. Storms, fires and floods can damage crops grown outdoors, which may impact the horticulture subsector (Clothier et al, 2012). Some crops, such as tomatoes, are already grown in greenhouses which may protect them from exposure to extreme events (Deloitte, 2018).

The viticulture subsector may also face reduced productivity from soil erosion in the form of reduced growth of vines and grapes. As with horticulture, producers experiencing high levels of soil erosion may have reduced crop outputs which may in turn affect producers' profitability. Extreme weather events, including storms, drought hail and floods can damage vine and fruit. Fruit in particular is vulnerable to damage from extreme weather events (Clothier et al, 2012), and the viticulture subsector in Auckland may face a reduction in crop output. However, although 20 per cent of New Zealand's vineyard are in Auckland, only 1 per cent of grapes are grown within the region, as many grapes are shipped in from other regions (Coriolis, 2017). The ability to obtain grapes from other areas of New Zealand reduces the risk to this subsector.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Crops and livestock are damaged or destroyed				
Manufacturing	-	-	-	Medium agreement, medium evidence
Supply Chain	-	-	-	
Food Tech	-	-	-	
Wholesale	-	-	-	
Agriculture	Insignificant	Minor	Moderate	
Horticulture	Insignificant	Minor	Major	
Viticulture	Insignificant	Minor	Moderate	

4.2.12 Disruptions to systems that are sensitive to seasonality and changes in climatic parameters

Primary industries within the food and beverage sector are climatically-sensitive and New Zealand's economy is particularly sensitive to impacts on the food and beverage sector given New Zealand's reliance on primary sector exports (Cradock-Henry and Fountain, 2019). The agriculture, horticulture and viticulture sector may be impacted by changes to seasonality and average climatic parameters, which may affect production output. The sector may also face a risk of increasing input costs due to increasing incidence of invasion of pests and diseases and increased growth of weed species, which may have varying consequences across the three different primary industries. Raw products in New

Zealand account for 7 per cent of all exports and total 79 per cent of all export earnings (Statistics New Zealand, 2018). Any reductions in output of raw produce may have significant economic implications for food producers (Clothier et al, 2012).

This consequences of this risk to the food and beverage sector fall into two areas:

1. Reduction in outputs from livestock and crop production due to changing seasonality
2. Increasing input costs due to increasing incidence of invasion of pests and diseases and increased growth of weed species

Reduction in outputs from livestock and crop production due to changing seasonality and climatic parameters

Changes in temperature and seasonality can influence the length of growing seasons. A combination of decreased rainfall, warmer temperatures and increased droughts may reduce yields and increase production costs for producers. Changing seasonality can also impact the quality of horticulture products, such as size, shape and taste (Cradock-Henry, 2017). Mean minimum temperature changes may impact upon the winter dormancy period of some crops, having downstream impacts on quality and yields, impacting upon production costs and resultant profits (Clothier et al, 2012). Many horticultural businesses in Auckland are family-owned, and producers currently experience challenges to food production in the form of increasing land costs, intensive growing, competition for water and sourcing labour (Deloitte, 2018). Some of these challenges may be exacerbated by climate change constraints.

Soil moisture in Auckland may decrease as a result of increased evaporation and changing rainfall patterns (Lorrey et al, 2018). Reduced soil moisture may have significant implications for horticulture, agriculture and livestock management (Lorrey et al, 2018). Drier soils can affect soil functionality, which in turn may reduce pasture and crop growth (Lorrey et al, 2018). Reduced soil moisture can also increase the risk of erosion - the consequences of this are discussed in Section 4.2.13. Changing seasonality may also disrupt the timing of harvesting, availability of labour and processing at key times and movement of labour between sectors.

Higher concentrations of carbon dioxide stimulate carbohydrate production and plant growth and may lead to larger crop outputs (Benschop et al, 2018). Although carbon dioxide isn't a climatic parameter itself, it is a driver of the changes in climatic parameters. However, this can lead to reduced nutrition in outputs, which can cause adverse implications on human nutrition. In particular, potatoes are at risk of increased growth and resultant decrease in nutrient density – 20 per cent of the nationwide potato crop is grown in Pukekohe (Deloitte, 2018). Nutrient deficit crops could affect consumers' willingness to pay an increased price for a decreased crop size. Due to this conflict, increased crop growth has not been identified as a key opportunity for the primary sectors.

Dairy and horticulture producers may also be affected by changes in average climatic parameters such as mean minimum and maximum temperatures. Increases in mean maximum temperatures and heatwaves can cause heat stress in cattle. Heat stress in dairy cattle can cause weight loss, decreased feed intake and lower reproductive rates (Davison et al, 1996). Heat stress can also lower the immune systems of beef and dairy cattle increasing their vulnerability to illness (Benschop et al, 2018). Housing animals indoors could lead to overcrowding which may facilitate establishment of new pests and diseases, the establishment of which may result from increasingly warmer temperatures and increasingly humidity (Benschop et al, 2018).

Subsector	Risk rating			Confidence
	Present	2040	2110	
Reduction in outputs from livestock and crop production due to changing seasonality and climatic parameters				
Manufacturing	Insignificant	Insignificant	Minor	High agreement, medium evidence
Supply Chain	-	-	-	
Food Tech	-	-	-	
Wholesale	Insignificant	Insignificant	Minor	
Agriculture	Insignificant	Minor	Moderate	
Horticulture	Insignificant	Minor	Major	
Viticulture	Insignificant	Minor	Major	

Increasing input costs due to increasing incidence of invasion of pests and diseases and increased growth of weed species

Warming temperatures may result in an increasing likelihood of invasion of exotic pests and diseases that could harm food production systems (Benschop et al, 2018). Auckland is one of the most vulnerable areas in New Zealand to the establishment of new invasive species due to warmer temperature projections (Kean et al, 2015). Weed species are also projected to increase growth in Auckland's climate due to a combination of warmer temperatures and reduced frosts (Kean et al, 2015). Species invasion from both diseases and weeds may increase the costs of inputs needed to control threats, such as fertiliser (Benschop et al, 2018). The primary sectors may be particularly affected by these seasonality changes.

For the agriculture sector, increased incidence of diseases in livestock may require additional animal pest control activities resulting in increased costs. Due to an increase in weed species in Auckland, there may be reduced feed for animals due to reduced grass and feed productivity. This may require producers to purchase additional feed, increasing production costs.

The horticulture and viticulture sectors are also vulnerable to the invasion of exotic pests and diseases. In Auckland, subtropical fruit flies are significant threat to the horticultural subsector (Deloitte, 2018) and pose an increased threat under a warmer climate. There is slightly reduced exposure for the horticulture sector to this risk, as some crops are grown indoors in greenhouses, which reduces the exposure of these crops to pests and diseases.

Increases in pest management inputs and the associated labour inputs across all sectors may result in higher costs of production. An increase in fertiliser use may have negative implications for water quality due to fertiliser run-off from food-producing land (Pearce et al, 2018). An increase in inputs may lead to a resultant increase in production costs for producers; these costs may in turn be passed on to consumers (Deloitte, 2018). Small and medium-sized enterprises may be less likely to cope with increasing costs of inputs which may place economic pressure on these businesses.

The perception of New Zealand as a country that is clean and safe contributes to New Zealand's high quality reputation in overseas food and beverage markets (Coriolis, 2019). New Zealand is free of diseases that are in other countries' food production systems, such as foot and mouth, blue tongue and classical swine fever). This reputation may be impacted by an increasing incidence of pests and diseases.

The consequences from a changing climate may result in either reduced outputs or increased input costs which may impact food producers' profits. Smaller businesses generally have lower financial reserves than larger businesses which may result in smaller horticultural producers being pushed out of the market, leading to greater market corporatisation. Climate change may require primary food

producers to adapt their production processes which may add additional costs to producers, particularly those that are small to medium-sized. (Cradock-Henry and Fountain, 2019).

Subsector	Risk rating			Confidence
	Present	2040	2110	
Increasing input costs due to increasing incidence of invasion of pests and diseases and increased growth of weed species				
Manufacturing	-	-	-	High agreement, medium evidence
Supply Chain	-	-	-	
Food Tech	-	-	-	
Wholesale	-	-	-	
Agriculture	Insignificant	Minor	Moderate	
Horticulture	Insignificant	Minor	Moderate	
Viticulture	Insignificant	Minor	Moderate	

4.2.13 Large scale ecosystem change

Auckland may experience large scale ecosystem change from rising sea levels (Pearce et al, 2018). The primary sector faces risks to productivity and output from sea level rise. Loss of land is presently a key constraint to food production in Auckland, with urban sprawl placing downward pressure on the amount of food producing land available (Deloitte, 2018; Chibnall and Curran-Courngage, 2014). Slow-onset sea level rise may exacerbate the shortage of food producing land, placing pressure on producers to either increase the intensity of the food production systems or to move their production systems outside of Auckland. Sea level rise may also result in loss of major infrastructure for businesses; insurance companies many not provide compensation for damage from coastal inundation and sea level rise given insurance trends overseas (Iorns, 2018).

The most recent report on Auckland's exposure to sea-level-rise looks at Auckland's rural subsector exposure to sea level rise by both land use capability classes (LUCs) and land use types (Golubiewski et al, 2019). Rising sea levels may reduce the amount of land available for primary production processes.

In terms of the agriculture subsector, the land use types most exposed are rural subsector and grazing land (used by mixed sheep and beef, beef and dairy) (Golubiewski et al, 2019). Dairy farming contributes 10 per cent of Auckland's total land use (Chibnall and Curran-Courngage, 2014). Between 3-6 per cent of mixed sheep and beef, beef and dairy land may be exposed to 1 metre of sea level rise, and between 4 -11 per cent of this land may be exposed to 2 metres of sea level rise. Rising sea levels may reduce the amount of land available for livestock grazing, which may lead to higher stocking rates on the remaining land. Increasing the intensity of dairy farming production systems is already a current trend in Auckland (and New Zealand as a whole). Between 2002-14, the average herd size increased by 32 per cent; yet the land used for dairy farming decreased by 20 per cent. Sea level rise may exacerbate these trends and in extreme cases may result in farmers selling land and moving production out of Auckland.

Elite and prime soils in Auckland are typically used for horticulture production (Deloitte, 2018). From a land use capability perspective, land with elite and prime soils is exposed to sea level rise (Golubiewski et al, 2019). Approximately 5 per cent of all land with elite and prime soils may be exposed to sea level rise of between 0.25 and 0.5 metres by 2050. In 2100, more than 6 per cent of all land with elite and prime soils may be exposed to sea level rise. Sea level rise may force growers to grow more produce on reduced land sizes, which has downstream implications for both soil and water quality in addition to crop performance (Deloitte, 2018). The horticulture subsector in Auckland is presently facing increasing constraints on horticultural land supply due to an increasing urban

sprawl yet contributes significant economic value (Deloitte, 2018). Prime soils, proximity to a significant market (Auckland) and key transport routes are key reasons why the horticulture subsector has such a significant contribution to Auckland's GDP (Deloitte, 2018). If producers are forced to move out of Auckland due to sea level rise this may reduce the subsector's profits.

The viticulture subsector is less exposed to sea level rise. Only 1.1 per cent of this land class may be exposed to 1 metre of sea level rise, with 2.1 per cent of this land class potentially being exposed to 2 metres of sea level rise (Golubiewski et al, 2019). Exposed vineyards may lose tracts of grape-producing land which may reduce profitability. However, this sector is less vulnerable to sea level rise as the majority of grapes used to process wine are imported from outside of Auckland. Although 20 per cent of New Zealand's vineyards are in Auckland, only 1 per cent of grapes are grown within the region, as many grapes are shipped in from other regions (Coriolis, 2017). The ability to obtain grapes from other areas of New Zealand reduces the risk to this subsector.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Reduction in land available for primary sector activities due to sea level rise				
Manufacturing	-	-	-	Limited agreement, medium evidence
Supply Chain	-	-	-	
Food Tech	-	-	-	
Wholesale	-	-	-	
Agriculture	Insignificant	Minor	Moderate	
Horticulture	Insignificant	Insignificant	Insignificant	
Viticulture	Insignificant	Insignificant	Insignificant	

4.2.14 People are exposed to environmental hazards

Exposure to extreme heat is the most significant environmental hazard to food and beverage sector employees (Pearce et al, 2018). The majority of primary sector employees work outside, undertaking physical activities and are therefore highly exposed to extreme heat (Parsons, 2014). Exposure to extreme heat can cause heat stroke, dehydration, exhaustion and can also worsen pre-existing diseases such as cardiovascular diseases (Orlov et al, 2020). Across all sectors, heat stress may likely result in reduced productivity of workers via an increase in breaks, which may reduce the quantity of outputs produced (Fernandez & Golubiewsksi, 2019). During heatwaves there may likely be periods where employees are unable to work outside, which may affect subsector productivity by reducing the number of working hours. Aside from reduced working hours, there are additional impacts that hot weather has on workers cognitive functions, which further reduces worker productivity and can lead to an increase in workplace accidents (Zander et al, 2015).

Increasing heat may also result in additional business compliance costs. Under New Zealand law, a *'person conducting a business or undertaking'* (PCBU) has a duty of care to identify any hazard and to eliminate such risks emanating from the hazard as far as is reasonably practicable (Worksafe, 2019). PCBUs across the food and beverage sector are legally required to mitigate risks such as extreme heat. Mitigating risks from an increasing incidence of hot days may add additional costs to businesses' health and safety requirements, from associated paperwork through to investment in cooling equipment such as air-conditioning.

There is variability in exposure across the subsectors. Employees in the food technology and manufacturing subsectors are typically involved in sedentary work. They are less adversely affected by heat stress than employees working outdoors, such as those in the primary sectors (Orlov et al, 2020). Despite the sedentary nature of manufacturing, this subsector attracts employees from low socioeconomic backgrounds and the socioeconomic characteristics of the workforce increases the

workforce's vulnerability to heat stress (Fernandez & Golubiewsksi, 2019). Those from low socioeconomic backgrounds typically have a higher incidence of chronic health conditions, including cardiovascular conditions and diabetes and these conditions make them more vulnerable to heat stress and heat-related illnesses (Fernandez & Golubiewsksi, 2019; Royal Society, 2017).

It is much harder to mitigate the risks for workers exposed to heat stress outdoors. Many employees within the primary sector work outdoors in physically active jobs, increasing their exposure to heat stress. Employees in the horticulture subsector are particularly vulnerable given they may spend time in extreme heat environments such as greenhouses.

For the supply chain and warehouse subsectors, there is likely to be great variability in exposure of workers to extreme heat. Some workers may work in air-conditioned environments (such as truck cabs and warehouses) doing sedentary activities, such as transporting food and beverage products. Other may spend time in the outdoors engaging in physical labour, including loading food and beverage products into domestic and international carriers and manning farmers market stalls. A proportion of these subsector may therefore have greater exposure to outdoor temperatures than manufacturing and food technology workers who may typically be housed indoors.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Employees are exposed to environmental hazards				
Manufacturing	Insignificant	Insignificant	Minor	Medium agreement, medium evidence
Supply Chain	Insignificant	Insignificant	Insignificant	
Food Tech	Insignificant	Insignificant	Insignificant	
Wholesale	Insignificant	Insignificant	Insignificant	
Agriculture	Insignificant	Insignificant	Minor	
Horticulture	Insignificant	Insignificant	Moderate	
Viticulture	Insignificant	Insignificant	Minor	

4.3 Construction

4.3.1 Sector overview

The Construction sector in this report is comprised of the following subsectors: residential, non-residential, and infrastructure. Table 8 below outlines the definition and geographical spread of the three construction subsectors considered in this report.

Table 8: Construction subsectors

Construction Subsector	Definition
Residential	Preparation, clearing and development of land for residential use; and the construction, installation, alteration, repair and deconstruction/demolition of domestic residential buildings (e.g. houses, flats and apartments).
Non-Residential	Preparation, clearing and development of land; and the construction, installation, alteration, repair and deconstruction of commercial or other non-residential purposes buildings (e.g. warehouses, offices, factories, schools).
Infrastructure	Construction, installation, alteration, repair and deconstruction of built infrastructure (e.g. roads, rail, bridges, water, wastewater, power, telecommunications).

The construction sector is a vital component of Auckland's economy. In 2019 it employed over 86,000 people in 24,192 businesses accounting for almost 7 per cent of Auckland's Gross Domestic Product (Huang and Wilson, 2020). The construction sector was also the second largest sector in Auckland as measured by employment (10 per cent of the Auckland total). More than one in five (22 per cent) of the sector's employees and one in three (34 per cent) businesses were in Residential Building Construction (Huang and Wilson, 2020).

Residential and non-residential construction is funded by a mix of public and private businesses. In 2019, over half of the total value of building work (residential and non-residential) in Auckland was new residential buildings ($5.7 billion in 2019 dollars), and the rest was new non-residential buildings ($3.3 billion) and alterations ($1.8 billion) (Huang and Wilson, 2020). This work is driven by Auckland's population growth and demand for housing. Auckland Council's development strategy influences the location of new residential and non-residential construction through development controls and signalling the location of future growth areas and nodes (Auckland Council Unitary Plan, 2016; Auckland Council Auckland Future Urban Land supply strategy, 2017 Auckland Plan 2050, 2018).

Auckland's infrastructure is provided by a combination of central government, local government and the private sector through a mix of operational and capital budgets. Auckland Council and associated council-controlled organisations (CCOs), along with central government agencies, fund the majority of infrastructure projects in Auckland. The delivery of horizontal infrastructure is characterized by large amounts of unavoidable risk as a function of both its intimate relationship with the physical environment (i.e. ground conditions, and the inclusion of large-scale highly complex projects). This risk drives the need for high levels of technical expertise and specialization in fields such as tunnelling, bridging, roading and rail (Entwine, 2018).

4.3.2 Characteristics of Auckland's construction sector

Key components of the construction sector are land, labour costs, materials costs, compliance costs and profit. Materials consumed by the construction sector are diverse and include: brick, concrete, aggregates, aluminium, glass, plasterboard, timber, sand, steel, and weather board. Several key materials are manufactured in Auckland including steel, aggregate, plasterboard and concrete. Imported materials, particularly from China and Australia are a significant component of the construction supply chain. The sector utilises the outputs of the manufacturing sector, and turns them into usable infrastructure, extending the capital stock, adding significant value as part of this process (PWC, 2016).

Compared to most other sectors, Auckland's construction sector generally has smaller businesses (fewer employees per business unit). Notwithstanding, people in the construction sector are still more likely to be in self-employment compared to other sectors. The rate of self-employment in the sector (35 per cent) was more than twice the rate in the total Auckland economy (16 per cent) (Huang and Wilson, 2020). The cyclical nature of the sector means that many small businesses in the construction sector have little incentive or resources to invest in business growth and capacity building (PWC, 2016). This lack of capacity building may mean they are less prepared to weather climate related shocks such as disrupted supply changes and may take longer to adapt to changes in regulations.

The construction sector is labour intensive and is not highly automated (PwC, 2016). The sector has also been facing difficulties in finding labour. A report by Rider Levett Bucknall (2019) forecasts that New Zealand's construction sector would require 57,600 more skilled workers by 2026. Profit margins rise and fall with economic cycles and can also be indicative of the ability of firms to raise prices in response to cost pressures. The ability of SMEs to absorb costs or raise prices will likely reflect a number of internal and external variables such as demand, competition, consumer expectations, and operating costs.

4.3.3 Overview of most significant risks and consequences for the construction sector

All construction sub sectors will likely become increasingly exposed to heatwaves, floods and storms resulting in delays, rework, reduced productivity, increased costs, and increased insurance burden. There is likely to be increasing time and money lost to non-work days, damaged materials and equipment, disrupted supply chains and increased litigation associated with weather related construction disruption. Water scarcity leading to increased cost of water could result in increased

costs for water intensive construction activities or products such as concrete curing, dust suppression and steel.

There may be increasing demand for emergency maintenance and repairs, deconstruction, and hazard protection works, as more existing built assets and infrastructure are exposed to sea level rise and flooding. This is a potential opportunity for the construction sector. There is a risk that the residential and commercial construction sectors construct buildings that may not perform effectively under future climatic conditions with respect to cooling, durability and drainage. This risk is in part addressed through evolving building code and design specifications which are increasingly considering climate change.

The three most significant physical risks to the construction sector have been identified as:

- Partially constructed buildings and infrastructure, construction sites and equipment are damaged or destroyed. This risk was rated minor in 2040 for all subsectors rising to moderate/Major in 2110.
- Maritime infrastructure and maritime transportation assets are damaged or destroyed disrupting the construction sector supply chain. This risk was rated minor in 2040 rising to moderate in 2110.
- Changes to seasonality and average climatic conditions which result in failure of buildings and infrastructure to meet or maintain the level of service expected by owners or end users. This was rated Minor in 2040 rising to moderate in 2110 for the residential and non-residential subsectors.

4.3.4 Maritime infrastructure and maritime transportation assets are damaged or destroyed

Maritime transportation assets for this sector include ports and port assets associated with sea freighting construction materials. Auckland is a significant import port and imported materials to service the construction sector arrive in Auckland, therefore damage or destruction of key import infrastructure such as port assets could disrupt construction supply chains.

Imports by the construction sector, as a percentage of output generated are on par with the New Zealand average (PWC, 2016). However, imports by the construction sector have been increasing over the last decade. In particular, the volume of imported steel used in structures has increased. There has been a trend in the residential construction subsector to import non- traditional building materials, such as wall boards and insultation, especially where imports can meet the same quality standards required of New Zealand-made products as there is potential to use these products to reduce the cost of construction of homes, buildings and infrastructure (PwC, 2016).

Long-term shortages of imported materials may have a significant effect on the construction sector. For example, according to the Australian Construction Industry Forum (ACIF), Australia imports approximately 60 per cent of its annual $6bn spend on construction materials from China. Delays are expected on constructions of building projects, as sourcing of these materials are anticipated to be difficult for up to six months (as a result of COVID-19) (RSM, 2020). However COVID-19 has highlighted the risk of depending heavily on supplies from one locality (China). Julien Leys, Chief Executive, Building Industry Federation of New Zealand, suggests the building supply chain is already mitigating this risk by working again with local manufacturers of components and materials, providing certainty and business continuity for these local businesses (Leys, 2018). This suggests that if disruptions to imports as a result of maritime transportation assets being damaged or destroyed were long lasting, the construction sector would shift to a more local supply chain.

The construction supply chain also utilises trans-shipping between the North and South Island for bulky or heavy products such as cement (Samarasinghe, 2014). While concrete suppliers are located in Auckland, most cement is transported by ship (Deloitte, 2018b). Bringing in cement by road from another port would likely increase the cost of this input to the production of concrete due to the increased cost of transportation. This transport cost increase is likely true for a range of inputs and materials that may need to be transported further than usual to reach the Auckland market if port assets were damaged or destroyed.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Maritime transportation assets are damaged or destroyed				
Residential	Insignificant	Minor	Moderate	Medium agreement Limited evidence
Non-Residential	Insignificant	Minor	Moderate	
Infrastructure	Insignificant	Minor	Moderate	

4.3.5 Road networks are damaged or destroyed

The roading network is required to transport labour and materials for the construction sector. The Auckland Plan identifies a number of motorways and major roads at risk from sea level rise and flooding. Transport costs are a significant portion of building materials costs in New Zealand (Ying and Robertii, 2013). For this reason, supplies are often sourced from the closest available merchant (Samarasing, 2014).

Damage or destruction to road networks has the potential to escalate transportation costs and or contribute to delays in construction. The wider construction supply chain may also be negatively affected by disruptions to roading network as 70 per cent of New Zealand's freight is transported by road (Ministry of Transport, 2014).

Consequences to individual businesses in the sector will depend on access to alternative suppliers, contractual arrangements, and the response from the supply chain to disruptions. The existence of alternative routes and suppliers ensure that construction processes can continue, albeit with some delays or increased transportation costs.

Businesses who collaborate with their suppliers can have positive wider effects through building capacity and increasing the resilience of supply chain partners

Subsector	Risk rating			Confidence
	Present	2040	2110	
Road networks are damaged or destroyed				
Residential	Insignificant	Minor	Minor	Medium agreement Medium evidence
Non-residential	Insignificant	Minor	Minor	
Infrastructure	Insignificant	Insignificant	Minor	

4.3.6 Water supplies are reduced, disrupted or contaminated

Due to an increasing incidence of drought and increasing rainfall variability, water supplies across the Auckland region are likely to reduce (Pearce et al, 2018). Water is used on construction sites for a range of activities including dust suppression and concrete curing and cutting (WRAP, 2012). The amount of water used on construction sites is largely unknown, in part because the majority of on-site sources are not paid for and are therefore not metered. Therefore, it is difficult to deduce whether drought and increased rainfall variability will impact upon the construction sector in a material way.

The construction sector, like all sectors in Auckland, may face increased costs for water due to increased water scarcity. Within Auckland, water sources for construction projects across the subsectors would typically be provided from Watercare's municipal supply network. As discussed at 3.6, for construction sites attached to Auckland's municipal supply, whether the cost of water increases due to projected water scarcity would really depend on Watercare's policies.

Not all construction sites will be connected to Watercare's municipal supply. If the construction sites are adjacent to natural water sources sites may also apply for water consent takes from bores and streams. These currently cost at least $7,000 per site (Auckland Council, 2020). Water scarcity may result in an increase in the price of water consent applications or increased difficulty in obtaining a consent application.

There may be upstream supply chain costs for the construction sector due to the increased cost of materials as a result of water scarcity. For example, steel manufacturing is a water-intensive process. At the Glenbrook Steel Mill in South Auckland; approximately one million tonnes of water is circulated around the site daily to produce steel outputs (New Zealand Steel, 2020). The Steel Mill has its own water supply that it takes from the Waikato River and larger industrial facilities and is therefore has some capacity to self-manage their supply (New Zealand Steel, 2020). However decreasing rainfall variability and increasing drought may impact upon the amount of water New Zealand Steel is able to extract for the River, or may result in local authorities placing a cap on overall water takes from the Waikato River (Pacific Institute, 2009). These consequences would require New Zealand Steel to purchase additional water, which in turn increases their production costs. These costs are likely to be passed onto consumers, although they are dependent on the market and it is very difficult to predict where costs will fall.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Water supplies are reduced, disrupted or contaminated				
Residential	Insignificant	Minor	Minor	Medium agreement Limited evidence
Non-residential	Insignificant	Minor	Minor	
Infrastructure	Insignificant	Minor	Minor	

4.3.7 Built assets that are necessary for service provision are damaged or destroyed

This consequences of this risk to the construction sector fall into two areas:

1. Disruption to Auckland based construction supply chain
2. Increased frequency of emergency maintenance and repairs; deconstruction/demolition services; and hazard protection works resulting from assets becoming increasingly vulnerable to flood, coastal inundation and storms (opportunity).

Disruption to Auckland-based building supply chain

The construction sector relies on built assets where products used in construction are extracted, manufactured, stored and sold. Key construction materials produced in the Auckland Region include: steel, aggregates, sand, plasterboard, and concrete. Disruption of local production due to production assets being damaged or destroyed could result in a shortage of these materials in the short term, leading to cost increases due to decreased supply. The impact will depend on which type of material production is disrupted and whether there are readily available alternative sources from outside Auckland.

Building supply merchants and wholesalers store and sell construction materials from multiple locations across Auckland. Damage to a materials storage or sales facility may require additional transport of materials to site as construction companies seek alternative suppliers in turn increasing input costs. However the duplication of providers likely means damage to one wholesaler/retail merchant would not have a significant impact on the construction sector.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Disruption to Auckland-based construction supply chain				
Residential	Insignificant	Insignificant	Minor	Medium agreement Low evidence
Non-residential	Insignificant	Insignificant	Minor	
Infrastructure	Insignificant	Insignificant	Minor	

Opportunity: Increased frequency of emergency maintenance and repairs; deconstruction/demolition services; and hazard protection works

When buildings and infrastructure are damaged as a result of extreme weather events, flooding, and coastal inundation, they are either repaired or disassembled/demolished. Increasing vulnerability of buildings and infrastructure may result in increased damage or destruction of built infrastructure and therefore an increase in demand for repair and disassembly services from the construction sector. These services may be required during recovery from a hazard event or while the event is still ongoing, such as a storm or a flood. This work may present additional health and safety challenges. In addition, the skills required for reparation of buildings and infrastructure repair may be different from what is currently present in the market and presents an opportunity for the construction sector.

Analysis by Paulik, et al (2020) revealed that 1,790 buildings in Auckland are, at present, exposed to a 100-year extreme sea-level flood event. By 2110, at 1.2 m of sea level rise, the number of buildings exposed more than quadruples to 7,296. To avoid damage or destruction, these buildings are likely to be either need to be deconstructed and removed or provided flood protection. An increasing number of properties being exposed to extreme sea-level flood events may lead to an increasing demand for these services from the construction sector.

Subsector	Opportunity rating			Confidence
	Present	2040	2110	
Increased frequency of emergency maintenance and repairs and planned hazard protection works				
Residential	Insignificant	Insignificant	Minor	Medium agreement Low evidence
Non-residential	Insignificant	Insignificant	Minor	
Infrastructure	Insignificant	Insignificant	Minor	

4.3.8 Construction sites, crops and livestock are damaged or destroyed

Both construction activities (particularly those in the early phases of constructing new buildings and infrastructure) and demolition activities are exposed to the elements. Weather is consistently rated as one of the most frequent and harmful causes of construction project delays (Assaf and Al-Hejji 2006, AlSehaimi and Koskela 2008, Orangi et al. 2011, Mentis 2015 as cited in Cooke, 2018) by ruining partially constructed, unprotected and exposed constructed elements (El-Rayes and Moselhi 2001 as cited in Cooke). Increased frequency or severity of extreme weather events could increase damages to partially constructed infrastructure and buildings, construction sites and equipment.

The construction sector is accustomed to working in inclement weather. Notwithstanding this, extreme weather events are currently a source of delays and disputes (Moselhi and El-Rayes 2002, Nguyen et al. 2010 as cited in Cooke 2018). Increasing frequency and severity of extreme weather may exacerbate impacts increasing construction delays, damage to equipment, increased construction costs associated with additional site flood mitigation measures, increased insurance cost, and damage to property and assets (Smith, 2013).

More intense and less predictable rainfall events could cause costly delays to construction, as well as damage to assets through increased rain and moisture penetration, increased ground and foundation movement; and degradation and failure of pipe and waterway structures (Smith, 2013). There is likely to be increased costs associated with construction to mitigate against these impacts (Hurlimann, 2019). Increasing damage caused by extreme weather events are a key factor in insurers refusal to insure extremely vulnerable regions of Australia and increasing insurance premiums over the last few years (Insurance Council of Australia, 2015). Higher insurance premiums may be absorbed by profitable businesses, and wealthy infrastructure asset owners, however lower income asset owners, and small businesses will likely be sensitive to changes in insurance premiums. However, unlike existing assets, construction works insurance for residential work is often site based and relevant for the duration of the construction process. This means the insurance cost can be incorporated as a direct cost of the project and passed on to the consumer rather than become an escalating cost of doing business for the sector.

Delays and damage due to extreme events combine to result in decreased productivity for the construction sector and increasing cost of delivering built infrastructure. It is difficult to predict how the costs will be spread across the construction sector and wider economy.

In a paper which explored the climate change preparedness of the Australian construction sector by conducting stakeholder interviews, respondents expected the sector to continue to respond to extreme weather through innovation of existing processes. However, respondents also acknowledged there was a high financial risk to pricing projects to allow for potential costs of weather-related impacts and construction disruptions. The difficultly for smaller businesses to respond to changing risks was also acknowledged by those interviewed (Hurlimann, 2019).

Subsector	Risk rating			Confidence
	Present	2040	2110	
Damage to partially constructed infrastructure and buildings, construction sites and equipment				
Residential	Insignificant	Minor	Major	High agreement
Non-residential	Insignificant	Minor	Moderate	Medium evidence
Infrastructure	Insignificant	Minor	Moderate	

4.3.9 Disruptions to systems that are sensitive to seasonality and changes in climatic parameters

Changes to average climatic parameters in Auckland could result in failure of buildings and infrastructure to meet or maintain the level of service expected by owners or end users. Hurlimann (2019) found that building sector climate adaptation actions consist more of activities which benefit the organisation and less of activities related to changing the constructed products so they are less sensitive to climate change. Actions which benefit the organisation include processes such as prefabrication in a controlled environment to avoid extreme weather, whereas an action to adapt the end product would be exceeding design standards to meet changing climates (Hurlimann, 2019).

Building materials may not have been tested to understand whether they are able to withstand the expected climate of the future. There are examples of imported building materials failing in New Zealand due to Ultraviolet radiation and salt effects (BIFNZ, 2013; Samarasinghe, 2014) and the New Zealand building sector suffered from the ‘leaky homes’ crisis, where a number of buildings using monolithic cladding systems were not watertight. Liability for leaky homes was reported to be a contributing factor in construction company Mainzeal going into receivership (National Business Review, 2018). Cases were also bought against suppliers of the cladding.

Negative reputation is another potential consequence for architects, engineers, and building suppliers if buildings and infrastructure fail to perform adequately under changing climatic conditions e.g overheating of recently constructed buildings. As building regulations change, properties are

becoming more airtight, which although effective at retaining heat in winter can lead to overheating in summer when adequate ventilation is not also fitted (Gupta & Greggs, 2012; White, 2017, as cited in Joynt and Golubiewski, 2019). This effect may become more prevalent as hot days increase.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Available infrastructure components, building materials and design fail to meet functional requirements				
Residential	Insignificant	Minor	Moderate	Medium agreement Limited evidence
Non-residential	Insignificant	Minor	Moderate	
Infrastructure	Insignificant	Minor	Minor	

4.3.10 People are exposed to environmental hazards

Climate projections for Auckland, including warming temperatures and an increasing incidence of hot days indicates that the most significant environmental hazard to construction workers is exposure to extreme heat (NIWA, 2018a; Orlov et al, 2020). Workers may also be exposed to stormy conditions or flooded areas, particularly if involved in response and repair following an event. This will lead to increased health and safety mitigation measures and a reduction in working hours.

Many employees in the construction sector work outdoors and engage in physical activity as part of their routine tasks. Construction workers who fall into these two categories will be at increased risk of heat stress and other heat-related illnesses (Orlov, et al 2020; Parsons, 2014). Research on how heat stress may affect worker productivity is still in its infancy (Orlov et al, 2020). However, in extreme heat environments workers will need additional rest breaks and during heatwaves there will likely be periods where employees are unable to work outside, which will affect subsector productivity by reducing the number of working hours on-site.

Aside from reduced working hours, there are additional impacts that hot weather has on workers cognitive functions, which further reduces worker productivity and can lead to an increase in workplace accidents (Zander et al, 2015). Although these consequences lie across a spectrum of severity, they may as a whole result in delays to construction projects.

Under New Zealand law, a PCBU has a duty of care to identify any hazard, and to eliminate such risks as far as is reasonably practicable (Worksafe, 2019). PCBUs that are managing construction sites across the infrastructure residential and non-residential sub-sectors are legally be required to mitigate risks such as extreme heat. Increasing extreme heat will add additional costs to businesses' health and safety requirements.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Increased health and safety mitigation and reduction in working hours				
Residential	Insignificant	Insignificant	Minor	Medium agreement Medium evidence
Non-residential	Insignificant	Insignificant	Minor	
Infrastructure	Insignificant	Insignificant	Minor	

4.4 Screen

4.4.1 Sector overview

Screen sector	The industries that produce film and television content for domestic and international audiences and service international productions coming to New Zealand. The screen and creative sector includes the following subsectors: • Film industry infrastructure • Filming locations

Over the past four decades, Auckland's screen sector has expanded, and plays a major role in Auckland's economy and culture. It generates significant direct economic benefits, supports tourism, and connects global and domestic audiences to New Zealand's locations, stories, way of life and character in a way that is powerful and authentic. This sector also supports activity in other creative industries such as advertising, marketing and public relations, publishing, music, performing arts and digital. The production of screen content creates indirect employment through the need for provision of ancillary services such as accommodation, corporate catering, security providers, cafes near studios, and equipment rentals.

4.4.2 Characteristics of Auckland's screen sector

In Auckland the screen sector has 1800 businesses, employing 7,400 people, and contributing $900 M to Auckland's GDP. More than half of all jobs are highly-skilled and are well-paid. The workforce skews younger, and the sector is dynamic and leverages technological innovations to produce content for domestic and international audiences.

The sector however, is not without its challenges. Although a multi-billion-dollar sector, it remains, in many respects, a cottage industry. It is often considered to have three tiers: bottom-tier films that are low-budget with no offshore investment; middle-tier productions that generally have medium-budgets and some offshore investment; and top-tier features that have high-budgets and mainly or entirely offshore investment (Ferrer-Roca, 2017). Within each tier, many individuals, contractors and businesses operate on a small scale, on temporary projects, and they have little capacity to withstand unforeseen shocks.[26] Screen production is a highly expensive and risky undertaking (Oslberg, 2019), and the sector, despite its success, is reliant at every level on some form of government support.

4.4.3 Overview of most significant risks and consequences for the screen sector

Climate change poses a risk to the screen sector by impacting film sector infrastructure or the critical lifeline infrastructures that the sector needs to produce content, and by impacting the availability, safety, and accessibility of filming locations. Acting in concert, these climate change risks, if not adapted to, may restrict growth in the sector. However, with appropriate adaptation, the sector will be able to continue to thrive, and will be able to benefit from its highly skilled workforce, innovativeness, and the growing demand for screen content.

The three most significant physical risks to the screen sector have been identified as:

- Large scale ecosystem change. This risk was rated minor in 2040, rising to moderate in 2110.
- Built assets, such as studios, that are necessary for service provision are damaged or destroyed. This risk was rated minor in 2040, and increases to moderate in 2110.
- Flights to and from Auckland International Airport are disrupted. This risk was rated insignificant in 2040, rising to moderate in 2110.

4.4.4 Information and Communication Technology systems are disrupted

Communications infrastructure, such as superfast broadband, is critical for contemporary film-making purposes where large files need to be transmitted at high speed. Ongoing availability of mobile

[26] ATEED, draft screen strategy. 2020 in press

services is also essential in a sector heavily dependent on people working on unique projects, across locations and in tight timeframes (Olsberg, 2019). Any disruptions to ICT systems have the potential to delay production or post-productions, which may impact production schedules and increase overall production costs. If disruptions to ICT infrastructure in Auckland become more frequent and more prolonged than in other production destinations such as Australia, the United States and the United Kingdom, the sector will be at a competitive disadvantage.

Disruptions to ICT infrastructures may constrain the opportunities that the sectors have to use new digital infrastructures to maximise audience reach.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Information and Communication Technology systems are disrupted				
Film Sector Infrastructure	Insignificant	Insignificant	Minor	Medium agreement, medium evidence
Filming locations	-	-	-	-

4.4.5 Electricity supplies are disrupted

The production of screen content depends on a reliable supply of electricity. Without power it is not possible to operate lighting, cameras, communications infrastructure, or regulate the temperature of workplaces. Temporary filming locations, in general, run on power generated onsite, and are thus unlikely to be impacted by disruption to mains electricity supplies.

Permanent facilities, including temporary warehouses are dependent upon the continued functioning of the electricity grid. Disruption to power supplies will impede the ability to shoot scenes, engage in pre and post-production, build sets, refrigerate food for staff, cool or heat accommodation and production facilities. Protracted disruptions may have negative implications for the safety and comfort of employees, and on production schedules and production costs.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Electricity supplies are disrupted				
Film Sector Infrastructure	Insignificant	Insignificant	Minor	Medium agreement, medium evidence
Filming locations	Insignificant	Insignificant	Insignificant	Medium agreement, limited evidence

4.4.6 Built assets that are necessary for service provision are damaged or destroyed

Climate change-related hazards have the potential to constrain the ability of the sector to produce content. The availability of high-quality physical infrastructure is a key factor in the attractiveness of a screen production destination (Olsberg, 2019). This infrastructure includes studios, sound stages, tanks, green screens, workshops, standing sets / scene docs, warehouses, as well as post and pre-production facilities. Many of these assets, necessary to production, are highly specialised. Auckland's screen sector is enabled by several fully-resourced production studios, including the Kumeu Film Studios, Kelly Park Film Studio, Auckland Film Studios, Studio West, X3 Studio, and a brand-new augmented reality and virtual reality hub, AR/VR Garage. Approximately 50 per cent of the sector utilises these specialised assets. The other 50 per cent of the sector uses low-quality warehouse stock which is leased on a temporary basis. This is because growth in screen sector infrastructure has not been able to keep abreast of demand for content driven by major

streaming services and the cyclical nature of productions which creates a challenging investment environment for permanent specialised infrastructure.

These assets are distributed across the central Auckland region. This distribution reduces the likelihood of a single hazard event causing simultaneous damage or disruption to multiple facilities. However, due to the scarcity of production space, a single protracted disruption could have moderate consequences for the sector. The scarcity of studio space has meant that Auckland "has, and will continue to, lose significant international productions potentially worth hundreds of millions to competing cities around the world because Auckland's current studios are at capacity, and we can only offer empty industrial warehouses which are far from ideal" (ATEED, 2016, para 19).

In addition to being "far from ideal", these warehouses are often low quality, and are at risk of water ingress and flooding, which may damage electrical equipment and staging. Specialist facilities, in general, are less sensitive to hazards as they are recently built to higher construction standards, they are well maintained. There is a strong incentive to adapt specialised assets – the services a high-value sector, and the assets are constantly used for film specific purposes. The adaptive capacity of low-quality industrial warehouses is lower, and productions are disinclined to invest in increasing climate resilience in a space that is leased on a temporary basis.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Built assets that are necessary for service provision are damaged or destroyed				
Film Sector Infrastructure	Insignificant	Minor	Moderate	Medium agreement, medium evidence
Filming locations	-	-	-	-

4.4.7 Road networks are damaged or destroyed

The filming locations that have contributed to the development of Auckland's screen sectors are dispersed throughout the region. Roads are the primary means of transportation to most mainland locations. Any inundation, damage, or destruction of roads may therefore reduce the ability to access filming locations and film sector infrastructure. Fortunately, most locations on mainland Auckland can be accessed by multiple routes. Certain remote areas may have fewer access points, and roads to these locations may be older, and less frequently maintained, increasing their sensitivity to climate hazards. Rerouting may cause inconvenience and increases costs, and complete loss of access to sites may require rescheduling, or the utilisation of an alternative location.

Damage to road networks across New Zealand may also reduce access to locations, which may decrease the desirability of New Zealand, and Auckland as a filming location.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Road networks are damaged or destroyed				
Film Sector Infrastructure	Insignificant	Insignificant	Insignificant	Medium agreement, limited evidence
Filming locations	Insignificant	Insignificant	Minor	Medium agreement, limited evidence

4.4.8 Flights to and from Auckland International Airport are disrupted

The majority of personnel associated with international productions that make use of Auckland's screen sector capabilities arrive via Auckland International Airport. Delays or grounding of aeroplanes

my cause inconvenience and reputational damage for the sector, impact production scheduling, or increase costs. It may also limit the ability for international and domestic production crews to move to other regions of New Zealand. Because ease of mobility is an important factor in the selection of destination for international productions (Olsberg, 2019) disruption to Auckland airport has the potential to materially impact the competitiveness and desirability of Auckland as an international production hub. The domestic sector is less sensitive to this risk, as these productions use Auckland airport's services less frequently.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Flights to and from Auckland International Airport are disrupted				
Film Sector Infrastructure	-	-	-	-
Filming locations	Insignificant	Insignificant	Moderate	Medium agreement, limited evidence

4.4.9 Large scale ecosystem change

Changes to New Zealand's ecosystems and landscapes may have adverse consequences for the screen sector. The sector relies heavily upon New Zealand's pristine and stunning landscapes to attract international productions. Loss or degradation of Auckland's beaches, the Franz Joseph glacier, or snow-cover in alpine regions, for example, could therefore reduce the attractiveness of the sector. Domestic and international productions may suffer from the loss of these ecosystems, however it is unlikely that domestic content producers will be able to seek alternative locations, thus attenuating the impacts to the sector.

Many of the landscapes that are important locations are also vulnerable to the spread of pests and diseases. The screen sector is highly mobile – it may move from a farm to a studio to a regional park within a number of days – and may face restrictions on entering some landscapes, to avoid the spread of pests and diseases that can be transported on shoes, clothes or equipment, or vehicles. ATEED has recently advised the screen sector on steps to reduce the spread of *phytophthora agathidicida*, which can infect and kill Kauri, a national taonga (Auckland Council, 2017). In the future, as pests and diseases have wider ranges, it is possible that additional restrictions are imposed, which may limit access to sites, or increase the admirative burden and activities required to be undertaken to access sites.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Large scale ecosystem change				
Film Sector Infrastructure	-	-	-	-
Filming locations	Insignificant	Minor	Moderate	Medium agreement, limited evidence

4.4.10 People are exposed to environmental hazards

The production of screen content often requires people to work in areas that are exposed to the weather. The increasing frequency of hazards such as wildfire, extreme heat, storms, and heavy rainfall increase may pose risks to the health and safety of the workforce. The sector has the capability to reduce the exposure of workers to these hazards, through rescheduling when severe or

dangerous weather is forecasted, however this may slightly constrain the number of days available for filming. The reduction of days is likely to be minor.

Employees may also be exposed to some hazards while working in indoor spaces. Heat build-up in studios is already significant due to lighting and equipment, higher outdoor temperatures may exacerbate warm temperatures, or increase the costs of cooling.

Subsector	Risk rating			Confidence
	Present	2040	2110	
People are exposed to environmental hazards				
Film Sector Infrastructure	Insignificant	Insignificant	Minor	Medium agreement, medium evidence
Filming locations	Insignificant	Insignificant	Minor	Medium agreement, limited evidence

4.5 Visitor Economy

4.5.1 Sector Overview

Visitor Economy	The production of goods and services for consumption by visitors. The visitor economy includes the following subsectors: • Tourism • International Education • Business and Major Events

Auckland is the gateway to New Zealand, and a major destination in its own right. Millions of people visit on an annual basis, bringing vibrancy to the region, and supporting its economy. The region welcomes more than 2.6 million international visitors each year and nearly as many domestic visitors. These visitors spend more than $8 billion annually (ATEED, 2018a). The majority of international visitors to Auckland visit for holiday reasons, while the majority of domestic visitors to Auckland visit friends and relatives. Business and major events and international education also attract many people to the Auckland region.

4.5.2 Characteristics of Auckland's Visitor Economy

Auckland's tourism subsector has diverse offerings, from nature-based experiences to shopping, dining and cultural experiences and major events. Across the sector, the majority of businesses are small and medium enterprises, who serve domestic and international markets. The sector is also an important economic sector for Māori, generating revenue and employment opportunities. The tourism subsector is heavily reliant upon Auckland's natural assets, and natural assets across New Zealand that draw visitors to the region.

The friendliness of Auckland's residents, and high service standards of accommodation, high quality food and wine, and the smoothness of logistics attract thousands of high-value business visitors to Auckland. Across New Zealand, convention and conference delegates spend approximately twice as much per night as international leisure visitors (Tourism New Zealand, nd). Business visitors are also high-value in terms of the knowledge benefits and business networking opportunities they bring with them.

The International education subsector adds diversity to Auckland's export industries while contributing significantly to economic and cultural life. International students come to Auckland to learn and experience New Zealand's culture, and lead to increased economic activity in other sectors, build skills in the labour force and attract talent, and supports business links.

4.5.3 Overview of most significant risks and consequences for the visitor economy

Climate change poses a number of risks to the visitor economy. Impacts to critical lifeline infrastructure can disrupt service provision and reduce mobility, and other built assets can be damaged by hazards such as floods, fires and sea level rise. Changes to landscapes and ecosystems across New Zealand and the region are likely to impact the viability of certain tourism offerings, and changes to weather might impact the enjoyment people derive from their stays.

The three most significant physical risks to the visitor economy have been identified as:

- Flights to and from Auckland International Airport are disrupted. This risk is rated minor in2040, rising to major in 2110.
- Large scale ecosystem change. This risk was rated minor in 2040, rising to moderate in 2110.
- Built assets and Māori cultural heritage sites, that are necessary for service provision are damaged or destroyed. This risk was rated minor in 2040, and increases to moderate in 2110.

4.5.4 Maritime infrastructure and maritime transport assets are damaged or destroyed

Damage to, or destruction of, ports, ferry terminals, and marinas and moorings has the potential to constrain growth in the cruise industry, reduce access to islands, and impact upon pleasure craft-related tourism.

Auckland derives significant economic benefits from the cruise industry. Although most cruises in New Zealand typically visit multiple locations, Auckland as New Zealand's key exchange port, captures the largest value add (Market Economics Limited, 2014). In 2013-2014 cruises contributed $159 million to Auckland's economy. Damage to port infrastructure may reduce the capacity of Auckland's ports to sustain or accommodate growth in the cruise sector.

The consequence of ferry disruption, and the associated reduction in access to Auckland's Islands will most likely be felt by businesses located on, or associated with, the Auckland region's islands. In addition to reducing revenue for affected businesses, disruption of access to these islands may have adverse consequences for the broader tourism sector, as the Hauraki Gulf & Islands activities and attractions received the highest satisfaction rating of all regions from the international market and strengthen Auckland's reputation as a destination (ATEED, 2020).[27]

Damage to marina berths or recreational boats may also impact Auckland's tourism sector. Auckland is known as the "city of sails" and has more boats per capita than anywhere else in the world (New Zealand Tourism, n.d.). Boating holidays in New Zealand are common, and key destinations include Auckland's Hauraki Gulf and offshore islands.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Coastal transport assets are damaged or destroyed				
Tourism	Insignificant	Minor	Moderate	Medium agreement, medium evidence
Business and Major Events	-	-	-	-
International Education	-	-	-	-

[27] Visitor insights report.

4.5.5 Information and Communication Technology systems are disrupted

Many tourism activities, particularly nature-based activities, are not highly dependent on ICT infrastructures, although ICT systems are increasingly required to engage with customers, and for routine business practices such as invoicing and payments, booking and reservations. Disruptions to ICT infrastructures will interfere with the subsectors ability to undertake these essential tasks, however, many of these tasks are not highly sensitive to short-term disruption.

Many of Auckland's major events are highly dependent upon ICT technologies, for the organisation and delivery of events, and for participants, who are often reliant on mobile phones and social media to locate friends and family, and share their experiences of the event. ICT technologies are necessary to deliver most business events, and for attendees use at such events. At present, disruptions are rare and relatively inconsequential, however disruptions to ICT could be increasingly consequential over time as demand for hybrid conferences – the combination of face-to-face and virtual conferences/meetings – grows (Business Events New Zealand, 2020).

The international education sector is increasingly utilising ICT infrastructures such as video and audio-conferencing, and online or E-learning in pedagogical practices. Many international students also rely on ICT infrastructure to retain contact with family and friends living in other countries. At present universities have been faster to adopt e-Learning practices (Ministry of Education, 2011), but greater uptake of e-Learning, and the corollary reliance on ICT services, is likely to increase over the next few decades.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Characteristics of Auckland's Visitor Economy				
Tourism	Insignificant	Insignificant	Insignificant	Medium agreement, limited evidence
Business and Major Events	Insignificant	Insignificant	Minor	Medium agreement, medium evidence
International Education	Insignificant	Insignificant	Insignificant	Medium agreement, medium evidence

4.5.6 Electricity supplies are disrupted

Disruption of electricity supplies will impact almost all businesses across the subsectors. Without electricity, many services will be unable to function, and visitor experience will be severely compromised. For example, disruptions of electricity supplies will interfere with the ability to meet the needs of business events and major events visitors, particularly with regard to accommodation, dining, and the hosting of events. Disruptions of electricity supplies will interfere with the ability of education institutions to deliver lectures, seminars and engage in research. Protracted disruptions may have negative implications for the safety and comfort of employees.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Electricity supplies are disrupted				
Tourism	Insignificant	Insignificant	Minor	Medium agreement, medium evidence
Business and Major Events	Insignificant	Insignificant	Minor	Medium agreement, medium evidence
International Education	Insignificant	Insignificant	Minor	Medium agreement, medium evidence

4.5.7 Road networks are damaged or destroyed

Many of the Auckland's tourism destinations are peripheral to central Auckland, requiring access by road-based transportation. For the year ending December 2019, three quarters of domestic visitors, and almost half of international visitors used a private or rented vehicle (ATEED, 2020). Most locations in Auckland can be accessed by multiple routes, although rerouting may cause inconvenience and dissatisfaction with the tourism experience. Some coastal locations however may be particularly affected.

The business and major events and international education subsectors are unlikely to be materially affected by damage to road networks. These visitors are generally not as mobile as tourists, and their movements are primarily within urban areas of Auckland, where there is a dense concentration of roads and many alternative routes to reach destinations. However, disruptions in the city could compound frustrations domestic and international visitors already have with congestion and parking (ATEED, 2020). While many events are clustered in central Auckland, the *Auckland Major Events Strategy 2018-2025* aims to spread major events throughout the Auckland region to disperse visitors and spread the benefits of these events (ATEED, 2018b). This may increase the consequences of disruption to road networks in regional areas, but decrease the consequences of disruption to road networks in central Auckland.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Road networks are damaged or destroyed				
Tourism	Insignificant	Insignificant	Moderate	Medium agreement, limited evidence
Business and Major Events	Insignificant	Insignificant	Insignificant	Medium agreement, limited evidence
International Education	Insignificant	Insignificant	Insignificant	Medium agreement, limited evidence

4.5.8 Flights to and from Auckland International Airport are disrupted

Most tourism businesses depend upon the international and domestic flights into Auckland Airport. Disruptions to airport services can delay travel, disrupt itineraries, and cancellations may lead to loss of business. The consequences across subsectors differs based upon the sensitivity of customers to delays and disruption. Attendees of business events and major events, which are generally quite short, are highly sensitive to disruption. Conversely, the international education sector, where trips are significantly longer, sometimes lasting up to several years, is much less sensitive to delays, or

rerouting. The tourism sector splits the difference, and depends upon the intended duration of the trip, and the flexibility of the itinerary. Businesses have limited capacity to reduce this risk, and they are reliant upon action been taken by Auckland Airport. Frequent inundation of airport by 2110 would significantly reduce tourist mobility.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Flights to and from Auckland International Airport are disrupted				
Tourism	Insignificant	Minor	Major	Medium agreement, limited evidence
Business and Major Events	Insignificant	Minor	Major	Medium agreement, limited evidence
International Education	Insignificant	Insignificant	Moderate	Medium agreement, limited evidence

4.5.9 Water supplies are reduced, disrupted or contaminated

Anecdotal evidence indicates that increasingly polluted or contaminated water could pose a risk to the reputation of the tourism sector. The Tourism Export Council has expressed concern that worsening pollution problems could conflict with tourist expectations of a 100% Pure New Zealand promise if freshwater resources are not appropriately managed (Cropp, 2017). Climate change is but one pressure on New Zealand's water sources, however the significance will increase over the century, and compound degradation.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Water supplies are reduced, disrupted or contaminated				
Tourism	Insignificant	Insignificant	Minor	Medium agreement, limited evidence
Business and Major Events	-	-	-	-
International Education	-	-	-	-

4.5.10 Built assets that are necessary for service provision are damaged or destroyed

This consequences of this risk to the visitor economy fall into two areas:

1. Damage to essential tourism assets
2. Loss of and damage to Māori cultural landscapes and heritage sites

Damage to essential tourism assets

The tourism sector depends on a range of assets, including accommodation facilities, huts and trails. These assets are distributed across the entire region and are exposed and vulnerable to a range of hazards. Damage to these assets may lead to increased costs for reconstruction, or increased insurance premiums, which may limit opportunities for reinvestment in business growth, and constrain

profits. Severe damage to key public assets, such as trails and huts, is likely to reduce the viability of tourism businesses that rely on these assets.

The business events and major events sub-sector is exposed to a similar array of hazards, and assets necessary for these events - event and convention centres, stadium or showgrounds, hotels, other accommodations (motels and motor parks), and other establishments such as vineyards, restaurants and theatres (MBIE, 2018) – are generally located in the Auckland CBD, South Auckland, and near Auckland International Airport. Single hazard events may impact a greater percentage of the subsector simultaneously. Hazards may lead to increased costs for asset owners, due to direct damage, or from increased insurance premiums. Severe damage to key assets – Auckland's few large conference centres and stadiums – have the potential to flow through to reduce demand for ancillary accommodation, tourism and food and beverage businesses.

International education sector built assets are even more geographically clustered in central Auckland. The larger proportion of large businesses involved in international education enhances the subsector's ability to absorb disruptions to and costs associated with damage to university and polytechnic campuses, research facilities and student accommodation.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Built assets that are necessary for service provision are damaged or destroyed				
Tourism	Insignificant	Minor	Moderate	Medium agreement, medium evidence
Business and Major Events	Insignificant	Insignificant	Minor	Medium agreement, medium evidence
International Education	Insignificant	Insignificant	Minor	Medium agreement, medium evidence

Loss of and damage to Māori cultural landscapes and heritage sites

Promoting Māori cultural visitor experiences is a key element of *Destination AKL*, because it will support the broader tourism sector, and is a source of continued potential for the Māori economy. Yet Māori cultural heritage and places of significance, including archaeological sites, historical buildings and structures, and cultural landscapes are under threat from sea level rise and changes to climatic means. In addition to the severe implications for Māori cultural wellbeing and spiritual health, identity, and capacity to sustain livelihoods, damage to and loss of, Māori cultural heritage will impact upon Auckland's tourism sector.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Loss of and damage to Māori cultural landscapes and heritage sites				
Tourism	Insignificant	Minor	Moderate	Medium agreement, limited evidence
Business and major Events	**-**	-	-	-
International Education	**-**	-	-	**-**

4.5.11 Disruptions to systems that are sensitive to seasonality and changes in climatic parameters

The weather influences overall demand for tourism activities, what activities tourists want to do, how much money they spend, and how much satisfaction they derive from tourism experiences (Gössling and Hall, 2006). The degree to which it does so depends upon the activity. In a survey of tourist perceptions about optimal weather conditions for beach, mountain and urban environments, Scott, Gössling & de Freitas (2008) found that sunshine was the most important variable for beach environment activities, while the absence of rain was the most important climate parameter for activities in mountain areas. Unsurprisingly, weather conditions are less important for tourism in urban environments as tourists spend significant periods of time indoors, and can easily avoid undesirable conditions such as rain.

Auckland is the only location in New Zealand with a population and visitor mass large enough to support a variety of all-weather built attractions and experiences (ATEED, 2018a, p. 30). The Auckland region boasts a wide array of tourist offerings, from restaurants and wineries and shopping, to nature-based activities and cultural experiences. Changes to the weather will inevitably impact upon people's preference for, and enjoyment of some of these activities. Evidence about the impacts of changing weather to the visitor economy is limited, however some key trends are apparent. In aggregate, Auckland's tourism sector is likely to be relatively resilient to changes in 'weather' due to climate change, and certain activities may even benefit.

Subsector	Risk rating			Confidence
	Present	2040	2110	
Disruptions to systems that are sensitive to seasonality and changes in climatic parameters				
Tourism	Insignificant	Minor	Minor	Medium agreement, medium evidence
Business and Major Events	-	-	-	-
International Education	-	-	-	-

Opportunity: Grow business event and major event activity in shoulder and off-peak periods

Auckland's mild climate is a factor that influences demand for, and enjoyment of major events and business events. However, it is one of many factors, and unlikely to be a significant driver of demand. Tourism New Zealand (2018) notes that the factors most considered by prospective business event visitors relate to the quality, availability and cost of accommodation, venues, and transport. Warmer winter weather does have the potential to support the aspirations of the business events and major events sector to grow event activity in the shoulder and off-peak periods (ATEED, 2013; ATEED, 2018b). Growing major event and business event activity in the shoulder and off-peak periods helps to increase visitor demand across the year, supporting businesses across Auckland.

Subsector	Opportunity rating			Confidence
	Present	2040	2110	
Grow business event activity in shoulder and off-peak periods				
Tourism	-	-	-	-
Business and Major Events	Insignificant	Insignificant	Minor	Medium agreement, limited evidence
International Education	-	-	-	-

4.5.12 Large scale ecosystem change

Many international visitors come to New Zealand to experience it's stunning and unique landscapes. Many of these landscapes, including Auckland's Hauraki Gulf islands, Waitakere Ranges, and New Zealand's alpine, freshwater, coastal ecosystems and indigenous forests are vulnerable to changes in temperature, wind, rainfall, coastal inundation, and wildfires (MfE, 2020). Degradation and destruction of these landscapes are likely to reduce tourism demand, and the viability of businesses reliant on visitors to these areas. The impacts to other destinations in New Zealand, such as the alpine regions and the Franz Joseph glacier may flow through to an overall reduction in demand for Auckland's tourism sector.

Limitations may be placed on visitor numbers in certain areas to protect at-risk landscapes from additional degradation, or the introduction of pests and diseases. Historically, many biodiversity incursions have been linked to tourists, and several kauri forests have recently been closed due to fears that visitors could be transporting Phytophthora agathidicida on their shoes (Parliamentary Commissioner for the Environment, 2019).

Subsector	Risk rating			Confidence
	Present	2040	2110	
Large scale ecosystem change				
Tourism	Insignificant	Minor	Major	Medium agreement, limited evidence
Business and Major Events	-	-	-	-
International Education	-	-	-	-

4.5.13 People are exposed to environmental hazards

Tourists are increasingly likely to be exposed to multiple hazards, including floods, storms, extreme heat, wildfire, or smoke from wildfire (Becken, Wilson and Resisinger, 2010; Scott and Lemieux, 2010). Death and severe harm are likely to remain infrequent even for nature-based tourism activities, however, the reputation of a region, or tourism offering may be compromised if an event is amplified in national and international media (Rosselló, Becken and Santana-Gallego, 2020). Risks to safety across New Zealand in general may influence perceptions of safety in Auckland. Businesses may also need to invest in additional risk reduction measures.

The business events and international education subsectors are much less vulnerable to this risk, as attendees and students are primarily indoors, and are therefore less exposed to adverse weather

events. These subsectors may face additional costs associated with cooling demand on hot days, to ensure the comfort and safety of employees and visitors. Major events, which often draw large volumes of people to a single, and sometimes outdoor location may require additional mitigation measures to reduce risks associated with extreme heat and crowding.

Subsector	Risk rating			Confidence
	Present	2040	2110	
People are exposed to environmental hazards				
Tourism	Insignificant	Minor	Moderate	Medium agreement, limited evidence
Business and Major Events	Insignificant	Insignificant	Minor	Medium agreement, limited evidence
International Education	Insignificant	Insignificant	Insignificant	Medium agreement, limited evidence

5.0 Transition Risks

There is increased recognition that the best way to reduce physical climate risks and create opportunities from climate change is to decarbonise the global economy as soon as possible. New Zealand, as a signatory to the Paris Climate Agreement, has committed to reaching net zero emissions nationally on all greenhouse gas (GHG) emissions excluding biogenic methane emissions (methane emissions from the agricultural and waste sectors) by 2050. The target for biogenic methane emissions is a 24-47 per cent reduction by 2050 compared with a 2017 baseline. Auckland has committed to achieving net zero emissions by 2050 and has an interim target to reduce GHG emissions by 50 per cent by 2030, relative to a 2016 baseline.

Transition risks and opportunities are those that may result from the process of adjustment towards a low-carbon economy. In contrast to the physical risks posed by climate change, climate-related transition risks and opportunities are highest in the next few decades (as action is taken to reduce emissions), are broader in scope, and are dependent on the speed and scale of transition. Transition risks and opportunities arise from:

- Policy and Litigation:
  - Policy actions that support mitigation or promote adaptation, and the potential costs involved.
  - Climate-related litigation claims being brought before the courts.
- Technology:
  - Improvements or innovations that support the transition to a low-carbon economy.
- Markets:
  - Shifts in supply and demand for certain commodities, products, and services.
- Reputation:
  - Perceptions of an organization's contribution to the transition to a low-carbon economy.

5.1 Transition risks and opportunities

Key risks to the four sectors of the economy[28] identified in this assessment are presented in Table 9 and Table 10. Risks were derived from a transition scenario developed for this assessment. For more information on the scenario, refer to **Appendix A**. In general, the level of risk depends upon the ability of the economic entities within the sector/subsector to absorb costs or to pass costs on to consumers, and the sensitivity of consumers to changes in products and prices. Transition risks were not rated as part of this study. Key opportunities identified are presented in Table 11.

[28] Several risks and opportunities identified by workshop participants do not relate directly to the four sectors. These risks are excluded from this assessment unless they lead to direct and significant impacts on the focus sectors. These include the exacerbation of inequality due to increasing electricity, transportation and housing costs, an increase in labour market precarity for older employees and those without formal qualifications working in 'sunset' industries, and a decrease in the inequitable outcomes of urban air pollution due to overall decline in air pollution.

Table 9: Transition risks applying to all sectors

Transition risk	Commentary
Increased costs of transporting input materials across the sectors due to increasing fuel costs	Risk depends upon the distance inputs to production must travel, the distance to consumer markets, and the mode of transportation. This risk applies to land-based transportation, aviation and shipping
Higher electricity costs causing reductions in demand, or reductions in profit margins	Risk depends upon the energy intensity of the production of a good or service, the ability of the business to absorb costs or to pass costs on to consumers, and the sensitivity of consumers to changes in price
Increased costs of inputs to production due to price on carbon	Risk depends upon the volume of material inputs, the emissions intensity of the material, and the technological viability of decarbonising the relevant production and supply chains.
Additional capital outlays required for fuel switching and energy efficiency retrofits in response to policy, regulation, consumer demand or market signals, stressing balance sheets and cash flows.	Risk depends upon the magnitude of the capital outlays required, and the ability of the business to access necessary capital.
Stranded assets: Investments see their economic life curtailed due to technological, regulatory and/or market changes, stressing balance sheets	Risk depends on current or likely future existence of substitutes for production processes or goods and services, the emissions intensity of assets, asset adaptability, asset useful life, and the capital intensity of sector outputs.
New costs of compliance associated with carbon-related regulation such as the TCFD causing reductions in profit margins via increased operating costs	Risk depends on the size of the business (i.e. employees, market capitalisation) and ownership structure (i.e. public, private), and emissions intensity of sector.
Reputational risk if skills required to the transition, or prosper from the transition, are not present in the labour market	Risk depends on the need for new skills (i.e. is the transition driven through changes to labour, or capital?), the adaptability of the labour-force, the ability to attract appropriately skills workers from outside the Auckland region.
Increased risks from wildfires due to afforestation efforts	Risk depends upon locations of assets and workforce exposure to smoke. Risk may also flow through transport networks and other linear infrastructures.
Reduction in the competitiveness of exports if other markets do not take action to reduce emissions.	Risk depends on importance of exports to the sector
Increased Directors and Officers (D&O) liability insurance costs	Risk depends on size of the business and likely liability under transition scenarios

Table 10: Transition risks applying to specific sectors

Visitor Economy	• Reduction in demand due to increased price of air travel. Risk depends upon distance travelled • Reduction in demand due to the increasing awareness of the significance of aviation sector emissions. Risk depends upon distance travelled • Increase in urban and environmental amenity due to reduction in noise, air and water pollution (from switch to EV's etc). Risk depends on other factors influencing urban and environmental amenity such as land use changes, ecological protection.
Screen	• Reduction in the number of filming locations due to landscape change relating to afforestation, wind turbines, urban densification and changes to agricultural landscapes.
Food and Beverage	• Lack of producer knowledge and support to transition to low carbon food and beverage production systems • Reduction in animal product consumption (e.g. milk and meat) due to increasing consumer awareness about the carbon-intensive nature of livestock production systems
Construction	• Increased costs of materials used in construction e.g. fuel, steel and cement as a result of the increasing cost of carbon • Rising compliance costs from net zero carbon building regulations and policies • Increase in capital outlays required to build new assets to higher energy and water efficiency standards, and to upgrade existing assets (with insulation, solar panels etc) • Lack of workforce capability and capacity to build net zero buildings and infrastructure.

Table 11: Transition opportunities

All	• Increasing demand for locally produced goods and services as imports increase in relative price due to higher transportation costs • Onsite electricity generation / microgrids may increase resilience to disruption to external energy network shocks • Ability to expand into new markets through the provision of low-carbon goods and services • Access to new financial products (e.g. green bonds, sustainability linked loans, sustainability linked bonds) to support business growth
Visitor Economy	• Increased opportunities for recreation, tourism and conservation due to afforestation • Higher education institutions may benefit from funding made available for low-carbon research • Higher education institutions may be able to develop new service offerings to equip students for professions likely to prosper in a low-carbon economy
Screen	• A higher percentage of the workforce sourced from Auckland to minimise aviation emissions and costs • Increase investment in technologies such as landscape scanning, augmented reality, virtual reality, animation etc to reduce the need to travel to sites during production
Food and Beverage	• Improved catchment hydrology as a result of afforestation
Construction	• Additional opportunities from demand for low-carbon buildings and infrastructure • Increased energy efficiency of houses and other buildings leading to reduced operational energy costs • Strengthened local supply chains

6.0 Implications for recovery from COVID-19

6.1 COVID-19 impacts to date

The global response to COVID-19 has had profound economic and social implications. Physical distancing measures and enforced lockdowns were a common mitigation strategy used by many countries to curb the impacts of the pandemic which have resulted in severe social and economic implications (Treasury, 2020a).

There have been wide reaching impacts both nationally and regionally. Nationally, key economic indicators such as GDP, unemployment and seasonally adjusted labour force participation have decreased from the previous December 2019 quarter. Senior economists at both ANZ Bank and ASB Bank have predicted New Zealand will experience a deep but short-lived contraction in GDP growth as a result of the pandemic. (Gray, 2020).

Various economic packages have been developed in an attempt to reduce the economic impacts of the pandemic. On 9 March 2020 the government announced the Business Continuity Package. As part of the New Zealand budget announced on 14 May 2020, an additional $50 billion was put towards establishment of the COVID-19 Response and Recovery Fund (Treasury, 2020b). Within this Fund, the Government has offered specific support for small to medium-sized enterprises including interest free loans, tax relief to SMEs. The government also offered specific support to regional businesses, including webinars and business mentoring support (Treasury, 2020c).

6.2 Sector-specific impacts

The Food and Beverage, Construction, Tourism and Screen sectors all face unique challenges as a result of COVID-19. Key challenges to the food and beverage sector include labour shortages and a contracted market for premium food and beverage distribution channels (due to contraction of the hospitality sector) (KPMG, 2020a). Exporters reliant on airfreight may need to find additional avenues of transport due to the contraction of this industry (KPMG, 2020a). The challenges to this sector are exacerbated by the impacts of a severe drought faced by the upper half of the North Island for the first half of this year (KPMG, 2020a).

The COVID-19 outbreak has demonstrated that international consumers will pay a premium price for food that they consider is safe (KPMG, 2020a). Ensuring New Zealand remains free from pests and diseases that overseas primary produce markets are exposed to is key to ensuring New Zealand retains this competitive advantage.

Lockdowns have highlighted the vulnerability of food and beverage supply chains and the risks around food security (KPMG, 2020a). While part of the government's response has been to invest in shovel-ready projects, investing in stimulus packages to support rural resilience such as rural connectivity and water storage and distribution will increase food security (KPMG, 2020a).

For the construction sector, site shut-down resulted in increased delays to construction projects and significant losses for major construction companies (KPMG, 2020b). Although construction sites are now open, construction companies have faced increased health and safety costs from additional requirements needed to comply with level 3 and 2 restrictions. These restrictions have eased now that the country is at level 1. However, border restrictions continue to limit the ability to import labour and either limit or increase the complexity required to import specialised construction skills from overseas. The sector is vulnerable to labour shortages if overseas workers cannot be sourced, which may impact on the sectors overall ability to deliver major infrastructure works (both private and public) (KPMG, 2020b).

In the short-term, the construction sector may experience either late or default payment from built assets in the residential sector, which will have flow-on effects for developers and construction companies (KPMG, 2020b). In the long-term, there may be reduced/deferred funding for private developments and capital projects depending on how much the sector contracts (KPMG, 2020b).

The screen sector faced major impacts when lockdown hit, as production houses were unable to film/rehearse and artists were unable to publicly perform. Approximately 55 projects were affected by the lockdown period; 47 domestic productions and 8 international productions (Hunt, 2020).

However, as New Zealand maintains a low number of COVID-19 cases, the country has a competitive advantage as a relatively safe area for filming productions. Annabelle Sheehan, Chief Executive of the New Zealand Film Commission, has indicated that many international studios have expressed interests filming productions in New Zealand (Hunt, 2020).

Although New Zealand has strict border controls in place, they have demonstrated support to the sector by recently allowing international filming crews to enter New Zealand to film Avatar 2 (Roy, 2020). This provides confidence to other international film studios that the government is willing to be flexible around immigration to support growth in the domestic film sector.

6.3 Recovering from COVID

6.3.1 The COVID-19 recovery context

Across the world, emergency COVID-19 economic rescue packages have been designed and implemented to ensure the continued solvency of businesses and the livelihoods of citizens. These packages have focused on prevention of immediate harm. In the coming months longer term COVID-19 economic recovery packages will be introduced by governments around the world, including New Zealand. New Zealand's recovery package will have a significant impact on the ability of Auckland and New Zealand to achieve emissions reduction targets. With this in mind, Auckland should focus on increasing employment and economic growth, while accelerating the transition to a low-carbon economy and adapting to physical climate change risks.

To meet these goals ATEED could advocate for and implement projects and policies:

- with **high economic multipliers** to create jobs
- that can be **rapidly implemented** to reduce the time people spend out of work
- that **accelerate progress towards net-zero emissions** by 2050 to reduce greenhouse gas emissions and attendant physical climate change risks
- which increase the **climate resilience** of Auckland's communities and economies.

6.3.2 Auckland Council COVID-19 recovery response

Auckland Council is expecting a sizable drop in revenue next year. Operating cash income across the Council is currently projected to be over $525 million less than what was previously budgeted. The impacts of the COVID-19 pandemic on Auckland will be substantial over the 2020/2021 year. As a community, New Zealanders are working together to fight the health impacts of COVID-19. Auckland Council has noted that they need to manage the financial impacts of COVID-19 in ways that are sustainable and aid a quick financial recovery while also upholding key principles important to the Auckland region.

In June 2019, Auckland Council declared a climate emergency, signalling its intention to put climate change at the forefront of decision making. During, and post the first COVID-19 lockdown, Auckland Council continued finalising Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan with formal adoption on 21 July 2020.

Through conversations and workshops with Auckland Council and ATEED, AECOM recognises that Auckland Council's desired response to post COVID-19 economic recovery identifies the need to invest in a future-focused and ecologically sustainable economy, building greater resilience to a variety of shocks. This response also drives Auckland Council to examine its economic and social roles to support the Auckland community, both presently and into the future. The desired response supports actions that guide Auckland towards a low-carbon and resilient future, aligning with the principles and outcomes of Auckland Plan 2050 and Te Tāruke-ā-Tāwhiri. For example: Auckland Council and ATEED need to continue climate-positive ways of working and living; prioritise infrastructure that supports climate-positive behaviours; reinforce the connection between climate action and post-COVID-19 recovery; prioritise implementation of the climate plan on key opportunities that support long-term, resilient recovery; advocate for climate focus in government recovery, future-ready industries; and reinforce the equity dimension of climate action and ensure interventions help the most vulnerable to be more prepared for the next shocks.

During the Stage 2: Review workshops with ATEED and Auckland Council we covered potential desired responses (provided by ATEED) for the Development, Tourism, Tertiary Education and Food System subsectors. Note that these subsectors do not accurately align with the sectors and subsectors that form part of this CCRA. The desired responses for these subsectors have been outlined below. We have also included additional subsector responses that we believe are relevant to the four key sectors which are the subject of this CCRA. Potential response actions for each area have been tabulated and then themed according to whether such actions accelerate the low-carbon transition and enhance climate resilience.

In general, the desired responses outlined below will support the transition to a low carbon economy, and will enhance climate resilience. However, these subsector responses may lead to adverse outcomes if the effects of climate change are not fully considered. Auckland Council needs to consider all their economic recovery activities and programmes with a climate lens to ensure that they reduce risk.

Visitor Economy

The two tables below analyse the potential response of two relevant subsectors to the Visitor Economy: the tourism subsector and the tertiary education subsector.

Tourism

Potential response action to recovery	Accelerates the low-carbon transition	Enhances climate resilience
Showcase Māori tourism	No significant effect	May increase sensitivity to loss or damage or Māori cultural heritage sites.
Develop local small scale and environmentally sustainable tourism	Potential to reduce transport related GHG emissions	No significant effect
Use technology to provide events and experiences	Potential to reduce transport related GHG emissions and consumption-based GHG emissions.	Potential to reduce dependence on natural environments, and exposure to environmental hazards. Potential to increase sensitivity to risks associated with ICT and electricity system disruptions.
Emphasise and celebrate Auckland's cultural diversity	No significant effect	No significant effect
Retrain and redeploy labour into other sectors	Potential to build labour force capacity in low-carbon growth sectors. Potential to build labour force capacity in high-carbon sectors.	Potential to reduce sensitivity to all visitor economy related risks.
Repurpose accommodation stock into rental stock or apartments	No significant effect	No significant effect
Repurpose facilities to other uses	No significant effect	May increase adaptive capacity to respond to climate risks if other venues are available.
Repurpose the visitor offer to a new sustainable model	Potential to reduce transport related GHG emissions and consumption-based GHG emissions.	May reduce degradation of the natural environment

Tertiary Education Sector

Potential response action to recovery	Accelerates the low-carbon transition	Enhances climate resilience
The multiple tertiary training providers to look at alternative ways of teaching and offering	No significant effect	No significant effect
Assessment the strengths and vulnerabilities of the international student model across the whole sector	No significant effect	Increasing awareness of strengths and vulnerability may encourage risk reduction efforts
Invest in remote /distance learning	Potential to reduce transport related GHG emissions and consumption-based GHG emissions.	Potential to increase sensitivity to risks associated with ICT and electricity system disruptions.
Vocational training alongside taught courses	Potential to build labour force capacity in low-carbon growth sectors. Potential to build labour force capacity in high-carbon sectors.	No significant effect
ATEED's Study Auckland team to support this direction	No significant effect	No significant effect
Provide students alternatives to upskilling and practical employment opportunities in council	No significant effect	No significant effect
Increase existing career and education services for rangatahi Māori to support upskilling for a post COVID-19 world.	Potential to build labour force capacity in low-carbon growth sectors.	Potential to reduce sensitivity of Māori visitor economy related risks if they are employed in a less-risky sector.
ATEED to work with sector on alternatives to attract students	No significant effect	No significant effect

Construction Sector

The two tables below analyse the potential response of two relevant subsectors to the Construction sector: development and waste and recycling.

Development

Potential response action to recovery	Accelerates the low-carbon transition	Enhances climate resilience
Recovery stimulus = ideal opportunity towards meeting NZ emission targets	Acknowledging the opportunity provided by COVID-19 is a pre-requisite for targeted emissions reduction efforts	Can enhance climate resilience if investment does not increase exposure to physical risk.
Right investments contribute to greater resilience and adaptation	No significant effect	Acknowledging the need to invest in climate resilience and adaptation is a pre-requisite for efforts to build climate resilience
Invest towards emission reduction by 2030 and achieving greater resilience	Direct investment in emissions reduction efforts will support the transition to a low carbon economy	Direct investment in adaptation and planning will support climate resilience
Increase investment in long term sustainable projects	Direct investment in emissions reduction efforts will support the transition to a low carbon economy	Sustainable projects will likely support climate resilience
Capitalise on likely lower project costs due to competition and sharper pricing	Lower project costs are common to all projects, including non-transition aligned projects.	Lower project costs may support the delivery of climate resilience building efforts that would otherwise be economically unviable
Mix and spread stimulus projects to benefit SMEs and Māori enterprise	May help reduce transition risks	Benefits to SME's and Māori enterprises has the potential to increase adaptive capacity.

Waste and Recycling

Potential response action to recovery	Accelerates the low-carbon transition	Enhances climate resilience
Invest in recycling and refuse infrastructure	Potential to reduce transport related GHG emissions and GHG emissions embedded in supply chains. Potential to develop new skills that are required for the low-carbon transition. Potential to support consumer choice to reduce consumption related GHG emissions.	Potential to reduce the risk of disruption to supply chains
Explore options to design waste out of the system		
Support the waste and recycling market		
Work with the construction sector as it recovers, to reduce waste to landfill		
Turn waste into wealth (innovative and productive uses of waste)		
Advocate to central government for onshore processing		
Advocate for product stewardship (e.g. national container deposit scheme)		

Potential response action to recovery	Accelerates the low-carbon transition	Enhances climate resilience
Lead by example, improve waste diversion from our own activities	No significant effect	No significant effect
Integrate waste minimisation into design, manufacturing, retailing and consumer choices	Potential to reduce transport related GHG emissions and GHG emissions embedded in supply chains.	Potential to reduce the risk of disruption to supply chains and to ensure products are fit for purpose
Increase resilience by exploring onshore processing solutions and align with Te Ao Māori worldview	Potential to reduce emissions through adoption of Māori knowledge that leads to more sustainable design and construction practices	
Advocate for ongoing central government stimulus funding for waste minimisation	Potential to reduce GHG emissions embedded in supply chains.	No significant effect
Accelerate investigation into the future options for paper and cardboard processing	Potential to reduce GHG emissions associated with land-use change	No significant effect

Food and Beverage

The table below analyses the potential response for the Food and Beverage sector using: the Food System.

Potential response action to recovery	Accelerates the low-carbon transition	Enhances climate resilience
Develop an urban agriculture sector, also helping unemployment	Potential to reduce transport related GHG emissions	Diverse systems, in different locations, easily accessible to the population may enhance climate resilience Increased urban green space can help with urban heat island effects and may reduce flooding
Low-carbon diets	Has significant potential to reduce diet-based greenhouse gas emissions	No significant effect
Support local business through a local, sustainable food procurement policy	May increase capacity for sector to engage in lower carbon production practices	No significant effect
Develop long-term supplier contracts that build capacity and provide business security to council suppliers	May increase capacity for sector to engage in lower carbon production practices	May increase adaptive capacity by providing certainty to allow investments and planning over longer timeframes
Support community groups, Not for profits and marae to play a greater role in a sustainable food system and food security	Potential to reduce transport related GHG emissions	Community engagement and capacity development may increase climate resilience
Support transition to regenerative urban and rural food production	Potential to reduce transport related GHG emissions	

Potential response action to recovery	Accelerates the low-carbon transition	Enhances climate resilience
Support community led local food movements and low-carbon diet behaviour	Potential to reduce transport related GHG emissions Potential to reduce diet-based greenhouse gas emissions	No significant effect

7.0 Conclusion

AECOM has undertaken this economic CCRA across four key Auckland economic sectors to support ATEED in developing their potential responses to COVID-19 economic recovery. AECOM analysed climate drivers at both the present, 2040 and 2110 timescales to identify both physical risks and opportunities for each of the sectors. AECOM also developed a transition scenario (detailed in **Appendix A**) to highlight potential transitional risks and opportunities for the respective sectors. Results from both the physical and transitional risk assessments provide ATEED with an understanding of the implications of climate change related risks and opportunities.

This understanding can support ATEED to incorporate relevant measures into economic recovery planning. Incorporating a climate lens into such planning will assist ATEED and Auckland Council in managing climate-related risk.

8.0 References

AECOM. (2017). Coastal and Flood Risk Assessment: Auckland Airport.

ARUP. (2019). *Climate Change Risks in Auckland.* Auckland*:* Auckland Council (TR2019-019).

ATEED. (2013). Auckland's Business Events Plan.

ATEED. (2016). Auckland screen growth reinforces need for new infrastructure https://www.aucklandnz.com/film/news/auckland-screen-growth-reinforces-need-new-infrastructure.

ATEED. (2018a). Destination AKL 2025.

ATEED. (2018b). Auckland's Major Events Strategy 2018–2025.

ATEED. (2020). Auckland Visitor Survey (AVS) Insights Report.

ATEED. (2020). Invest: Food and Beverage. Retrieved from https://www.aucklandnz.com/invest/focus-sectors/food-beverage.

Auckland Airport. (2020). January 2020 (Updated) Monthly traffic update.

Auckland Council (2020). Resource consent fees and deposits. Retrieved from https://www.aucklandcouncil.govt.nz/building-and-consents/resource-consents/Pages/resource-consent-fees-deposits.aspx

Auckland Council. (2016). The Auckland Unitary Plan. Retrieved from the Auckland Council website - https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/unitary-plan/Pages/default.aspx.

Auckland Council. (2017). Auckland Future Urban Land Supply Strategy. Retrieved from https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/auckland-plan/development-strategy/Pages/anticipated-growth-where-when.aspx

Auckland Council. (2017). Kauri Dieback. Retrieved from https://www.aucklandnz.com/film/news/kauri-dieback.

Auckland Council. (2020). *Strategic Response to COVID-19 Lockdown Impacts.* Auckland: Auckland Council.

Auckland Council. (nd). Destination AKL 2025.

Auckland Council. (2016a). Auckland Unitary Plan (*operative in part*). Auckland Council, Auckland, New Zealand.

Auckland Plan 2050 (2018). Our Development Strategy. Retrieved from https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/auckland-plan/development-strategy/Pages/default.aspx

Auckland Plan 2050 (2019). Auckland's horticultural production. Retrieved from Auckland Plan 2050's website - https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/auckland-plan/development-strategy/Pages/aucklands-horticultural-protection.aspx.

Auckland Transport. (2018). Asset management plan 2018.

Ballesteros-Pérez, P., Smith, S. T., Lloyd-Papworth, J. G., & Cooke, P. (2018). Incorporating the effect of weather in construction scheduling and management with sine wave curves: application in the United Kingdom. *Construction management and economics*, *36*(12), 666-682.

Basher, L. R., Hicks, D. M., Handyside, B., & Ross, C. W. (1997). Erosion and sediment transport from the market gardening lands at Pukekohe, Auckland, New Zealand. *Journal of Hydrology (New Zealand)*, 73-95.

Becken , S., Wilson , J., and Reisinger, A. (2010). Weather, Climate and Tourism: A New Zealand Perspective. Canterbury: Lincoln University.

Bell, C, and Beeston, H. (2008). Producers' Markets in New Zealand. Conference Paper, Auckland. December 2008. Auckland: University of Auckland.

Benschop, J., Bolton, A., Brightwell, A., Burgess, S., G., Cookson & Lake, R., Tait, A. *Adapting to climate change: Information for the New Zealand food system.* Prepared for the Ministry for Primary Industries. Accessed online at https://www.mpi.govt.nz/dmsdocument/28164/direct.

Building Industry Federation New Zealand (BIFNZ). (2013). *Residential Construction Sector Market Study. Submission on Issues Paper.* Retrieved from https://www.bifnz.co.nz/documents/BIF%20Market%20study%20submission%20FINALpdf.pdf .

Business Events New Zealand. (2020). New Zealand is ready to meet: How to attract business events in a post COVID-19 environment.

Chappell (2013). *The Climate and Weather of Auckland* (2nd ed). NIWA.

Chappell, P.R. (2013). *The Climate and Weather of Auckland.* (2nd ed). NIWA.

Chibnall, E and Curran-Cournange, F. (2014). *Soil Quality for Dairy and Converted Dairy Sites in the Auckland Region in 2014 and Changes after 18 years*. Research and Evaluation, Auckland: Auckland Council.

Clothier, B. Hall, A. Green,S. (2012). Adapting the horticultural and vegetable industries to climate change. In: *Impacts of Climate Change on Land-based Sectors and Adaptation Options. Technical Report to the Sustainable Land Management and Climate Change Adaptation Technical Working Group* (pp.241-289). Wellington, New Zealand: Ministry for Primary Industries.

Coriolis. (2017). *Investor's Guide to the New Zealand Beverage Industry.* Prepared for the Prepared for the Ministry of Business, Innovation and Employment, New Zealand Trade and Enterprise and Ministry for Primary Industries. Accessed online at https://www.mbie.govt.nz/assets/2fd30de252/investors-guide-to-the-new-zealand-beverages-industry-2017.pdf.

Coriolis. (2019). *Investor's Guide to the New Zealand Food and Beverage Industry.* Prepared for the Ministry of Business, Innovation and Employment, New Zealand Trade and Enterprise and Ministry for Primary Industries. Accessed online at https://www.mbie.govt.nz/assets/aaefdb3085/investors-guide-nz-food-beverage-industry.pdf.

Cradock-Henry, N. A., & Fountain, J. (2019). Characterising resilience in the wine industry: insights and evidence from Marlborough, New Zealand. *Environmental Science & Policy*, 94, 182-190.

Cradock-Henry, N. A., Flood, S., Buelow, F., Blackett, P., & Wreford, A. (2019). Adaptation knowledge for New Zealand's primary industries: Known, not known and needed. *Climate Risk Management, 25*, 100190.

Cropp, A. (2017). 'NZ reputation hurt by declining water quality, tourism industry says' *Stuff.nz.co,* 24 February.

Dairy NZ. (n.d). Leptospirosis. Retrieved from https://www.dairynz.co.nz/animal/cow-health/leptospirosis/

Davison, T., 1996. *Managing hot cows in Australia*. DPI Queensland.

Deloitte. (2018). *Cost of residential housing development: A focus on building materials.* Retrieved from Deloitte's website - https://www2.deloitte.com/nz/en/pages/economics/articles/cost-residential-housing-development-building-materials.html.

Deloitte. (2018). *New Zealand's food story: The Pukekohe Hub.* Prepared for Horticulture New Zealand. Retrieved from https://www.hortnz.co.nz/assets/Deloitte/Summary-report-New-Zealands-food-story-The-Pukekohe-hub.pdf.

Dutkiewicz, J. Taylor, A. Vettese, T (2020 April 16). The COVID-19 pandemic shows we must transform the global food system. *The Guardian.* Retrieved from https://www.theguardian.com/commentisfree/2020/apr/16/coronavirus-COVID-19-pandemic-food-animals.

EATON. (2019). Blackout Tracker: Australia and New Zealand Annual Report 2018.

Entwine (2018*). Creating Value Through Procurement: A report into public sector procurement of major infrastructure projects*. Retrieved from Infrastructure New Zealand's website https://infrastructure.org.nz/resources/Documents/Reports/Infrastructure%20NZ%20Procurement%20Study%20Report%20FINAL.pdf.

Eyles, R., Niyogi, D., Townsend, C., Benwell, G., & Weinstein, P. (2003). Spatial and temporal patterns of Campylobacter contamination underlying public health risk in the Taieri River, New Zealand. *Journal of Environmental Quality*, *32*(5), 1820-1828.

Fernandez M.A & Golubiewsksi, N.E (2019). *An Assessment of Vulnerability to Climate Change in Auckland.* Auckland: Auckland Council (TR2019/011).

Ferrer-Roca, N. (2017). Three-tier structure of the New Zealand feature film industry, *Studies in Australasian Cinema.*

Fitzgerald, W. Norton, S. and Stephenson J. (n.d). *Future-proofing New Zealand's Agricultural Food System; energy-related risks and opportunities.* Retrieved from University of Otago Centre for Sustainability website - https://www.otago.ac.nz/centre-sustainability/otago623147.pdf.

Gabzdylova, B., Raffensperger, J. F., & Castka, P. (2009). Sustainability in the New Zealand wine industry: drivers, stakeholders and practices. *Journal of Cleaner Production*, *17(11*), 992-998

Golubiewski, N. Balderston, K.Hu, C. Boyle, J. (2019). Auckland's exposure to sea level rise: part 1 – regional inventory. Auckland: Auckland Council (TR2019/017).

Gössling, S. & Hall, M. (2006). Uncertainties in predicting tourist flows under scenarios of climate change. *Climate Change.*

Gray, J. (2020, March 29). Covid 19 coronavirus: NZ economy set to contract by 6 per cent in 2020 - ASB, ANZ Bank. *New Zealand Herald.* Retrieved from https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=12320466.

Huang, T and Wilson, R. (2020) *Auckland's Construction Sector: Industry Snapshot and Trends to 2019*. Auckland: Auckland Council (TR 2020/002).

Hurley, S. (2017 May 8). Clevedon residents watch livestock floating down river in 'worst ever' floods.*New Zealand Herald.* Retrieved from https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11814259

Hurlimann, A. C., Warren-Myers, G., & Browne, G. R. (2019). Is the Australian construction industry prepared for climate change? *Building and Environment, 153,* 128-137.

Infometrics (2015a). *F&B Full Sector Sector Profile 2015*. Auckland: New Zealand.

Infometrics. (2015b). Dispelling myths about air freight exports. Retrieved from https://www.infometrics.co.nz/dispelling-myths-about-air-freight-exports/.

Insight Economics. (2014). Estimating the Regional Economic Importance of Auckland Airport. Prepared for Auckland International Airport Limited.

Insurance Council of Australia. (2012). Submission. *Recent trends in and Preparedness for Extreme Weather*. Retrieved from Parliament of Australia website https://www.aph.gov.au/parliamentary_business/committees/senate/environment_and_communications/completed_inquiries/2010-13/extremeweather/report/index.

International Civil Aviation Organization. (2016). ICAO environmental report 2016: aviation and climate change.

International Labour Organisation. (2019). Working on a warmer planet: The impact of heat stress on labour productivity and decent work.

Iorns, C. (2018). *Case Studies on Insurance and Compensation after Natural Disasters.* Retrieved from the Deep South Challenge website: https://www.deepsouthchallenge.co.nz/sites/default/files/2020-01/Case%20Studies%20on%20Insurance%20and%20Compensation%20Iorns%20Final%202019_0.pdf.

IPCC, (2014) Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

IPCC. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report *of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK.

IPCC. (2012). Determinants of risk: exposure and vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 65-108.

IPCC. (2014). Climate Change 2014 Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Irons, C. (2008). Case Studies on Insurance and Compensation after Natural Disasters. Research Report for the Deep South National Science Challenge. Retrieved from https://www.deepsouthchallenge.co.nz/sites/default/files/2020-01/Case%20Studies%20on%20Insurance%20and%20Compensation%20Iorns%20Final%202019_0.pdf.

Jones, R., Bennett, H., Keating, G., and Blaiklock, A. (2014). Climate change and the right to health for Māori in Aotearoa/New Zealand. *Health and Human Rights*, 16(1), 54–68.

Joynt and Golubiewski. (2019). *Development of the Auckland Heat Vulnerability Index.* Auckland: Auckland Council. Technical report 2019/012.

Kean, J. M., Brockerhoff, E. G., Fowler, S. V., Gerard, P. J., Logan, D. P., Mullan, A. B. & Ward, D. F. (2015). *Effects of climate change on current and potential biosecurity pests and diseases in New Zealand*. Ministry for Primary Industries. Wellington: New Zealand.

KPMG. (2020a). COVID-19 Sector Implications: Agri-food. Retrieved from https://home.kpmg/nz/en/home/insights/2020/03/business-implications-of-COVID-19-coronavirus/industry-implications.html.

KPMG. (2020b). COVID-19 Sector Implications: Construction. Retrieved from https://home.kpmg/nz/en/home/insights/2020/03/business-implications-of-COVID-19-coronavirus/industry-implications.html

Learnz. (nd). New Zealand Roads. Retrieved from http://www.learnz.org.nz/memorialpark134/bg-standard-f/new-zealand-roads.

Leys, Julian. (2018). The supply chain and recovery. The Supply Chain and Recovery. *Dealing with Crisis: Build 178.* Retrieved from http://www.buildmagazine.org.nz/index.php/articles/show/the-supply-chain-and-recovery.

Lorrey, A.M., Pearce, P.R., Barkus, C., Anderson, S.J., and Clement-Jones, A. (2018). *Auckland Region climate change projections and impacts: Summary report.* Prepared by the National Institute of Water and Atmospheric Research (NIWA) for Auckland Council. Auckland Council Technical Report, TR2017/031-2.

M.E Consulting. (2019). Auckland's Food and Beverage Sector: Initial Linkage Analysis. Report prepared for Auckland Tourism, Events and Economic Development, New Zealand.

Manhire, T. (2020 May 6). NZ ranked first in world for COVID-19 response communications. *The Spinoff.* Retrieved from https://thespinoff.co.nz/politics/06-05-2020/nz-ranked-first-in-world-for-COVID-19-response-communications/

Market Economics Limited. (2014). Economic Impact of the New Zealand Cruise Sector 2014 Summary Report.

MBIE. (2018). Convention Activity Survey Year to March 2018 report.

McGlone, M., & Walker, S. (2011). Potential effects of climate change on New Zealand's terrestrial biodiversity and policy recommendations for mitigation, adaptation and research. *Science for Conservation*, (312).

Ministry for Primary Industries. (2019). Primary Industries Workforce. Retrieved from https://www.mpi.govt.nz/dmsdocument/29273/send.

Ministry for Primary Industries. (2020). Land and Soil. Retrieved from https://www.mpi.govt.nz/protection-and-response/environment-and-natural-resources/land-and-soil/.

Ministry of Agriculture and Forestry. (2009). Winegrowing in a Changing Climate. Retrieved May 28, 2020, from http://www.hortinfo.co.nz/downloads_process_fs.asp?fid=climate\\ATACC_FS1_WineGrowing.pdf.

Ministry of Business, Innovation and Employment, New Zealand Trade and Enterprise and Ministry for Primary Industries. Retrieved from https://www.mbie.govt.nz/assets/2fd30de252/investors-guide-to-the-new-zealand-beverages-industry-2017.pdf

Ministry of Business, Innovation and Employment. (2018). *Beyond commodities: Manufacturing into the future.* Retrieved from https://www.mbie.govt.nz/assets/f0f81b6194/new-zealand-manufacturing-sector-report-2018.pdf.

Ministry of Business, Innovation and Employment. (2019). *Agritech in New Zealand: Towards an Industry Transformation Plan – draft strategy for the Agritech sector.* Retrieved from https://www.mbie.govt.nz/dmsdocument/5878-growing-innovative-industries-in-new-zealand-agritech-in-new-zealand-towards-an-industry-transformation-plan.

Ministry of Civil Defence and Emergency Management (MCDEM). (2019) *National Disaster Resilience Strategy.* Retrieved from https://www.civildefence.govt.nz/assets/Uploads/publications/National-Disaster-Resilience-Strategy/National-Disaster-Resilience-Strategy-10-April-2019.pdf

Ministry of Education. (2011). E-Learning Provision and Participation Trends, Patterns and Highlights

Ministry of Transport (2014). Statement of Intent. Retrieved from https://www.transport.govt.nz/about/governance/statementsofintent/statementofintent2011-2014/roadoperatingintentions/.

National Business Review (2018 July 11). Leaky buildings, Chinese supply botch fell Mainzeal over just $20m. Retrieved from https://www.nbr.co.nz/article/leaky-buildings-chinese-supply-botch-fell-mainzeal-over-just-20m-bd-135457.

New Zealand Education. (2018). International Education Strategy 2018-2030.

New Zealand Food Innovation Network. (2020) FOODBOWL. Retrieved from https://foodinnovationnetwork.co.nz/locations/foodbowl

New Zealand Forest Owners Association. (2018). *Forest Fire Risk Management Guidelines.* Retrieved from https://www.nzfoa.org.nz/resources/file-libraries-resources/standards-and-guidelines/670-forest-fire-risk-management-guidelines/file.New Zealand Forest Owners Association: Wellington.

New Zealand Institute of Economic Research. (2014). *Water Management in New Zealand; a road map for understanding water value.* Retrieved from https://nzier.org.nz/static/media/filer_public/d2/ce/d2cef6fa-3b58-4f11-bb0b-7b2a684ac181/nzier_public_discussion_paper_2014-01_-_water_management_in_nz.pdf.

New Zealand Steel (2020). Water - an essential resource. Retrieved from https://www.nzsteel.co.nz/sustainability/water-an-essential-resource/.

New Zealand Tourism. (n.d.). Fact file: New Zealand - a sailing nation. Retrieved from https://media.newzealand.com/en/story ideas/fact-file-new-zealand-a-sailing-nation/

NZ Hot House. (2018). Sustainability and Environment. Retrieved from https://nzhothouse.co.nz/growing.

Orlov, A., Sillmann, J., Aunan, K., Kjellstrom, T., & Aaheim, A. (2020). Economic costs of heat-induced reductions in worker productivity due to global warming. *Global Environmental Change*, *63*, 102087.

Pacific Institute (2009). *Water Scarcity and Climate Change.* Ceres: Oakland. Retrieved from https://www.fcrn.org.uk/sites/default/files/Water_scarcity_and_climate_change.pdf

Parliamentary Commissioner for the Environment. (2019). Pristine, popular... imperilled? The environmental consequences of projected tourism growth.

Parsons, K. (2014). *Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort, and performance*. (2nd ed). New York, United States: Taylor & Francis.

Pearce, P., Bell, R., Bostock, H., Carey-Smith, T., Collins, D., Fedaeff, N., Kachhara, A., Macara, G., Mullan, B., Paulik, R.,Somervell, E., Sood, A., Tait, A., Wadhwa, S., Woolley, J.-M. (2018). *Auckland Region climate change projections and impacts*. Prepared by the National Institute of Water and Atmospheric Research, NIWA, for Auckland Council. Auckland Council (TR2017/030-2).

Perry, N. (2020 June 8). With recovery of last case, New Zealand has eradicated virus. *Associated Press.* Retrieved from https://apnews.com/9503e13b40d8815e107e9891da1bfdcb

PwC. (2016). *Valuing the role of construction in the New Zealand economy.* Retrieved from PwC's website - https://www.pwc.co.nz/insights-and-publications/2016-publications/valuing-the-role-of-construction-in-the-new-zealand-economy.html

Radio New Zealand. (2020, June 30). *Auckland's use of Waikato River to be fast-tracked – government.* Retrieved from https://www.rnz.co.nz/news/national/420168/auckland-s-use-of-waikato-river-to-be-fast-tracked-government.

Richard Paling Consulting. (n.d.). Journey to Work Patterns in the Auckland Region: Analysis of Census Data for 2001-2013.

Rider Levett Bucknall. (2019). *Oceania Report: Construction Market Intelligence*. Retrieved from https://s28259.pcdn.co/wp-content/uploads/2019/01/RLB-Oceania-Report_Q1_2019_2.pdf.

Robertson, G. (2020 March 9). *Cabinet approves Business Continuity Package in response to COVID-19* [Press release]. Retrieved from https://home.kpmg/xx/en/home/insights/2020/04/new-zealand-government-and-institution-measures-in-response-to-covid.html.

Rosselló, J., Becken, S., & Santana-Gallego, M. (2020). The effects of natural disasters on international tourism: A global analysis. *Tourism Management*, 79.

Royal Society | Te Apārangi. (2017). *Human Health Impacts of Climate Change for New Zealand*. Retrieved from https://www.royalsociety.org.nz/assets/documents/Report-Human-Health-Impacts-of-Climate-Change-for-New-Zealand-Oct-2017.pdf.

RSM. (2020). Economic Impact of COVID-19 on the Property and Construction Sector. Retrieved from RSM's website - https://www.rsm.global/australia/insights/industry-insights/economic-impact-COVID-19-property-and-construction-sector.

Samarasinghe, D. A. S. (2014). *Building materials supply chains: an evaluative study of the New Zealand residential construction* (Doctoral dissertation, Auckland University of Technology).

Scott, D., & Lemieux, C. (2010). Weather and Climate Information for Tourism. *Procedia Environmental Sciences*, 1, 146–183.

Scott, D., Gössling, S., & de Freitas C. R. (2008). Preferred climates for tourism: case studies from Canada, New Zealand and Sweden. *Climate Research.*

Shaikh, T. (2018). 'April 2018 storm highlights vulnerabilities of Auckland businesses' *Stuff.co.nz.* 20 October 2018. Retrieved from https://www.stuff.co.nz/business/107968517/april-2018-storm-highlights-vulnerabilities-of-auckland-businesses.

Smith M.H (2013). *Assessing Climate Change Risks and Opportunities for Investors: Property and Construction Sector.* Investor Group on Climate Change and ANU. Retrieved from https://igcc.org.au/wp-content/uploads/2016/04/Property-and-Construction-1.pdf.

SriRamaratnam, R. (2008). Seasonal Labour for Horticulture and Viticulture Industries: Use of Regional Surveys and Forecast in Allocation Decisions. *Labour, Employment And Work In New Zealand*. DOI: https://doi.org/10.26686/lew.v0i0.1640.

Statistics New Zealand (2018). Methods of transporting imported and exported goods. Retrieved from http://archive.stats.govt.nz/browse_for_stats/industry_sectors/imports_and_exports/overseas-merchandise-trade/Methods-transporting-imported-and-exported-goods.aspx#:~:text=One%20way%20we%20can%20describe,goods%20(planes%20and%20ships).

Statistics New Zealand. (2009). Information and Communication Technology in New Zealand and Australia

Statistics New Zealand. (2020a). Gross domestic product: March 2020 quarter. Retrieved from https://www.stats.govt.nz/information-releases/gross-domestic-product-march-2020-quarter.

Statistics New Zealand. (2020b). Unemployment Rate. Retrieved from https://www.stats.govt.nz/indicators/unemployment-rate

Statistics New Zealand. (2020c). Labour market statistics: March 2020 quarter. Retrieved from https://www.stats.govt.nz/information-releases/labour-market-statistics-march2020quarter#:~:text=The%20seasonally%20adjusted%20labour%20force,from%2075.1%20percent%20last%20quarter.

Task Force on Climate-related Financial Disclosures [TCFD] (2017). Recommendations of the Task Force on Climate-related Financial Disclosures – Final Report. Retrieved from https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-2017-TCFD-Report-11052018.pdf.

The Royal Society of New Zealand. (2016). *Climate change implications for New Zealand.*

Tourism New Zealand. (2018). Business Events: Market information about our Visitors and our Active Considerers. Retrieved from https://www.tourismnewzealand.com/media/3425/business-events-infographic.pdf.

Tourism New Zealand. (nd). Business Events: Market information about our Visitors and our Active considerers. Retrieved from https://www.tourismnewzealand.com/media/3425/business-events-infographic.pdf.

Treasury. (2020a). Monthly Economic Indicators. Retrieved from https://treasury.govt.nz/publications/mei/monthly-economic-indicators-march-2020 .

Treasury. (2020b). COVID-19 Response and Recovery Fund. Retrieved from https://budget.govt.nz/budget/2020/wellbeing/approach/COVID-19-response-recovery-fund.htm#:~:text=The%20Budget%20formally%20establishes%20a,address%20COVID%2D19%20related%20spending.&text=%246.9%20billion%20to%20extend%20the,funding%20announced%20on%2017%20March.

Treasury. (2020c). Wellbeing Budget 2020: Rebuilding Together. and the Wellbeing Approach. Retrieved from https://treasury.govt.nz/publications/budgets/budget-2020.

UNECE. (2013). Climate Change Impacts and Adaptation for International Transport Networks. Expert Group Report, ITC, UN Economic Commission for Europe.

UNECE. (2015).Transport for Sustainable Development: The case for inland transport. United Nations Economic Commission for Europe.

Water Services Limited. (2016). *Asset Management Plan 2016 – 2036.* Retrieved from https://www.watercare.co.nz/CMSPages/GetAzureFile.aspx?path=~%5Cwatercarepublicweb%5Cmedia%5Cwatercare-media-library%5Creports-and-publications%5Cwatercare-asset-management-plan-2016-2036.pdf&hash=c999a1177a85361b806adcf60f74c46bc687f7b4880bc036e62f663d8c7ee825

Williams, P. (2016). How will climate change affect air travel?. A seminar at ICAO seminar on green airports. https://www.icao.int/Meetings/greenairports/Documents/3.%20Paul%20Williams.pdf.

Worksafe. (2019). Managing Thermal Comfort at Work. Retrieved from https://www.google.com/search?q=managing+thermal+comfort+at+work&rlz=1C1GCEA_enAU884AU884&oq=managing+thermal+comfort+at+work&aqs=chrome..69i57j69i59j69i60j69i61j69i60l3.3345j0j7&sourceid=chrome&ie=UTF-8.

WRAP (2012). Auditing of water use on construction sites – Phase I & Phase II. Retrieved from WRAP http://www.wrap.org.uk/sites/files/wrap/Auditing%20of%20water%20use%20on%20construction%20sites%20-%20Phase%201%20and%202.pdf.

Ying, F and Roberti, H. (2013 February 1). Improving Construction Logistics. Canterbury Tales: Build 134. Retrieved from https://www.buildmagazine.org.nz/index.php/issues/show/build-134.

Zander, K. K., Botzen, W. J., Oppermann, E., Kjellstrom, T., & Garnett, S. T. (2015). Heat stress causes substantial labour productivity loss in Australia. *Nature Climate Change*, *5* (7), 647-651.

Appendix A

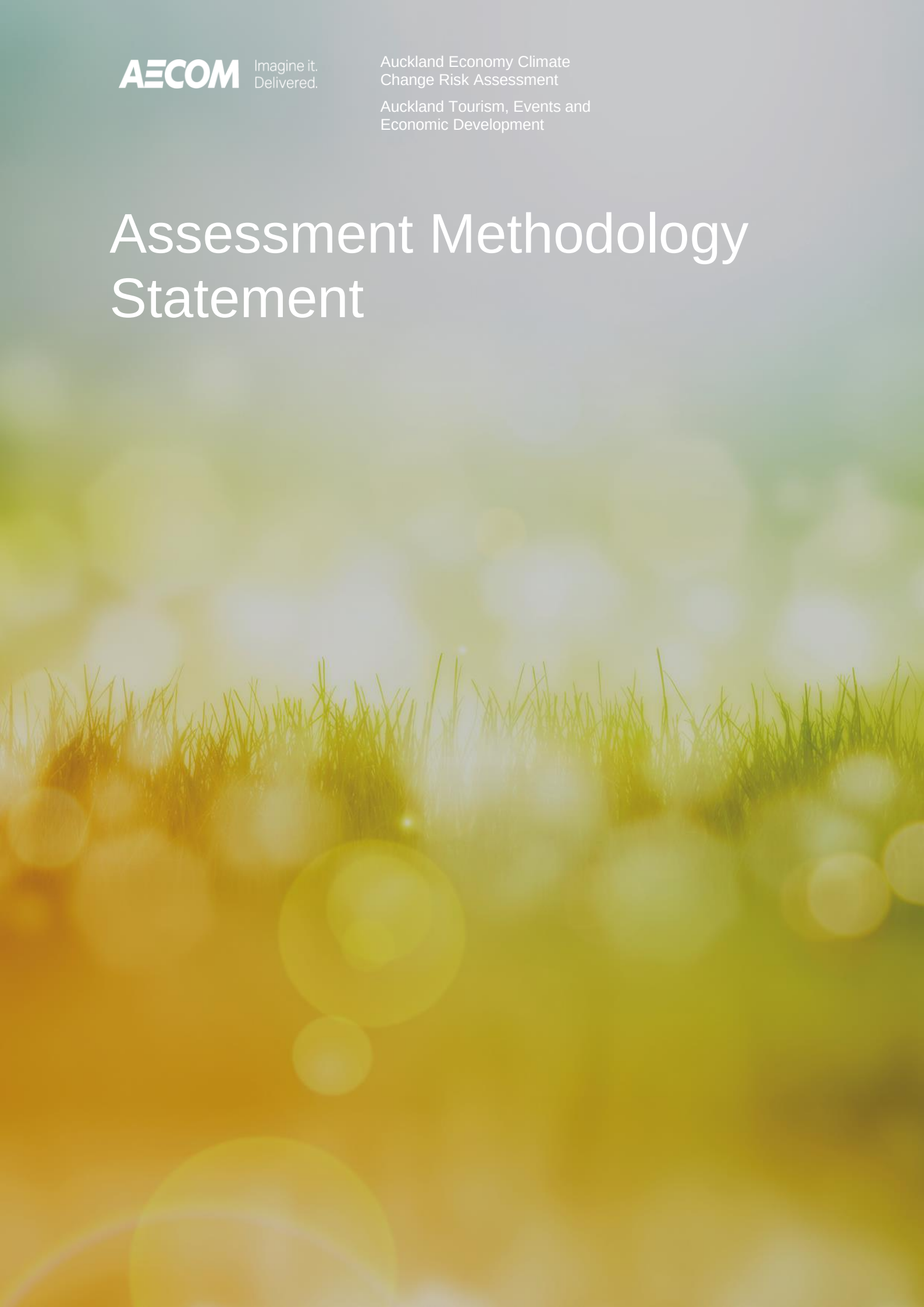
Assessment Methodology Statement

AECOM Imagine it. Delivered.

Auckland Economy Climate Change Risk Assessment

Auckland Tourism, Events and Economic Development

Assessment Methodology Statement



Assessment Methodology Statement

Client: Auckland Tourism, Events and Economic Development

ABN: 1

Prepared by

AECOM New Zealand Limited

8 Mahuhu Crescent, Auckland 1010, PO Box 4241, Auckland 1140, New Zealand

T +64 9 967 9200 F +64 9 967 9201 www.aecom.com

22-Jul-2020

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 AS/NZS4801 and OHSAS18001.

Quality Information

Document	Assessment Methodology Statement
Date	22-Jul-2020
Prepared by	James O'Donnell
Reviewed by	Victoria Chantra

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
0	29 May 2020	Draft	Victoria Chantra Associate Director - Environment	
1	22 Jul	Final	Victoria Chantra Associate Director - Environment	

Table of Contents

Glossary

Adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (Intergovernmental Panel on Climate Change [IPCC], 2014).
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2014).
Biodiversity	The variability among living organisms from terrestrial, marine and other ecosystems. Biodiversity includes variability at the genetic, species and ecosystem levels (IPCC, 2014).
Climate	Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system (IPCC, 2014).
Climate change	Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes or trends in the mean and/or the variability of its properties, and that persists for an extended period, typically decades to centuries. Climate change includes natural internal climate processes or external climate forcings such as variations in solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2014).
Climate projection	A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realized (IPCC, 2014).
Confidence	A qualitative measure of the validity of a finding, based on the type, amount, quality and consistency of evidence (e.g., data, mechanistic understanding, theory, models, expert judgment) and the degree of agreement (MfE, 2019).
Consequence	The outcome of an event that may result from a hazard. It can be expressed quantitatively (e.g., units of damage or loss, disruption period, monetary value of impacts or environmental effect), semi-quantitatively by category (e.g., high, medium, low level of impact) or qualitatively (a description of the impacts) (adapted from Ministry of Civil Defence and Emergency Management [MCDEM], 2019).
COVID-19	COVID-19 is a disease caused by a new strain of coronavirus. 'CO' stands for corona, 'VI' for virus, and 'D' for disease.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by a change in external stresses that a system is exposed to. In the context of climate change these are normally specific climate and other biophysical variables (IPCC, 2007).
Extreme weather event	An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability

	density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season) (IPCC, 2014).
Forest Fire Danger	Fire danger in New Zealand is assessed via a Fire Danger six class system, which uses fire intensity to indicate the difficulty of fire suppression (New Zealand Forest Owners Association, 2018). There are six ratings, which range from low (green) to very extreme (purple).
Greenhouse gas	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and b clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere.
Hazard	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC, 2014).
Likelihood	The chance of a specific outcome occurring, where this might be estimated probabilistically (IPCC, 2014).
Lockdown	Refers to the period of time New Zealand spent at Alert System Level 4, which was from 25 March to 27 April 2020.
Mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2014).
Potential evapotranspiration deficit (PED)	As the growing season progresses, the amount of water that is lost from the soil can exceed the amount of rainfall which creates a deficit. The difference between this demand and the actual evapotranspiration is defined as the 'potential evapotranspiration deficit', or PED (Pearce et al, 2018).
Primary production	The production processes associated with agriculture, horticulture and viticulture production. Forestry is excluded.
Representative Concentration Pathway (RCP)	A suite of representative future scenarios of additional radiative heat forcing at the Earth's surface by 2100 (in Watts per square metre), which is the net change in the balance between incoming solar radiation and outgoing energy radiated back up in the atmosphere. Each RCP can be expressed as a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC for its Fifth Assessment Report (AR5) in 2014 (IPCC, 2014).
Physical risks	Physical risks relate to the physical impacts of climate change. Physical risks resulting from climate change can be event driven (acute) or gradual longer-term shifts (chronic) in climate patterns.
Resilience	The capacity of social, economic, and environmental systems to cope with a hazardous event, trend or disturbance by responding or reorganising in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC, 2014).
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. The term risk is used to refer to the potential, when the outcome is uncertain, for

	adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure. Risk results from the interaction of vulnerability, exposure and hazard. To address the evolving impacts of climate change, risk can also be defined as the interplay between hazards, exposure and vulnerability (IPCC, 2014).
Risk Assessment	The overall qualitative and/or quantitative process of risk identification, risk analysis and risk evaluation, with multiple entry points for communication and engagement and monitoring and reviews (AS/NZS ISO 31000:2009, Risk Management Standard).
Seasonal Severity Rating	Seasonal Severity Rating (SSR) is a seasonal average of the Daily Severity Rating (DSR), which captures the effects of both wind and fuel dryness on potential fire intensity, and therefore control difficulty and the amount of work required to suppress a fire. It allows for comparison of the severity of fire weather from one year to another (NRFA, n.d, as cited in Pearce et al, 2018).
Transition risks	Transition risks are risks-related to the transition to a lower-carbon economy. Transitioning to a lower-carbon economy may entail extensive policy, legal, technology, and market changes to address mitigation and adaptation requirements related to climate change. Depending on the nature, speed, and focus of these changes, transition risks may pose varying levels of financial and reputational risk or opportunities to organizations (TCFD 2018).
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

1.0 Introduction

1.1 Purpose of the Assessment Methodology Statement

This Assessment Methodology Statement (AMS) was developed to guide the delivery of the Auckland Economy Climate Change Risk Assessment (CCRA). It documents the methodology used to identify and assess climate risks and opportunities to the construction, food and beverage, visitor economy, and screen and creative sectors.

The AMS accompanied the Project Plan as a key project document for the Auckland Economy CCRA. The AMS was updated as required throughout the life of the project to reflect agreed changes in methodology and scope and provide an accurate record of the method applied.

2.0 Setting the context

2.1 Scope and objectives

Climate change is already affecting Auckland. The Auckland Economy CCRA will add to the knowledge of climate change risks already identified through the Climate Change Risk Assessment technical report series. The CCRA is focused on climate change risks and opportunities to the construction, food and beverage, visitor economy, and screen and creative sectors of Auckland's economy. The CCRA will identify and evaluate risks and opportunities that may arise from hazards that are caused, exacerbated or influenced by climate change. The CCRA will also identify risks and opportunities that may arise from a transition to a low-carbon economy.

The objectives of the Auckland Economy CCRA are to:

- Identify and evaluate physical climate change risks, and identify opportunities that may result from physical climate changes;
- Identify risks and opportunities that may results from a transition to a low-carbon economy;
- Explore potential interactions between physical and transition risks;
- Enhance ATEED's understanding of how Small and Medium-sized Enterprises (SMEs) within each sector may be impacted differently by both the physical and transition risks of climate change compared with larger businesses; and
- Explore the implications of climate change related risks and opportunities for economic recovery from Covid-19 to enable the incorporation of relevant measures into support packages as part of economic recovery.

This project will be limited to risks and opportunities that arise to the specified sectors in the Auckland region.

2.2 Sectors and subsectors at risk

The Auckland Economy CCRA will assess risks and opportunities to four sectors. Description of the sectors, and a list of the subsectors to be assessed within each sector are contained in **Table 1**.

Table 1 Description of economic sectors

Sector	Description
Construction[1]	Preparation, clearing (including demolition) and development of land, and the construction, installation, alteration, repair and deconstruction of buildings, structures and infrastructure. The construction sector includes the following subsectors: • Residential construction • Non-residential construction • Infrastructure construction
Food and Beverage	Growing and producing, processing, transporting and distributing fresh, prepared and packaged food, and alcoholic and non-alcoholic beverages. The food and beverage sector includes the following subsectors: • Manufacturing • Wholesale • Food Technology • Supply Chain

[1] This assessment will only consider the physical impacts of climate change to the built environment as they relate to the characteristics and level of demand for construction services.

Sector	Description
	• Agriculture • Viticulture • Horticulture
Visitor Economy	The production of goods and services for consumption by visitors. The visitor economy includes the following subsectors: • Tourism • International Education • Business Events
Screen	The industries that produce film and television content for domestic and international audiences and service international productions coming to New Zealand. The screen and creative sector includes the following subsectors: • Film industry infrastructure • Filming locations

2.3 Physical risks

2.3.1 Conceptual framework

The assessment used a risk-based conceptual framework, consistent with that which was adopted by the Intergovernmental Panel on Climate Change (IPCC) for the Fifth Assessment Report (AR5) and the National Climate Change Risk Assessment for New Zealand. As shown in **Figure 1**, risk is a function of hazards, exposure and vulnerability. Vulnerability in AR5 is understood as a function of sensitivity and adaptive capacity.

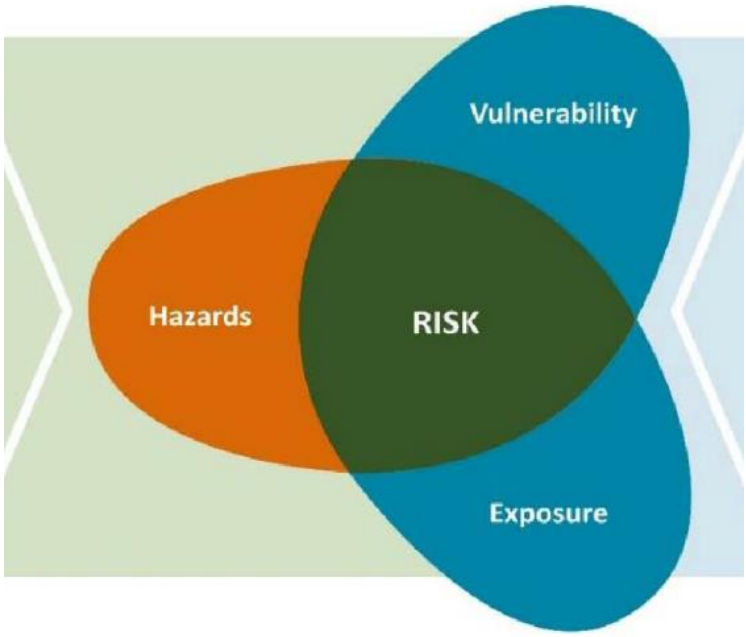


Figure 1 Schematic of the functional relationships between the elements of risk: hazards, exposure and vulnerability. Adapted from IPCC (2014).

2.3.1.1 Hazards

The term 'hazard' describes "the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources" (IPCC, 2014, p.5).

2.3.1.1.1 Climate change projections

Climate change projections depend strongly on our estimates of future greenhouse gas concentrations. Future greenhouse gas concentrations are uncertain; they depend on greenhouse gas emissions, which are driven by policy and factors such as economic activity, population changes and technological advances. This uncertainty is addressed by the IPCC through the use of Representative Concentration Scenarios (RCPs), four scenarios of future concentrations of greenhouse gases and climate warming by 2100.

This assessment used climate projections based on RCP8.5, a high emissions scenario characterised by increasing greenhouse gas emissions driven by population growth, increased use of land for agriculture, a heavy reliance on fossil fuels and a high energy intensity and low rates of technology development.

This assessment used projections prepared for the Auckland region by Pearce (et al., 2018). The assessment adopted the six-model average (the ensemble-mean) unless otherwise noted.

2.3.1.2 Exposure

Exposure is "the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected" (IPCC, 2014, p.5). The project team assessed the potential exposure of sectors and sub-sectors to hazards based upon GIS data provided by ATEED, and the Pearce (et al., 2018) climate change projections.

2.3.1.3 Vulnerability

Vulnerability is "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2014, p.5). It is a function of adaptive capacity - the ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term – and sensitivity - the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change.

2.3.2 Timeframes

The assessment identified and rated physical climate change risks for the periods outlined in **Table 3**. The timeframes align with climate change projections outlined in *Auckland Region climate change projections and impacts* (Pearce et al., 2018).

Table 2 Risk assessment timeframes

Timeframe	Description
Present	Risks occurring in the present day, and those that have been observed over the past 10 – 20 years.
Medium-term (2040)	20-year average for the period 2031-2050
Long-term (2110)	20-year average for the period 2101-2120

2.3.3 Consequence criteria

The project rated risks in accordance with the risk framework below. The framework was developed to allow the project team to rate risks across subsectors in a uniform way. The framework accounts for both the likelihood of the occurrence of a hazard, or series of hazards that give rise to the risk, and the scale and intensity of the impact of the risk. In this framework, risks are a function of the number of businesses exposed within a subsector, or the percentage of economic activity exposed within the subsector, and the severity of the consequences that stem from the exposure.

Put simply: Risk = exposure x consequence, where exposure and consequence are each scored 1-5.

Table 3 Exposure and consequence criteria

	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Exposure	Few (0-5%) of businesses affected. OR Insignificant percentage of economic activity within the subsector affected.	Limited number (6-15%) of businesses affected. OR Limited percentage of economic activity within the subsector affected.	A small number (16-30%) of businesses affected. OR Some percentage of economic activity within the subsector affected.	Many businesses (31-50%) affected. OR A large proportion of economic activity within the subsector is affected.	More businesses in the subsector are affected than those that are not affected. OR More economic activity within the subsector is affected than that which is not affected.
Consequence	Insignificant financial losses. AND No reduction in trust and consumer confidence. No media attention.	Minimal financial losses. No business failure. OR Limited reduction in trust and consumer confidence. Some national media attention.	Short-lived disruption in the ability to meet consumer needs. Moderate financial losses. Losses can be absorbed by almost all businesses. Minor business failure. OR Some reduction in trust and consumer confidence. Short term negative international or national media attention. Short term political attention.	Frequent short-lived and infrequent longer-term disruption in the ability to meet consumer needs. Large financial losses. Losses can be absorbed by most businesses. Some business failure. OR Major reduction in trust and consumer confidence. Sustained negative international or national media attention. Sustained political attention.	Long-term disruption in the ability to meet consumer needs. Large financial losses. Widespread business failure OR Substantial reduction in trust consumer and confidence. Sustained negative international or national media attention. Sustained political attention. Loss of social licence to operate.

Risk	Score (exposure x consequence)	Correlation to impacts on subsector
Insignificant	1-5	Limited impacts to subsector
Minor	6-10	Some impacts to subsector. Potential for growth in subsector is not significantly constrained.
Moderate	11-15	Subsector able to cope with consequence of risk, but growth in subsector may be constrained
Major	16-20	Subsector may be viable in a diminished or substantially changed form
Extreme	21-25	Subsector may no longer be viable

Opportunity

	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Exposure	Few (0-5%) of businesses affected. OR Insignificant percentage of economic activity within the subsector affected.	Limited number (6-15%) of businesses affected. OR Limited percentage of economic activity within the subsector affected.	A small number (16-30%) of businesses affected. OR Some percentage of economic activity within the subsector affected.	Many businesses (31-50%) affected. OR A large proportion of economic activity within the subsector is affected.	More businesses in the subsector are affected than those that are not affected. OR More economic activity within the subsector is affected than that which is not affected.
Consequence	Insignificant financial benefits. AND No increase in trust and consumer confidence. No positive media attention.	Minimal financial benefits. OR Limited increase in trust and consumer confidence. Some short term positive national media attention.	Moderate financial benefits. OR Some increase in trust and consumer confidence. Short term positive international or national media attention.	Large financial benefits. OR Major increase in trust and consumer confidence. Sustained positive international or national media attention.	Major financial benefits. OR Substantial increase in trust and consumer confidence. Sustained positive international or national media attention. Expanded social license to operate.

Opportunity = exposure x consequence

Opportunity rating	Score	Correlation to impacts on subsector
Insignificant	1-5	Limited impacts to subsector
Minor	6-10	Minor additional potential for growth in subsector
Moderate	11-15	Some additional potential for moderate growth in subsector
Major	16-20	Some additional potential for major growth in subsector
Extreme	21-25	Potential for significant growth in and increase in value-add of subsector

2.4 Transition Risks

New Zealand's and Auckland's emissions reduction targets are indicative of the scale and pace at which decarbonisation efforts must occur, however they provide limited guidance as to what a low carbon future may look like and how the economy will decarbonise. It has been suggested that New Zealand lacks strong policies required to meet its 2030 and 2050 targets (Climate Action Tracker, 2020).

The project team reviewed peer reviewed literature, reports, plans and strategies to develop one possible future scenario that connects present policies and greenhouse gas emissions to the net zero emissions targets. The scenario outlines in brief several trends that are likely to materialise during a transition to a low carbon economy. The purpose of the scenario was to facilitate a discussion on climate-related transition risks and opportunities to the four sectors. No modelling was undertaken. The scenario is presented below.

2.4.1 New Zealand and Auckland at present

New Zealand Policy and Targets

As a signatory to the Paris Agreement, New Zealand has committed to the global transition to net zero emissions, and to reaching net zero emissions some time in the second half of this century. The transition to a low carbon economy in New Zealand will mean dramatic change across all industries, particularly the Agriculture and Energy sectors, which contribute at 48 per cent and 41 per cent of gross emissions respectively, as shown in **Figure** 2.

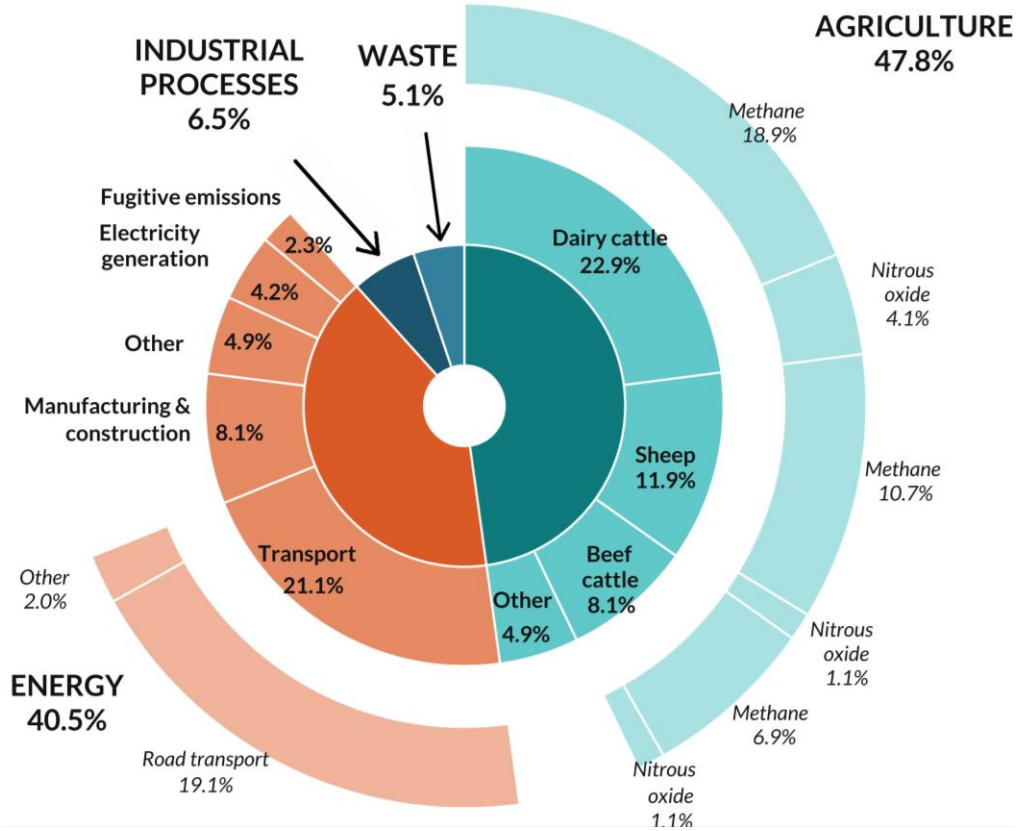


Figure 2 New Zealand's gross GHG emissions – 2018 (MfE, 2020a)

New Zealand has shown leadership by passing The Climate Change Response (Zero Carbon) Amendment Act 2019, the world's second-ever Zero Carbon Act, which aims to achieve net zero emissions of all greenhouse gases, except for methane emissions from agriculture and waste, by 2050. The Climate Change Response Act strengthens former targets to reduce GHG emissions by 50 per cent by 2050, however the Act, sets a framework, and does not introduce any new policies to reduce emissions.

At present, New Zealand's main instrument to reduce greenhouse gas emissions is an Emissions Trading Scheme (NZ-ETS). The NZ-ETS incorporates forestry, liquid fossil fuels, stationary energy and industrial processes, and waste and synthetic greenhouse gas sectors. A slow but steady increase in the price on carbon has occurred since the NZ-ETS has transitioned into a domestic-only scheme (MfE, 2016). The government is in the process of amending the NZ-ETS (New Zealand Parliament, 2019).

A green investment bank – New Zealand Green Investment Finance (NZGIF) – was established by the Crown in December 2018 to catalyse investment in low-emissions initiatives. NZGIF was set up with capital of NZD$100 million and is targeting the transport, process heat, agriculture, energy efficiency and distributed energy resources sectors for investment (New Zealand Green Investment Finance, 2019).

The New Zealand government is also pursuing initiatives to reduce agricultural emissions, such as the Productive and Sustainable Land Use Package, the New Zealand Agricultural Greenhouse Gas Research Centre, and the He Waka Eke Noa agreement, and to offset emissions through forestry (MfE, 2020b).

Auckland Policy and Targets

Auckland, like the rest of New Zealand, aims to deliver on the Paris Agreement commitments and limit warming to 1.5°C. Auckland has targets to reduce GHG emissions by 50 per cent by 2030 and reaching net zero GHG emissions by 2050 (Auckland Council, 2019a). As shown in **Table 5** and **Figure 3**, Auckland's primary sources of GHG emissions are primarily related to Energy and Industrial processes and product use, which accounts for approximately 70 per cent and 20 per cent of GHG emissions respectively.

Table 4 GHG emissions produced in Auckland in 2016 broken down in to five key sectors. Adapted from Auckland Council (2019a).

Sector		Description	Contribution to Auckland's 2016 GHG emissions (%)
Energy	**Transport**	Emissions from private and light commercial vehicles, trucks, buses, trains, ferries and other ships and aviation.	43.6
	Stationary energy	Emissions from energy consumption in buildings, including electricity and natural gas, and energy use in manufacturing and construction.	26.6
Industrial processes and product use		Non-energy related greenhouse gases from industrial processes, mainly steel production, and GHG emissions from industrial product, mainly associated with the use of hydrofluorocarbons (HFC's) and perfluorocarbons (PFCs) in air conditioning units and refrigerators.	20.2
Agriculture		Emissions include methane and nitrous oxide from livestock, animal wastes and fertiliser use.	6.4
Waste		Emissions from landfilled waste and wastewater treatment	3.1

In 2016, Auckland's net GHG emissions were 10.1 million tonnes of carbon dioxide equivalent (MtCO2e).[2] Under business-as-usual, Auckland's net GHG emissions are projected to increase by around 17 per cent by 2050.

To reach Auckland's goal, emissions need to peak and then rapidly decline. According to the Intergovernmental Panel on Climate Change "*pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems*" (IPCC, 2018, p. 17).

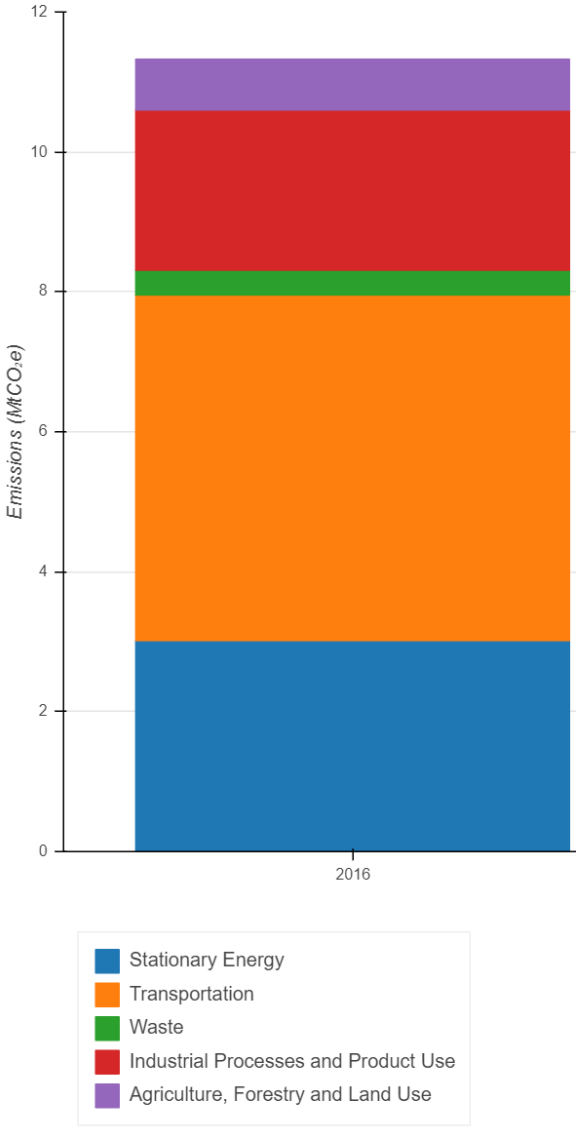


Figure 3: Auckland's Gross GHG emissions

[2] Gross GHG emissions were 11.3 MtCO2e. Carbon sequestration from forestry reduced emissions by approximately 10.5 per cent (Auckland Council, 2019b).

2.4.2 Transitioning to a low-carbon economy by 2050

Climate change has been described by Lazarus (2009) and Levin et al., (2012) as a 'super wicked problem' that requires successive governments to commit to policy reform, and to take actions now to avoid future harms (Boston, 2016). The Productivity Commission (2018) identifies key aspects of New Zealand's political and governance architecture that will need to come in to place to support an efficient and equitable transition to a low-carbon economy. These aspects, and their effects are summarised in Table 6.

Table 5 Key aspects of the political and governance architecture underpinning New Zealand's transition to a low

Key Development		Mechanism	Effect
Emissions pricing[3]	Pricing of long-lived greenhouse gases	NZ ETS	Encourages lower greenhouse gas emitting behaviour in all sectors covered by the price on carbon.
	Pricing of short-lived greenhouse gases[4]	Dual-cap NZ ETS or an alternative methane quota system (MQS)	
Stable policy, regulations and institutions	Legislated and quantified long-term GHG emissions reduction targets	Climate Change Response (Zero Carbon) Amendment Act (2019)	Provides a strong signal about future policy intentions and helps drive the development and implementation of a long-term policy response.
	Successive "emissions budgets"	Emissions budgets developed for 5-year periods	Translates long-term targets into clear short to medium-term emissions reduction goals.
	An independent expert advisory body	Climate Change Commission established under the Climate Change Response (Zero Carbon) Amendment Act (2019)[5]	De-politicises climate change action and reduces the likelihood of a weakening of emissions reduction ambition.
Innovation	Investment in research and development	Making available significant resources for low-emissions innovation	Supports cost-effective decarbonisation in carbon intensive sectors including agriculture, transport, buildings, and industrial processes. May create economic opportunities and other co-benefits.
	Deployment of offshore technologies	Building capabilities and resources to identify, absorb and adapt technologies	
Mobilising capital	Withdrawing investment from emissions-intensive activities	Green bonds, commercial equity, enabled by emissions pricing	Minimises risk of stranded assets. Ensures businesses can obtain capital to invest in actions that support a transition to a low carbon economy.
	Investing in low-emissions activities	Mandatory climate-related financial disclosures[6]	
		Targeted grants and loans	
		New Zealand Green Investment Fund	

[3] According to the Productivity Commission (2018), the price of carbon dioxide equivalent may need to rise to over $200 a tonne to achieve the domestic emissions reductions needed to meet New Zealand's international commitments.
[4] Greenhouse gases have different atmospheric lifetimes. Methane is relatively short lived, with the bulk of warming caused by atmospheric methane occurring in a 20 year period. Carbon dioxide remains in the atmosphere, leading to effectively irreversible warming. New Zealand is unique in its high proportion of short-lived gases relative to long-lived gases. This proportion should, and does, influence New Zealand's mitigation targets, emission-reduction trajectories, and policy frameworks. The Productivity Commission (2018) recommends that New Zealand "establish separate long-term emissions-reduction targets for short- and long-lived gases, as well as separate emissions "budgets" for short- and long-lived gases" (p. 4).
[5] The Climate Change Commission provides independent evidence-based advice to government to help Aotearoa New Zealand transition to a low emissions and climate resilient economy.
[6] The Government is proposing to require financial firms and listed companies to report on the impacts for their business and investments in a consistent way. In 2019 the Ministry for the Environment undertook a consultation last year on a regime regarding the financial impacts of climate change on businesses, how they are valued and reported on within financial markets in New Zealand. This may lead to new regulation.

These developments in policy and governance may result in three key shifts in New Zealand's economy (New Zealand Productivity Commission, 2018):

1. A transition from fossil fuels to electricity and other low-emission fuels across the economy;
2. Substantial afforestation; and
3. Changes to the structure and methods of agricultural production as shown in **Table 7**.

The shifts summarised relate to the entirety of New Zealand. They have been included because changes across New Zealand will flow through supply chains, the labour market, and the financial sector to the Auckland region.

Table 6 Shifts underpinning New Zealand's transition to a low carbon economy

Key shifts	Component of the shift	Detailed changes
A transition from fossil fuels to electricity and other low-emission fuels across the economy.	Increase in total electricity generation, with generation met by low-carbon energy.	Overall electricity demand increases from 44 TWh in 2019 to 57 TWh in 2035. 92% of electricity is from renewable sources by 2035 (Interim Climate Change Committee, 2019).
	Fuel switching in process heat.[7]	Switching approximately one third of fossil fuel used for food manufacturing to electricity. Replacing fossil fuel heating with heat pumps in schools, hospitals and businesses (for example in hot houses for indoor cropping).[8]
	Fuel switching in transport, i.e. rapid and comprehensive switch of the light vehicle fleet to electric vehicles and other very low-emissions vehicles.	EVs make up 80 per cent of new and used imports into New Zealand by the late 2020s, reaching 85% of new and used imports by 2035.[9]
Substantial afforestation	Large-scale afforestation.	Land planted in forests increases by between 1.3 million and 2.8 million hectares.[10] This land is mostly converted from marginally profitable beef and sheep land.
Changes to the structure and methods of agricultural production	Expansion in horticulture and cropping.	Rapid expansion in horticulture, from a small base, to between 500,000 and 1,500,000 ha. Regions such as Bay of Plenty, the West Coast and Auckland experience modest change in land-use.[11]
	Adoption of low-emissions practice on farms.	Practices include, use of genetic grains, reducing stocking rates, reducing nitrogen inputs, milking once a day, and using stand-off pads. Research into new technologies has the potential to further reduce agricultural emissions in the medium to long term.
	Reducing dairying emissions	
Changes to international transport[12]	It is assumed that international transport will be incorporated into carbon markets. Concept Consulting (2017) have estimated that an emissions price of $100 per tonne of CO2e could reduce domestic air travel demand by up to 12%. It is assumed that international air travel will decrease as the price on carbon increases.	

[7] Data and assumptions are derived from Interim Climate Change Committee (2019). It is assumed that the government will not pursue the 100% renewable electricity generation target due to the high marginal emissions abatement cost associated with greater than 98% renewable energy generation. This marginal abatement cost would require overbuilding of renewable energy infrastructure, and the high costs would hinder the electrification of the transport and industrial sectors.
[8] Modelling by the Interim Climate Change Committee (2019) was limited to low and medium-temperature heat, as users of high-temperature process heat have more limited fuel switching opportunities. It is estimated that switching away from coal to electricity or biomass will become economic in the range of $60-$120/t CO2e. Switching away from natural gas starts to become economic only above $120/t CO2e (Productivity Commission, 2018).
[9] This rate of EV uptake is comparable to that of ambitious countries such as the UK and Norway. It is assumed that uptake will be supported through the introduction of fees and rebates linked to the emissions intensity of imported vehicles, government procurement of EV's and investment in EV infrastructure projects to fill gaps in the charging network that are commercially unviable for the private sector.
[10] This will require a planting rate similar to the highest ever recorded in New Zealand to be sustained over the next thirty years (New Zealand Productivity Commission, 2018).
[11] The Productivity Commission (2018) notes that the scale of future change in land use up to 2050 is likely to vary considerably by region, with regions mentioned above likely to experience the most modest levels of change.
[12] International transport did not feature prominently in the Productivity Commission report, as emissions from international aviation and shipping lie outside national GHG emission obligations and emissions pricing schemes. At present, international commitments exclude international aviation emissions. However, these emissions are material. New Zealand's international transport emissions in 2015 were the equivalent of about 5% of New Zealand's total emissions (Ministry of Business, Innovation and Employment, 2017).

Auckland's transition to a low-carbon economy.

Auckland Council has identified one combination of climate actions that could reduce GHG emissions by 50 per cent by 2030 (against a 2016 baseline) and transition Auckland towards net zero emissions by 2050. The actions to the five sectors outlined in **Table 8**, have informed the Draft Auckland Climate Action Plan (2020).

Table 7 Key developments underpinning Auckland's transition to a low carbon economy

Sector		Actions that will result in emissions reductions
Energy	**Transport**	• Changing work practices change to reduce the need to travel. • Mode shift to public transport and active transport. • Switch to electric and zero emissions passenger, commercial and freight vehicles • Increase in fuel efficiency of vehicles. • Increase in Transport Orientated Developments.
	Stationary energy	• Switching from gas to electricity in process heat and adopting best practice technology and energy efficiency measures. • Energy efficient retrofits and replacement of natural gas boilers with heat pumps. • New residential and commercial buildings to operate at net zero emissions from 2030. • Percentage of grid electricity that is renewable increases to 94%.
Industrial processes and product use		• Increase energy efficiency and adopt best practice technology.
Agriculture		• Afforestation
Waste		• N/A

2.4.3 Timeframe

We identified transition risks that may arise between the present and 2050. Transition risks were not identified beyond 2050 as it is assumed that the domestic 2050 net zero emissions target will be met.

3.0 Stage 1: Identify and evaluate physical and transition risks and opportunities

The purpose of this stage was to:

- Identify the physical climate change risks and opportunities to the four priority sectors;
- Analyse and evaluate physical risks using an agreed risk framework;
- Identify transition related risks and opportunities to these sectors; and
- Analyse implications of findings for Auckland's economic recovery from the impacts of COVID-19

3.1 Identify physical risks and opportunities

The project team undertook a desktop review of peer reviewed literature, reports, and plans and strategies to identify climate change related risks and opportunities to the four priority sectors of Auckland's economy.

All risks were reviewed and validated by the project team and technical reviewers before being documented in a Microsoft Excel workbook.

Each risk is accompanied by an assessment of confidence in the finding, based upon the confidence scale in **Figure 4**.

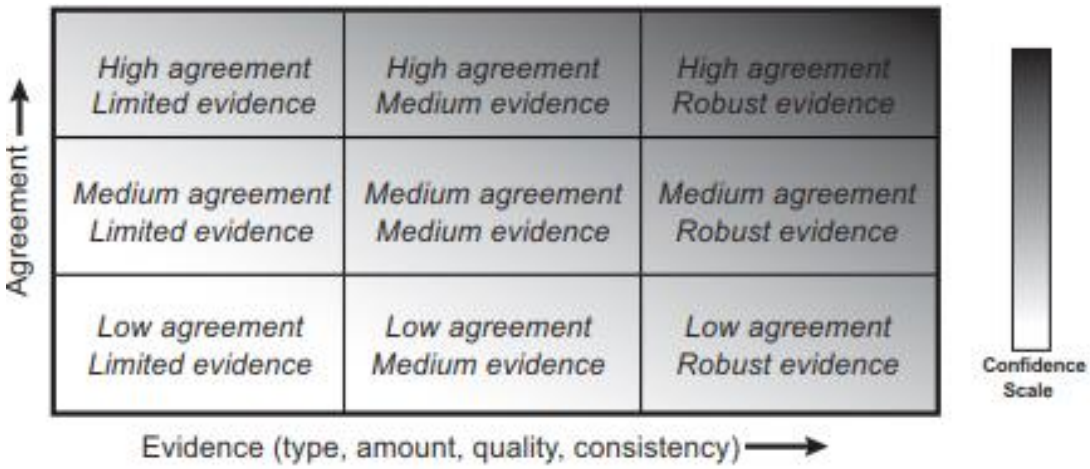


Figure 4 : Confidence scale (reproduced from Mastrandrea (et al. 2010)

3.2 Rate physical risks and opportunities

We rated the consequences of physical risks and opportunities across the timeframes specified in Section 2.3.2 using the consequence criteria detailed in Section 2.3.3. Consequence were estimated based upon the project team's understanding of the functional relationship between a hazard and its magnitude and frequency, exposure and vulnerability.

3.3 Identify transition risks and opportunities

We identified potential implications of the transition to a low carbon economy to the four sectors using a combination of peer reviewed literature, and the transition scenario detailed in 2.4.2.

The transition scenario, and a list of potential transition risks and opportunities were validated and explored further in the focus group sessions with ATEED and Auckland Council. During this workshop we assessed the materiality of the risks and opportunities to each sector.

3.4 Analyse implications of findings for Auckland's economic recovery from the impacts of COVID-19

We reviewed primary literature and preliminary planning that is being undertaken by Auckland Council on the economic recovery from the impacts of COVID-19. We prepared themes for discussion at the focus group sessions regarding the implications of climate change related risks and opportunities to recovery the impacts of COVID-19.

4.0 Stage 2: Stakeholder engagement

The purpose of this stage was to:

- Validate transition risks to the priority sectors;
- Present the findings of the desktop review; and
- Explore the implications of these findings for economic recovery from the impacts of COVID-19.

4.1 Focus group meetings

AECOM collaborated with ATEED to facilitate two, two-hour focus group meetings with representatives from across ATEED and Auckland Council who have been working on economic recovery. No external engagement was undertaken as part of this project. ATEED may undertake external consultation at a later date, including engagement with mana whenua.

At the first focus group meeting, AECOM:

1. Presented an overview of key trends related to the low carbon transition and risks associated with these trends; and
2. Facilitate an activity to identify additional transition risks to the priority sectors; and
3. Facilitate an activity to assess the materiality of transition risks to the priority sectors

At the second focus group meeting, AECOM:

1. Presented an overview of physical and transition risks identified for priority industries and their risk ratings where relevant; and
2. Facilitated a discussion on the implications of physical and transition risks arising from climate change for Auckland's economic recovery from the impacts of COVID-19.

AECOM developed and provided briefing materials to participants prior to the focus group meetings.

5.0 References

AECOM. (2020). Auckland Economy Climate Change Risk Assessment Project Plan: Revision A.

Auckland Council. (2019a). Te Tāruke-ā-Tāwhiri: Auckland's Climate Action Framework July 2019.

Auckland Council. (2019b). Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan (Draft V2).

Auckland Tourism, Events and Economic Development. (2018). Destination AKL 2025: A new direction for Auckland's visitor economy.

Boston, J. (2016). Anticipatory Governance how well is New Zealand safeguarding the future? *Policy Quarterly*, 12(3), 11–24.

Chappell, R. (2013). The Climate and Weather of Auckland. 2nd edition.

Climate Action Tracker. (2020). New Zealand. https://climateactiontracker.org/countries/new-zealand/.

Concept Consulting. (2017). Cost-effective energy options for transitioning New Zealand to a low-carbon economy. Wellington: Concept Consulting Group Ltd.

Connelly, A., Carter, J., Handley, J,m & Hincks, S. (2018). Enhancing the Practical Utility of Risk Assessments in Climate Change Adaptation. *Sustainability* 10.

Huang, T., & Wilson, R. (2020). Auckland's construction sector: industry snapshot and trends to 2019. Technical Report 2020/002 Auckland Council Research and Evaluation Unit.

Interim Climate Change Committee. (2019). Accelerated electrification Evidence, analysis and recommendations.

IPCC. (2014). Climate Change 2014 Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. (2018). Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. *World Meteorological Organization, Geneva, Switzerland.*

Lazarus, R. J. (2009). Super wicked problems and climate change: Restraining the present to liberate the future. *Cornell Law Review*, 94(5), 1153–1233.

Levin, K., Cashore, B., Bernstein, S., and Auld, G. (2012). Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences*, 45, 123–152.

Mastrandrea, M.D., Field, C., Stocker, T., Edenhofer, E., Ebi, K., Frame, D., Held, H., Kriegler, E., Mach, K., Matschoss, P., Plattner, G., Yohe, G., & Zwiers, F. (2010). Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties. Intergovernmental Panel on Climate Change.

Ministry of Business, Innovation and Employment. (2017). Unlocking our energy productivity and renewable potential. Wellington: Ministry for Business, Innovation and Employment.

Ministry for the Environment. (2016). The New Zealand Emissions Trading Scheme Evaluation 2016. Wellington: Ministry for the Environment.

Ministry for the Environment. (2020a). New Zealand's gross greenhouse gas emissions 1990-2018. Retrieved from https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/infographic%E2%80%93new-zealand%E2%80%99s-gross-greenhouse-gas-emissions-1990-2018.pdf.

Ministry for the Environment. (2020b). The transition to a low-emissions and climate-resilient Aotearoa New Zealand. Retrieved from https://www.mfe.govt.nz/climate-change/climate-change-and-government/climate-change-programme.

New Zealand Green Investment Finance. (2019). A guide to New Zealand Green Investment Finance. Retrieved from https://static1.squarespace.com/static/5cc8bb6fab1a623acbf93b1f/t/5dd4896e7d21622586c610c5/1574209902893/NZGIF+Guide_1.pdf.

New Zealand Parliament. (2019). Climate Change Response (Emissions Trading Reform) Amendment Bill - New Zealand Parliament. Retrieved from https://www.parliament.nz/en/pb/bills-and-laws/bills-proposed-laws/document/BILL_92847/climate-change-response-emissions-trading-reform-amendment.

New Zealand Productivity Commission. (2018). Low Emissions Economy.