The Cost of Fire in New Zealand

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Foreword

Fire and Emergency New Zealand provides services that benefit the whole of New Zealand, covering the four Rs – reduction, readiness, response and recovery. While some people are unfortunate to experience our response services directly, everyone benefits from the work we do to reduce the incidence of fire and to help people recover from emergency events. It is important for Fire and Emergency to identify and understand the economic and social value that it provides to New Zealand.

This mahi has helped us present an updated composite view of the cost of fire for New Zealand. The perspective of the report is that of economic costs, which means the focus is on valuing the resources used to prevent fire and to respond to fire, and those resources destroyed by fire. The report also acknowledges that there are other intangible costs of fire in New Zealand, such as the cost to employers of allowing Fire and Emergency volunteers to respond to incidents, but these costs are not able to be accurately estimated in economic terms.

As we move into developing our future levy model it is important we acknowledge the costs of fire are borne by numerous people in the system, from those investing in safer building design, those experiencing the consequences of fire at an individual or societal level, and those paying the Fire and Emergency levy. Investment in an improved service from Fire and Emergency will have benefits for all people in New Zealand, even if Fire and Emergency's costs are not reduced.

This is an important first step for us in articulating our value to the people of Aotearoa, but more mahi will be needed to ensure we can continue to tell this story in an impactful way.

Kerry Gregory

Chief Executive

Fire and Emergency New Zealand

The Cost of Fire in New Zealand

Prepared for Fire and Emergency New Zealand

Gary Blick and Lockie Woon
16 November 2021

Contents

Tables

Figures

Executive summary

Fire and Emergency New Zealand (FENZ) commissioned Sapere Research Group to prepare an estimate of the annual cost of fire in New Zealand. The purpose is to provide an estimate that can be used to help assess future policy initiatives aimed at reducing the cost of fire.

The perspective is that of economic costs, which means the focus is on valuing the resources used to prevent and respond to fire, and the resources destroyed by fire. Actual costs are used, where these are available. Where the costs of fire are not readily observable, an estimate has been prepared. There are three categories of costs – costs in anticipation, costs as a consequence, and costs in response.

The cost of fire in New Zealand estimated at $2.008 billion

The headline result is that the cost of fire in New Zealand is estimated at $2.008 billion in 2019/20. The plausible range is estimated at $1.598 to $2.435 billion (or ±21 percent), which represents the uncertainty inherent in an estimate.

Costs in anticipation are the largest of the three cost categories, accounting for $1.017 billion (i.e. 50.6 percent of the total), followed by costs as a consequence at $530 million (26.4 percent), and costs in response at $461 million (23.0 percent). Within these categories, the largest components of fire protection in buildings and fire-related damage to property are not easily measured, and so two estimation methods have been identified and compared in each case.

The result is equivalent to 0.6 percent of GDP

The estimate of the total cost of fire is equivalent to 0.6 percent of GDP in 2019/20, with the plausible range being 0.5 to 0.8 percent of GDP. This may appear to be on the low side, relative to prior studies, including one undertaken in New Zealand in 2005. However, a contributing factor is that the number of fatalities is much lower than those in the study in 2005. A further factor is that resource response costs have increased at a lower rate than that of GDP since then. Some of the component costs of fire increase more slowly than GDP over time, where components are not necessarily linked to growth in the economy. This might be expected in the case of the resource response costs (where there may be capacity) and fatalities and injuries (where safety activities can make an impact).

Several extensions to this work are possible

Several extensions to this work are possible. One step would be to improve the estimation of certain components if better data becomes available, for example, insights from the insurance industry, or data on the use of water in firefighting. Future work could also look to extend the scope of what has been quantified, for example, community costs and in safety costs, such as the cost of fire drills.

A next step would be to extend the cost model to examine the relationships between cost components over a multi-year timeframe. This would allow scenarios to be prepared to determine how changes in one area might affect downstream costs elsewhere, for example, the extent to which change in fire safety expenditure might impact on components within costs as a consequence.

1. Purpose and approach

This chapter outlines the purpose of this work and provides an overview of the approach taken.

1.1 Purpose of this report

Fire Emergency New Zealand (FENZ) commissioned Sapere Research Group (Sapere) to prepare an estimate of the annual cost of fire in New Zealand. This report documents the method and results. The purpose of this work is to provide a framework and an estimate that can be used to help assess future policy initiatives aimed at reducing the cost of fire.

1.2 Approach to this work

The scope of this work comprises all types of unwanted fire, including structural fires (i.e. fires in buildings) and vegetation fires.

The cost perspective is that of economic costs and so the focus is on valuing the total resource loss, in this case the resources used to prevent and respond to fire, and the resources destroyed by fire. Economic costs differ to financial costs by taking a societal perspective (rather than an individual or enterprise perspective), meaning the focus is on the impact to society as a whole and any transfers between members of society are excluded. Using this lens, sunk costs, transfers, depreciation, interest, and taxes are excluded from the analysis.[1] Economic costs are also in real terms, that is inflation is ignored.

The year in focus is 2019/20. Actual costs are used, where these are available. Where the actual costs of fire are not readily observable, an estimate of cost has been prepared and presented within a range to provide a sense of the uncertainty involved.

Prior studies of the cost of fire have typically used three categories of costs – costs in anticipation, costs as a consequence, and costs in response – and that is the approach used here. FENZ requested that the framework of cost components follow that used for estimating the cost of fire in England (DCLG, 2011a), with refinements appropriate for a New Zealand setting.

Figure 1 shows the structure of that framework, as adapted for the cost model prepared for this work.

- **Costs in anticipation** – costs arising from measures designed to either prevent fires or protective measures to mitigate the damage caused by fires. There are four cost components: (1) the costs of implementing fire protection measures in in buildings; (2) the costs of insurance administration; (3) the costs of fire safety activities; and (4) volunteering activity incurred in anticipation (e.g. training).

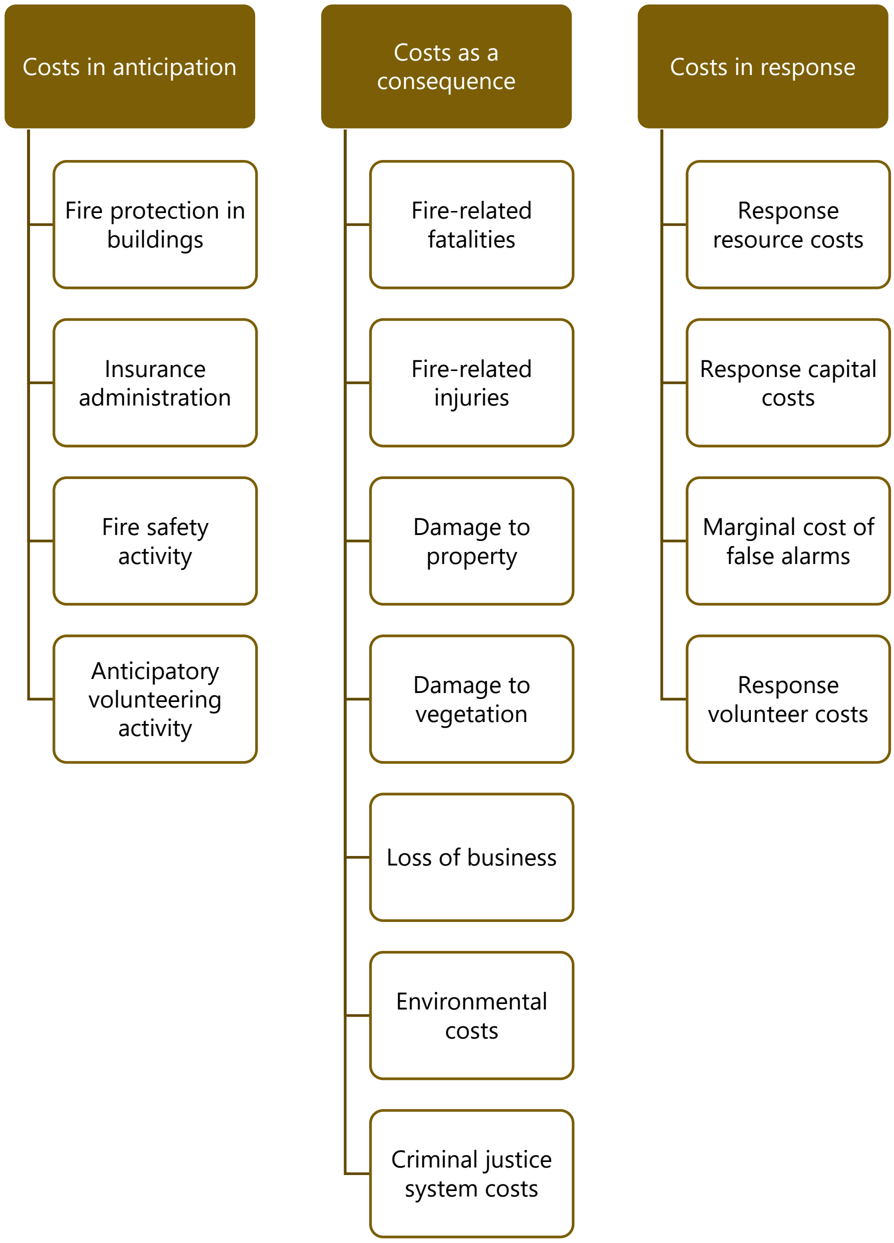
[1] Sunk costs are those that have already been incurred and cannot be recovered, while transfers relate to resources being moved around with a zero net impact to society.

- **Costs as a consequence** – costs occurring from the incidence of fire. There are seven cost components: (1) fire-related fatalities; (2) fire-related injuries; (3) the costs of damage to property (i.e. structural fires); (4) the costs of damage to vegetation; (5) the cost of lost business; (6) the costs to the justice system; and (7) environmental costs (including carbon emissions and the use of water) – this component is an addition to the framework.
- **Costs in response** – costs incurred in responding to fire incidents. There are four cost components: (1) the resource costs (i.e. operating expenses) incurred by FENZ; (2) the capital employed by FENZ; (3) the marginal cost of false alarms; and (4) the costs of volunteer firefighter time (an addition to the framework).

The detailed steps in estimating each component are outlined in subsequent chapters for each of the three main categories of cost. The general approach has been to use publicly available or readily available information, as much as possible, to enable future updates to be prepared. Costs that have not been quantified are detailed in the discussion chapter.

The results of this work are compared with prior studies in the discussion chapter. A report on the cost of fire prepared for the New Zealand Fire Service Commission in 2005 is a key reference (BERL, 2005).

Figure 1: Structure of cost model – categories and components



Source: Sapere

2. Costs in anticipation

Costs in anticipation are associated with costs in preventing or mitigating the damage caused by fire events. This section outlines the composition of costs in anticipation, comprising four components:

- fire protection in buildings
- insurance administration
- fire safety activity,
- anticipatory volunteering activity.

2.1 Fire protection in buildings

Fire protection in buildings – comprising active and passive forms – was highlighted as a major cost component across all prior studies. Those prior studies derive fire protection costs by either using a capital "consumption perspective" that depreciates the existing building stock based on expected life, or an "expenditure perspective" that focuses on the amount spent on fire protection in new buildings within a year. The focus here is on the expenditure perspective, for reasons of data completeness. Two estimation methods are used, referred to as the "top-down" and "bottom-up" methods.

- The top-down method relies on broad assumptions stated in a prior study, although the data and analysis underlying those assumptions were not reported.
- The bottom-up approach is based on QV cost builder data on the average cost of active fire protection per square metre by building type, applied to data on building activity.

When estimating the cost of fire protection in buildings, we place more weight on the bottom-up approach as we have more visibility over the data.

Method 1 – top-down estimation of expenditure

This method involves multiplying the annual value of building work by assumptions about the cost of fire protection as a proportion of new builds, similar to that previously applied by BERL (2005, 2012).

The annual value of building expenditure was observed in Stats NZ's quarterly data on building work put in place for 2019/20, split into residential and non-residential buildings.

The proportions attributable to fire protection cited in BERL (2005) were based on advice from BECA, this included residential (0-2 percent), and commercial, which was split into industrial (10-14 percent), commercial (4-5 percent), and other (6-7 percent). The cost of fire protection is estimated by taking a weighted average of the BERL (2005) estimates, resulting in 1.0 percent and 7.3 percent for residential and commercial buildings respectively.

Multiplying the value of building work by the respective fire protection proportions yields estimates of fire protection costs in residential and commercial buildings. Summing the residential and commercial estimates results in a total cost of fire protection of $781 million in 2019/20, as shown in Table 1. A range of $540-$1,021 million (±31 percent) is derived by using the lower and upper values of the proportion bands outlined above.

Table 1: Estimated cost of fire protection in buildings using "top-down" method, 2019/20

Category of building	Value of building work put in place ($ billion)	Fire protection assumption	Estimated cost of fire protection ($M)
Residential	15.16	1.0%	151.60
Commercial	8.63	7.3%	629.13
Total			**780.74**

Source: Stats NZ data, BERL (2005).

Method 2 – bottom-up estimation of expenditure

This method combines data from QV Cost Builder on the cost of active fire protection per square metre with Stats NZ building consent data series. A ratio of passive to active to fire protection costs is applied, derived from modelling work in England (DCLG, 2011a).

Active fire protection refers to fire detection and alarm systems, fixed fire extinguishing systems, water sprinklers, and spray systems (DCLG, 2011a). We observe the costs per square metre for active fire protection systems from the QV Cost Builder database. These costs are provided regionally for different building types. We average the regional figures to get an estimate of the cost per square metre for each building type and match the building types with the 14 building categories in the Stats NZ consent data. We observe the square metres of each building type from Stats NZ consent data, using the new floor area of new builds for the 2019/20 year. Multiplying this square metre data with the respective cost per square metre results in an estimate of the active fire protection in buildings.

Table 2: Estimated cost of active fire protection in buildings using "bottom-up" method, 2019/20

Category	Cost per square metre	Square metres	Cost of active protection ($M)
Apartments	$75.50	400,472	**30.24**
Hostels, boarding houses, and prisons	$75.50	97,893	**7.39**
Hotels, motels, and other short-term accommodation	$71.44	132,356	**9.46**
Hospitals, nursing homes, and other health buildings	$70.83	98,388	**6.97**
Education buildings	$104.40	188,404	**19.67**
Social, cultural, and religious buildings	$66.17	138,700	**9.18**
Shops, restaurants, and bars	$64.39	303,242	**19.53**
Office, administration, and public transport buildings	$57.10	170,645	**9.74**
Storage buildings	$75.50	759,733	**57.36**
Factories and industrial buildings	$63.33	383,955	**24.31**
Farm buildings	$63.33	982,551	**62.23**
Total active and passive			**256.07**

Source: QV cost builder fire services, Stats NZ consent data.

This estimate of active protection assumes that houses and townhouses do not have material levels of active fire protection. This is a simplifying assumption, given that fixed fire extinguishing systems, such as sprinkler systems, are typically not installed in these types of dwellings.

We then accounted for the passive protection costs, defined as the costs of fire safety design in buildings, such as structural fire protection, fire doors, flame retardant coatings etc. (DCLG, 2011a). These costs were not explicitly stated in the QV cost builder data; however, passive fire protection requirements are stated in the Building Act 2004. These requirements must limit the extent and effects of the spread of fire (Parliamentary Counsel Office, 2004), and can include systems such as dampers, fire doors, and fire penetration seals (BRANZ, 2017).

In the absence of having New Zealand specific data on passive fire protection costs, we examined the estimates of passive and active protections costs in England (DCLG, 2011a). We applied the ratio of passive to active costs to our estimate of active costs to obtain an estimate of passive costs. This includes an allowance for passive fire protection measures in townhouses (i.e. fire walls).

Table 3 combines these estimates of passive and active costs and shows the total cost of $730 million. This result is only slightly lower than the point estimate of $781 million derived under the "top-down" method and within the range estimated under that method (i.e. $540-$1.021 million). This "bottom-up" method is preferred as the estimate of active fire protection is based on recent and detailed data.

Table 3: Estimated cost of active and passive fire protection in buildings

Category	Active Protection ($M)	Passive Protection ($M)
Apartments	30.24	49.13
Townhouses, flats, units, and other dwellings	-	57.91
Hostels, boarding houses, and prisons	7.39	12.01
Hotels, motels, and other short-term accommodation	9.46	15.36
Hospitals, nursing homes, and other health buildings	6.97	11.32
Education buildings	19.67	31.96
Social, cultural, and religious buildings	9.18	14.91
Shops, restaurants, and bars	19.53	31.72
Office, administration, and public transport buildings	9.74	15.83
Storage buildings	57.36	93.20
Factories and industrial buildings	24.32	39.51
Farm buildings	62.23	101.11
Total active and passive	**256.07**	**473.97**
Total		**730.04**

Source: QV cost builder fire services, Stats NZ consent data, cost of fire UK 2006.

2.2 Insurance administration

Insurance administration is consistently highlighted as a cost in anticipation across all studies. Insurance premiums themselves are not an economic cost, as they are a transfer of funds from insurer to claimant and so, from a societal perspective, the transaction nets out at zero. However, the resources expended to administer this insurance represent an additional cost that would not be incurred in the absence of fire, representing a welfare loss and a cost that must be included.

Industry level insurance data was obtained from the Insurance Council of New Zealand's publicly available market data, including net earned premiums and net claims incurred by insurance type. From these, we can infer the total cost of insurance and estimate the administration cost.

Insurance administration costs are estimated at $190 million

The nature of insurance data means that obtaining a breakdown of industry level data is not straightforward and we were unable to obtain data on administration costs from insurance firms.

However, prior research by BERL (2005) was able to obtain some insurance data and therefore was able to derive assumptions of fire-related claims by policy type. These assumptions are set in section 3.3 Damage to property. Those assumptions are also used here, to inform our estimate of insurance administration costs using recent Insurance Council data.

Aggregated premium and claims data for 2019 and 2020 were averaged to obtain values for 2019/20. The data included insurance policy categories of building and contents claims, motor vehicle claims, and material damage claims. The purchase/claimant categories comprised household, commercial, and public, as shown in Table 4.

Table 4: Insurance premiums and claims by type of insurance, 2019/20

Premiums ($M)	Household	Commercial	Public	Total
Building and contents	1,268.95	-	-	1,268.95
Motor vehicle	1,347.42	336.85	-	1,684.27
Material damage	-	326.40	81.60	408.00
Business interruption	-	72.00	-	72.00
Total Premiums	**2,616.37**	**735.25**	**81.60**	**3,433.22**
Claims ($M)				
Building and contents	663.09	-	-	663.09
Motor vehicle	915.60	228.90	-	1,144.50
Material damage	-	199.57	49.89	249.46
Business interruption	-	44.02	-	44.02
Total Claims	**1,578.69**	**472.50**	**49.89**	**2,101.08**

Source: Insurance council market data, BERL (2005) assumptions

We then estimated the total cost of fire related claims for households, the commercial sector, and the public sector using prior assumptions of fire-related claims, as outlined in Table 12 (BERL, 2005). This method resulted in an estimate of the value of fire-related claims, shown in Table 5.

Table 5: Estimated value of fire-related claims, 2019/20

($M)	Household	Commercial	Public	Total
Building and contents	182.35	-	-	**182.35**
Motor vehicle	5.49	11.45	-	**16.94**
Material damage	-	74.84	11.23	**86.07**
Business interruption	-	20.91	-	**0.91**
Total fire related claims	**187.84**	**107.20**	**1.23**	**$306.26**

Source: Insurance council market data, BERL (2005) assumptions

The next step was to estimate fire-related insurance claims as a proportion of all insurance claims, for each policy holder group. As an example, the proportion for households is $187.84 million / $1,578.69 million or 11.9 percent. We apply these percentages to the respective total margin figures for each insurance holder group, where total margins are equal to reported total premiums minus reported total claims. Summing the resulting figures provides an estimate of the total insurance administration cost of $190.22 million in 2019/20. This step is shown in Table 6.

Table 6: Estimated cost of insurance administration, 2019/20

	Household	Commercial	Public	Total
Percent fire related	11.9%	22.7%	22.5%	**14.6%**
Total margins ($M)	1,037.68	262.76	31.71	**1,332.14**
Total ($M)	**123.47**	**59.61**	**7.13**	**190.22**

Source: Insurance council market data, BERL (2005) assumptions

2.3 Fire safety activity

Fire safety activity is aimed at reducing the likelihood of future fire incidents. FENZ has a role in providing advice to industries and councils on building design, educating the public, and fire permitting and enforcement, these costs are readily available. There will be some cross-over in these cost figures with cost in response. Specifically, the part of the organisation that delivers risk reduction (i.e. a cost in anticipation) also spends time investigating fires (i.e. a cost in response).

Spending on these activities is provided by FENZ for the year ended June 2018 through to the year ended 2020. Over this three-year period, the cost of providing advice increased substantially, from $1.6 million in 2017/18, to $9.0 million in 2019/20. Fire safety education increased by roughly $4 million annually, while permitting and enforcement remained relatively stable throughout the periods. Overall, these increased spending by an average of $7.3 million annually, suggesting the cost of fire safety activity is increasing over time. These figures are shown in Table 7.

Direct fire safety activity costs total $77 million

In addition to providing specific fire safety activity costs, FENZ included a portion of the cost of the transition to FENZ – currently being annuitized over future years. We include this in our model by adding a component of the transition to FENZ cost proportionate to the size of the other components i.e. fire safety activity, resource response costs, and reduced harm from activities costs. Since fire safety activity accounts for 12.9% (2019/20) of total year-on-year outputs, we add 12.9% of the transition cost to fire safety activity costs. This extra inclusion resulted in total costs of fire safety activity of $77.11 million.

Table 7: Fire safety activity

($M)	2017/18	2018/19	2019/20
Fire safety activity			
Advice to industry and councils on building design	1.62	7.70	8.98
Fire safety education to the public	32.13	36.70	40.82
Fire permitting and enforcement	25.74	24.98	24.96
Total direct fire safety activity (exc. transition)	**59.48**	**69.38**	**74.76**
Proportion of year-on-year output	12.6%	12.5%	12.9%
Transition to FENZ	2.94	2.68	2.35
Total direct fire safety activity (inc. transition)	**62.42**	**72.06**	**77.11**

Source: FENZ data

The total direct fire safety activity costs are increasing and volatile

There are significant fluctuations in costs over the three-year period. For example, the cost of providing advice to industries and councils increased over 400 percent from 2017/18 to 2018/19. We also note the declining cost of the transition to FENZ, however, this cost is only small relative to the other categories. The total cost of fire safety activity (both inclusive and exclusive) has seen a steady increase over the period, with this increase primarily driven by increasing costs in the advice to industry and fire safety education categories.

2.3.1 Indirect fire safety activity

Indirect fire safety activity is composed of a portion of FENZ's GHG emissions and maintenance of fire hydrants.

FENZ's anticipatory GHG emissions

FENZ's GHG emissions were also included under fire safety activity as an indirect cost. FENZ commissioned Enviro-Mark Solutions Limited (now called Toitū Envirocare) to undertake an emissions inventory for all operations in the 2019/20 year (Toitū, 2021). The inventory classified emissions under three categories:

- Direct GHG emissions (Scope 1) – including emissions from sources owned or controlled by FENZ.
- Indirect GHG emissions (Scope 2) – including emissions from the generation of purchased electricity, heat, and steam consumed by FENZ.
- Indirect GHG emissions (Scope 3) – including emissions that occur as a consequence of FENZ's activities but occur from sources not owned or controlled by FENZ.

This inventory stated gross emissions to total 12,408 tonnes of CO_2 equivalent. This figure was segregated into the three scopes and attributed to costs in anticipation and costs in response. In this case, Scope 2 was classed as a cost in anticipation (note Scope 1 and Scope 3 were assigned to costs in response) given purchased electricity and heat are used to run FENZ's anticipatory activities. While this is relatively crude, it gives a reasonable idea of the proportion of emissions that can be attributed to costs in anticipation.

Scope 2's emissions amounted to 1,788 tonnes of CO_2 equivalent. Combining this tonnage with NZTA's cost of CO_2 emissions of $63.04 per tonne results in fire safety GHG emission costs of $0.11 million.

Maintenance of fire hydrants

There is a legal requirement for Watercare to paint and replace fire hydrants. This requirement ensures hydrants are fit for purpose and are able to be used when needed. Watercare designates a proportion of their annual budget to outsource this painting and replacement, contact with Watercare revealed these costs are approximately $300,000 and $500,000 respectively. We note Watercare is only responsible for the maintenance of these hydrants, the initial establishment cost of the hydrants is born by property developers.

To extrapolate these figures to New Zealand, we observed two methods. Initially, we used regional water consumption as a proxy for the number of fire hydrants. However, an inspection of the distribution of consumption revealed metering to significantly impact regional water usage, and therefore the distributional figures. The second method involved using regional population estimates. Given that fire hydrant numbers and the population are likely correlated, it is reasonable to use population as a proxy for fire hydrant numbers.

The exact method of extrapolation involved leveraging Auckland's population as a proportion of New Zealand. This method involved observing population estimates from Stats NZ and assuming Auckland's percent of New Zealand's population is equal to Auckland's fire hydrant maintenance costs as a percent of New Zealand's fire hydrant maintenance costs i.e. because Auckland is 34% of New Zealand's population, Auckland's maintenance costs are 34% of total maintenance costs. Thus, we estimated total hydrant painting and replacement costs of $0.89 million and 1.48 million respectively.

2.4 Anticipatory volunteering activity

Volunteer costs were not mentioned in the UK studies. This absence is likely due to the large numbers of retained firefighters – these firefighters cover over 90% of the UK and are paid to spend long periods of time on call (The National Archives, 2005). However, given the prevalence of volunteers in Australia and New Zealand, Ashe et al. (2009) and BERL (2005) included volunteer cost estimations in their respective cost of fire papers. We follow a method similar to Ashe et al. (2009) by using the total number of volunteer hours to extrapolate a monetary figure for the cost of volunteers.

We disaggregate volunteer costs into costs in anticipation and costs in response. This section covers volunteer costs relating to anticipating and preparing for fire incidents i.e. the training of volunteers.

The data for this subsection are provided from FENZ and obtained from Stats NZ and NZTA. FENZ provided estimates of volunteer fire fighters' training and the dollar values of their expenses relating to volunteers, including volunteer payments, volunteer family/whanau payments, and volunteer annual reimbursement payments. Data on the earnings of New Zealanders were obtained from Stats NZ, and the value of travel time savings was obtained from NZTA.

The opportunity cost of volunteer hours is valued at 16.86 million

We distribute volunteer hours into work and leisure categories. Anticipatory volunteer hours are provided in two categories:

- structured training courses, and
- on station training.

Structured training courses are categorised as being undertaken only during work hours. These courses take place during the day and usually during the week, when it is assumed most volunteers would be working. We categorise station training hours as being undertaken only in leisure hours. On station training is undertaken over several training nights, meaning we assume the average volunteer would not usually be working these hours. While these categorisations may not be suitable for all training courses and hours e.g. for rural training courses, we argue these assumptions are reasonable given the lack of data and the offsetting that occurs with both assumptions i.e. some training courses may occur in leisure hours and some training hours may occur in work hours.

To attribute a monetary value to these lost hours, the average New Zealander's hourly earnings is used to value work hours, and NZTA's value of travel time saving is used as a proxy for the cost of leisure. NZTA's value of travel time saving is based on the theory that time spent travelling is an opportunity cost to an individual, whereby a reduction in travel time can be seen as a saved cost. In the context of fire, volunteers' hours spent training represent an opportunity cost of leisure.

The outcomes of this estimation can be seen in the following table:

Table 8: Estimating the opportunity cost, by work and leisure

Training time	Work	Leisure
Structured training courses (hours)	335,518	-
On station training (hours)	-	583,635
Total (hours)	**335,518**	**583,635**
Total cost ($M)	**11.00**	**5.86**

Source: FENZ data, Stats NZ earnings data, and NZTA monetised benefits and costs manual

We value the cost of work hours lost at $11.00 million and the cost of leisure time at $5.86 million.

Additional volunteer-related costs

Additional volunteer-related costs include FENZ's volunteer payments, volunteer family/whanau payments, and volunteer annual reimbursements. FENZ pays these costs to volunteers as appreciation for their role in fighting New Zealand's fires. However, as these costs are implicit in section 2.3 Fire safety activity, we do not include them in our model's anticipatory volunteering activity total – ensuring we do not attribute these costs to the wrong area of FENZ's activities. Instead, we display them in Table 9 to detail the full cost of volunteers' anticipatory activity and offer a more granular view of anticipatory costs.

Table 9: Volunteer cost components

Component	Total cost ($M)
Opportunity cost of time	16.86
Volunteer payments	2.55
Volunteer family/whanau payments	0.25
Volunteer annual reimbursement	2.59
Total	**22.25**

Source: FENZ data, Stats NZ earnings data, and NZTA monetised benefits and costs manual

3. Costs as a consequence

Costs as a consequence of fire are associated with costs that occur as a result of fire incidents. This section outlines the composition of costs as a consequence, comprising:

- fire-related fatalities
- fire-related injuries
- damage to property
- damage to vegetation
- lost business
- environmental costs,
- justice system costs.

3.1 Fire-related fatalities

Prior studies typically identify fatalities as a significant cost as consequence. These types of costs are generally associated with emotional harm and suffering that occurs from the loss of life in such an event. This section will use the number of estimated fatalities for the year ending June 2021 with the value of a statistical life to monetise the cost of a fatality.

FENZ's annual reports provided annual data on fatality numbers ranging from the year ended June 2014 through to the year ended June 2020. The focus is on avoidable fire fatalities – fatalities that occur in areas where FENZ's activities can reduce their risk of incidence i.e. the figure does not include other fatalities as a result of fire (these are often intentional, e.g. homicide, suicide).

The NZTA's value of a statistical life was observed from their paper on the social cost of road incidents (Ministry of Transport, 2020), this was adjusted to bring to 2021 dollars using the average income change over the period. Historic and projected populations were observed from Stats NZ.

While there are numerous methods to valuing the cost of death, the value of a statistical life is the most common. The majority of this approach uses a willingness-to-pay (WTP) valuation technique, putting a monetary value on the pain and suffering that occurs from death or decreased quality of life. Initially estimated in 1991, this figure is regularly indexed to the average hourly earnings to bring to present dollar values. Although there is debate on whether WTP to avoid road accidents is similar to fires, the fundamental drivers remain the same, meaning it is acceptable to use as a benchmark for the cost of life in the context of fire. Acknowledging this, the statistical value of life figure used in this report includes the dollar value associated with the loss of life, medical expenses, and legal and court expenses – we omit vehicle damage expenses included in the original NZTA figure given their irrelevance in the context of fire.

Our model estimates costs of fatalities of $52.26 million

Table 10 displays the annual avoidable fatalities and the rates of these fatalities (relative to New Zealand's population in the respective years). There are 11 fire fatalities in the 2019/20 year, a figure two higher than the previous two years and a notable increase, even after accounting for population changes. Fatalities and populations for the three periods were taken directly from the FENZ annual reports and Stats NZ data. The number of fatalities was used in conjunction with NZTA's statistical value of life ($4.75 million in 2021 dollars) to estimate the total cost of fatalities to be $52.26 million.

Table 10: Historical fatalities up to the year ended June 2020.

Year ended June 30	2017/18	2018/19	2019/20
Fatalities	9.00	9.00	11.00
Fatalities per 100,000	0.19	0.18	0.22

Source: FENZ annual reports

3.2 Fire-related injuries

Fire-related injuries were highlighted across all UK studies to be a cost as a consequence of fire. Similar to the cost of fatalities, these costs generally involve lost output, medical costs, and emotional damage. To monetise these costs, we first estimate the number of major and minor incidents. These numbers are then multiplied by the NZTA costs of major and minor incidents to estimate the total cost of non-fatal injuries.

Data sources include the Accident Compensation Corporation (ACC), the National Minimum Dataset's (NMDS) data, and NZTA. ACC data provided the number of new claims for fire related injuries from 2015 to 2019. NMDS data details the total number of hospital admissions by injury type, for the year ended June 2018, and NZTA's social cost of road crashes 2019 was used to cost major and minor injuries.

NZTA's cost of major and minor accidents includes costs from loss of life or permanent disability (derived from WTP), loss of output, medical expenses, legal expenses, and vehicles expenses. In the context of fires, we incorporate lost output (from the time spent in hospital away from work), medical expenses (from the cost of hospital care, emergency treatment and follow-up care for injuries), and legal expenses (from the court costs associated with remuneration or investigation of the injury). Combining these components yielded total costs for major and minor injuries of $20,654 and $2,202 respectively (2021 dollars).

Non-fatal injuries are estimated at $26.22 million

The total number of non-fatal injuries is estimated as ACC's number of fire related injuries. We estimate major injuries to be people admitted to hospital, in the NMDS data. The average stay of these patients was almost eight days, meaning these injuries are likely to be major and should be treated as such in our model. The number of minor injuries is then calculated as the balance of total ACC claims after accounting for major accidents.

To estimate the total number of major and minor incidents for the year ended June 2020, the ratio of major to minor incidents is first calculated for the 2017/18 year. This involved using the NMDS data (major injuries) relative to the ACC data (total injuries) to create a rate of major to minor injuries. The next step involved estimating the number of major claims in 2019/20, this required adjusting the 2017/18 rate for population increases. This adjustment means changes in New Zealand's population are factored into the final estimate. The final step involved applying the rate of major to minor incidents to the estimated number of major incidents for the year, resulting in 564 major and 6,557 minor claims.

The final cost of non-fatal injuries is estimated by applying these figures for major and minor injuries to the relevant NZTA figures. These results can be seen in Table 11, with a total cost of non-fatal injuries estimated at $26.22 million (in 2021 dollars).

Table 11: Cost of non-fatal injuries

	Incidents	Source	Cost per incident	Total cost ($M)
Major injuries	564	Loss of output	$1,468	0.83
		Hospital	$10,065	5.67
		Emergency	$1,258	0.71
		Follow-on	$4,928	2.78
		Legal	$2,936	1.65
Total cost major injuries				**11.64**
Minor injuries	6,622	Loss of output	$315	2.08
		Hospital	$105	0.69
		Emergency	$734	4.86
		Follow-on	$105	0.69
		Legal	$944	6.25
Total cost minor injuries				**14.58**
Total cost of non-fatal injuries				**26.22**

Source: ACC fire related injuries, NMDS hospital admissions, NZTA social cost of road accidents, and Stats NZ population data

3.3 Damage to property

Fire damage to property, in particular buildings, is typically a major cost in prior studies. This report explores two estimation methods: an "insurance claims" method and a "fire incidents" method.

Method 1 – insurance claims

The insurance claims method used Insurance Council data and a set of assumptions derived from prior studies to portion out total insurance costs that are related to fire. This derivation was done in the absence of direct estimates as the insurance companies approached were unable to provide data for this study. These fire related insurance damage figures were extrapolated to total fire damage using estimates of residential, commercial, and public populations without insurance.

The insurance method estimated $349.72 million of property damage

Insurance Council claims data was split into household, commercial, and public sectors, using prior assumptions (BERL 2005). We assume the portion of each insurance category attributable to these sectors is unlikely to have changed over time. The assumptions are:

- household sector accounts for 80 percent of motor vehicle claims,
- material damage is 85 percent and business interruption is 15 percent of total material damage, and
- the commercial sector accounts for 80 percent of material damages.

Table 12: Distribution of insurance council data

($M)	Household	Commercial	Public	Total
Building and contents	663	-	-	**663**
Motor vehicle	916	229	-	**1,145**
Material damage	-	200	50	**249**
Business interruption	-	44	-	**44**
Total Claims	**1,579**	**473**	**50**	**2,101**

Source: Insurance council market data

To determine fire related claims as a portion of these total claims, we also used BERL's (2005) assumptions. We were unable to verify these assumptions with New Zealand insurance companies, however, were able to test these assumptions using international data. We implemented the following assumptions for the percent of fire related claims:

- Building and contents claims – 27.5 percent of households.
- Motor vehicle claims – 0.6 percent of households and five percent of commercial.
- Material damage – 37.5 percent of commercial and 22.5 percent of public.
- Business interruption – 47.5 percent of commercial.

Combining these assumptions with the claims data yields estimates of fire-related claims in each category, as shown in Table 13.

Table 13: Fire related claims in the household, commercial, and public sectors

($M)	Household	Commercial	Public	Total
Building and contents	182.35	-	-	**182.35**
Motor vehicle	5.49	11.45	-	**16.94**
Material damage	-	74.84	11.23	**86.07**
Business interruption	-	20.91	-	**20.91**
Total fire related claims	**187.84**	**107.20**	**11.23**	**306.26**

Source: Insurance council market data

The final step in the insurance claims method is to extrapolate these figures to all of New Zealand, to account for both the insured and uninsured populations.

The study in England (DCLG, 2011b) uses the UK Family Expenditure Survey to extrapolate the household estimate. The equivalent of this in New Zealand is the Household Economic survey. We used the 2019 Household Economic survey as a proxy for households without insurance, in this case 13.9 percent. Prior studies (DCLG, 2011b); BERL (2005) comment on the difficulty of estimating the insured portion of the commercial sector, attributing this, in part, to a significant number of firms being insured privately. We therefore use the assumption of 10 percent, reasoning that there is unlikely to have been a major change in commercial sector insurance practice.

To estimate the portion of public sector buildings we observe BERL's (2005) flat rate and inflate it using the CPI to current year dollars. This observation was necessary given the lack of data in both New Zealand and internationally.

Combining the estimates for the uninsured portions of each sector with the respective sector estimates results in a total property damage estimate of $349.72 million, as shown in Table 14 below.

Table 14: Total property damage, insurance method

($M)	Household	Commercial	Public	Total
Total fire related claims	187.84	107.20	11.23	**306.26**
Uninsured	30.33	5.64	7.49	**43.46**
Total property damage from fire	**218.17**	**112.84**	**18.72**	**349.72**

Source: Insurance Council market data; Sapere analysis

To test the sensitivity of this figure to some key assumptions, we look at international estimates of fire related damage in the household and commercial sectors. The Insurance Information Institute (2020) estimated that 28 percent of household's total losses are attributable to fire, while ACGS (2018) estimated that 24 percent of the commercial sector's losses are attributable to fire.

Implementing these two assumptions into our model (although keeping motor vehicle's household claims at 0.6 percent) resulted in a total estimate of property damage of 353.57 million. This difference of 1.1 percent lends validity to our assumptions and suggests there is unlikely to be a significant shift in the percent of claims attributable to fire over time.

Method 2 – fire incidents

The incidents method used FENZ incidents data to estimate the fire damage in 49 building types classified by FENZ. These building types were mapped into Stats NZ building categories. We then calculate a weighted average of the fire damage in each Stats NZ building type and multiply these figures by the average cost for each building type. These are summed, resulting in a total cost figure for property damage.

We observe FENZ's data on the number of fire incidents, in a damage range, for 49 building types. Fire damage estimates were displayed by the percent of a structure saved, given in 10 percent intervals, from zero to 100 i.e. 0 to 10 percent, 11 to 20 percent etc. These 49 building types were mapped into the 14 Stats NZ building classifications, filtering out the incidents with no structural damage – the exact mapping and classifications can be found in Appendix A.

Table 15 displays the outcome of this mapping, note formatting restrictions meant only the first two categories of the percent of a structure saved are displayed.

Table 15: Fire incident data by percent of structure saved, classified into Stats NZ building types

Percent saved	0-10%	11-20%	Total
Houses	268	36	**2,679**
Apartments	12	1	**311**
Townhouses, flats, units, and other dwellings	12	1	**311**
Hostels, boarding houses, and prisons	3	1	**78**
Hotels, motels, and other short-term accommodation	2	-	**77**
Hospitals, nursing homes, and other health buildings	-	-	**129**
Education buildings	9	2	**204**
Social, cultural, and religious buildings	21	1	**122**
Shops, restaurants, and bars	7	-	**322**
Office, administration, and public transport buildings	7	-	**190**
Storage buildings	14	-	**89**
Factories and industrial buildings	5	-	**155**
Farm buildings	55	5	**162**
Miscellaneous buildings	79	3	**300**
Total	**494**	**50**	**5,129**

Source: FENZ incidents data, Stats NZ building consents

The next step estimated the average damage in each building type. To do so, we used the inverse of the median figure in each of the percent brackets previously stated, estimating the average damage in each bracket, i.e., for the 0-10 percent saved bracket, the median damage would be 95 percent. We then average the damage in each category, weighting by the number of incidents in each damage category. This process results in a weighted average of each building type's fire damage. Note, Stats NZ data excluded data for the miscellaneous building type. To deal with this issue, we took the average value of a building across all building types – a valid assumption given there is no evidence a miscellaneous building should be weighted more/less towards each end of the value spectrum.

We then estimate the average value of a structure in each building type. This estimation involved leveraging Stats NZ data by dividing the total value of all building consents, (inflated to 2021 dollars using the CPI) from 1991 to 2021, by the total number of consents issued during this time. This 30-year period is as far back as the data goes, and while we would like to observe a longer period to get a more accurate average value, this time frame is sufficient to give an accurate average value for each building type.

Finally, we estimated the total cost of property damage in each building type, this involved multiplying the total number of incidents with the respective weighted average damage estimate and the respective average value. Summing the resulting values estimates total property damage of $429.35 million. This final step can be seen in Table 16.

Table 16: Total property damage, incidents method

	Number of incidents	Weighted average	Average value ($M)	Total ($M)
Houses	2,679	20%	0.32	**183.14**
Apartments	311	12%	0.25	**9.20**
Townhouses, flats, units, and other dwellings	311	12%	0.20	**7.49**
Hostels, boarding houses, and prisons	78	10%	2.13	**17.49**
Hotels, motels, and other short-term accommodation	77	9%	1.26	**8.91**
Hospitals, nursing homes, and other health buildings	129	5%	2.91	**19.95**
Education buildings	204	12%	1.00	**24.91**
Social, cultural, and religious buildings	122	26%	1.07	**33.51**
Shops, restaurants, and bars	322	10%	1.02	**31.87**
Office, administration, and public transport buildings	190	10%	1.49	**29.28**
Storage buildings	89	25%	0.91	**20.24**
Factories and industrial buildings	155	11%	0.63	**11.98**
Farm buildings	162	47%	0.06	**5.11**
Miscellaneous buildings	300	35%	0.34	**13.86**
Total				**416.94**

Source: Stats NZ, FENZ incidents data.

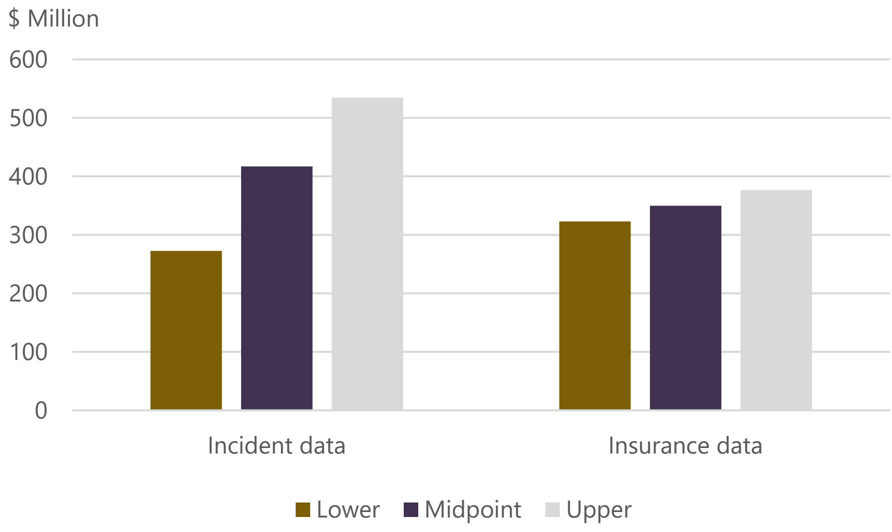
The incidents method is preferred

We recommend using the incidents method. This recommendation is based largely on the verifiability of assumptions. We cannot verify all of the assumptions used in the insurance method, given the lack of communication with insurance companies. However, the implicit assumptions in the incidents method rely less on historical assumptions, as such, have a higher degree of certainty and the incidents method is preferred.

For the incidents method, we note the omission of damage estimates for fires not attended by FENZ. Further research may wish to address this omission through communication with insurance firms to gauge an estimate of the proportion of total fire damage in incidents not attended by FENZ – note an estimate of unattended incident numbers alone is insufficient given FENZ's efforts are likely to bias the area damaged.

When comparing the two estimates, the incident method has a lot larger variance relative to the insurance method. All estimates of the insurance method fall within the range of the incident method, with the lower bounds of each method estimated within $40 million of each other - suggesting that although there is variability in the ranges, we can be confident of the minimum cost of property damage.

Figure 2: Variability in incident and insurance methods



Source: Insurance council market data, FENZ incidents data, Stats NZ.

3.4 Damage to vegetation

Vegetation damage was indicated by FENZ to be an economic cost of fire. Vegetation damage refers to the dollar value of the vegetation lost from wildfires. We base our method largely on BERL's (2009) report, the Economic Cost of Wildfires. Our focus is on the direct vegetation losses, omitting other losses associated with vegetation wildfires (e.g. response costs) given their coverage in other sections of this report.

We use data and assumptions from FENZ, and BERL's (2009) report to cost the damage to vegetation. FENZ provided the area (in hectares) of fire damage for the 2019/20 year, and we observed the distribution and cost of these vegetation fires from BERL (2009).

Total vegetation damages of $15.98 million

The 10,510 hectares of fire damage were split into the categories of grass, scrub, and forest based on their distributional averages from 1991/92 to 2007/08, i.e. given the 2019/20 hectares damaged is not split into grass, scrub, and forest, we extrapolate the average distribution over these years to 2019/20's vegetation damage.

BERL's (2009) report displayed the annual damage to grass, forestry, and scrub in 2008 dollars for the years 2002 to 2007. Grass damage per hectare cost estimates were derived from six-year averages of the Farmers' Mutual Group Ltd wildfire damage estimates, forestry damage per hectare cost estimates were derived from the New Zealand Forest Owners Association average price for Pinus radiata, and scrub damage per hectare estimates were derived from the Department of Conservation's fire management data.

To estimate the average cost per hectare, we inflated each category's cost figures to 2021 dollars and divided them by the respective numbers of hectares damaged. Multiplying these average costs per hectare with the hectares damaged estimates total vegetation damage costs of $15.98 million. This estimation is summarised below.

Table 17: Total vegetation damage

	Grass	Forest	Scrub
Hectares	4,955	800	4,755
Cost per hectare ($)	429	14,190	529
Total cost ($M)	**2.12**	**11.35**	**2.51**

Source: FENZ incidents data, BERL (2009).

We note that BERL (2009) attempted to estimate the flow-on effects of the damages to forestry i.e. the missed revenue of harvesting and transport companies from not having to process the timber. We argue that this is inappropriate. Revenue streams lost from not having timber to process will be mostly absorbed by other areas of the economy, e.g. transport companies taking on other work during the time period where they would otherwise have been transporting the timber from the burnt forests.

3.5 Lost business

The UK (2006) model highlights the cost of lost business as a significant cost of fire. Lost business costs are associated with the lost value from business interruption. However, a proportion of this lost business will be reabsorbed by other businesses in the local economy, meaning from an economy-wide perspective, the total loss is the net amount not absorbed by other businesses. The extent of this loss will be dependent on the substitutability of the good or service provided by the business, i.e., the more difficult a good is to replace, the more expensive the suppliers lost business will be.

Our approach uses Insurance Council's business interruption data. We continue with the assumptions portioning out business interruption claims fires as outlined in section 3.3. Conceptually, we know this direct insurance cost figure will need to be extrapolated to uninsured costs and to account for indirect costs – the costs that are incurred by suppliers of the affected businesses. Derived from the report on the cost of fire in the United States (2014), these indirect losses are incurred in addition to the direct costs at the following rates:

- 65 percent for manufacturing and industrial properties.
- 25 percent for public assembly, educational, institutional, store, and office.

- 10 percent for residential, storage, and special structure.
- 0 percent for vehicle and outdoor fires.

We then mapped FENZ's incident data, previously mapped into Stats NZ categories, into these four categories. The exact mapping can be seen in Appendix A.

The next step involved portioning out the business interruption costs to the four categories, based on their weighting by the number of incidents in each of these four categories, i.e., because manufacturing and industrial properties had 155 out of a total 5,129 incidents, we allocated manufacturing and industrial properties three percent of total business interruption costs.

Indirect costs were then calculated by combining the above assumptions with the respective direct cost figures. These calculations can be seen in Table 18 below:

Table 18: Indirect lost business calculations

	Direct business interruption ($M)	**Indirect costs ($M)**
Unable to classify	3.04	-
Manufacturing and industrial properties	0.63	0.41
Public assembly, educational, institutional, store, office	3.42	0.85
Residential, storage and special structure	13.82	1.38
Vehicle and outdoor fires	-	-
Total	**20.91**	**2.64**

Source: FENZ incident data, Hall (2014)

Summing the direct and indirect costs results in $23.56 million of business interruption. However, this figure is not adjusted for the uninsured sector. Borrowing the assumption for commercial properties as stated in section 3.3, we inflate this figure by 10 percent. As such, accounting for uninsured businesses and resulting in $26.18 million of total business interruption costs.

This figure does not represent a net loss to the economy. Given other businesses can reabsorb some of these business interruption costs, total insurance claims do not represent the total loss to the economy. However, not all of these losses will be reabsorbed. To deal with this, we use the UK 2006 model's assumption, a professional judgment in the absence of research, that 75 percent of all business is reabsorbed into the economy, with 25 percent representing the economic loss. This assumption means we estimate economy wide business losses of $6.54 million.

Table 19: Total lost business

	($M)
Direct and indirect business interruption costs	**23.56**
Uninsured	10%
Total business interruption costs	**26.18**
Reabsorption into economy	75%
Total lost business costs	**6.54**

Source: FENZ incident data, Hall (2014), UK 2006.

3.6 Environmental costs

In the 2006 UK study, a range of environmental costs were identified as being a significant part of the overall costs as a consequence of fire. However, given the extreme variability of the different types of incidents and the environmental sensitivity of any given location to the environmental consequences of fire, an aggregated cost for England was not estimated. Costs identified included:

- Emissions of greenhouse gases and other harmful substances
- Water consumption tackling fires
- Loss of biodiversity from fires, especially at incidents affecting high amenity sites
- Debris and other after fire arisings to landfill
- Environmental clean-up/decontamination costs

3.6.1 Emissions of greenhouse gases and other harmful substances

Valuing CO_2 emissions appropriately is becoming increasingly important, given the longevity and impact of these emissions on the atmosphere. We have used the NZTA tool to value CO_2 from the perspective of the societal cost of damage from emissions (New Zealand Transport Authority, 2021). This study establishes a value of NZ $61 per tonne of CO_2 in 2020 dollars (as at August 2021), which we have inflated to $63.04 in 2021 dollars. The monetary value used here, to value the social cost of emissions in project evaluations, has no relationship to the level of carbon tax or carbon price that the government might consider as a policy instrument to restrain CO_2 emissions.

Structural fire GHG emission costs are estimated to be between $1.1 million and $1.5 million

A House Fire GHG Emissions estimate tool was developed by Scion and BRANZ in 2010 (Love, Robbins, Page, & Jaques, 2010). Because of the estimation of the housing stock using an exemplar house approach,[2] the results are most relevant in terms of a national average. The scenarios considered in this study for comparison use an analysis period of 50 years.

The House Fire GHG Emissions estimate tool is based on input parameters for:

- Numbers of house structure fires per year,
- Current numbers of housing stock,
- Rate of increase of housing stock numbers,
- Percentages of house floor areas lost to fire,
- Types and amounts of materials involved in house structures,
- Numbers and masses of items included in house contents,
- CO2 yields for materials and items included in the framework,
- Effectiveness of suppression strategies considered, and
- Extent and rate of installation of these suppression strategies in houses.

[2] Construction of the NZ housing stock is diverse; therefore use of an exemplar house was used. Types and amounts of materials were estimated for exemplar houses representing the top six combinations of foundation, wall and roof claddings (reference Table 17 in the Scion and BRANZ report). Similarly, numbers of items and masses of contents were estimated for an exemplar house.

The results of the House Fire GHG Emissions estimate tool are reported in CO_2 equivalents. The House Fire GHG Emissions estimate tool only considers the GHG emissions related to the fire loss of the house structure and contents.

Total building damage is observed from FENZ incident data. Similar to property damage, this is given in ten percent brackets from zero to 100, although in this instance, we only use this single house category. Residential fire CO_2 emissions were then estimated by multiplying the median damage percent by the number of incidents in the damage bracket by the Love et al. emissions estimates. Because Love et al.'s emissions were reported as a range, we have a range for the cost of residential estimates.

We then extend the cost per fire structural estimate to commercial and industrial fires. In the absence of area damage data, we use the assumption that the average commercial fire is equal in size to a residential fire. We assume that per incident, industrial fires emit an average of 1.9 times more GHGs than residential fires. This figure is derived by using Stats NZ consent data to calculate the factor that the average square metres of 'factories and industrial buildings' is greater than the average floor area of 'houses', i.e. average floor area of houses divided by the average floor area of factories and industrial buildings. These assumptions result in the cost per fire estimates reported in Table 20. Combining these per fire cost estimates (commercial and industrial) with the respective damage estimates, estimated using the same method as residential fire damage (damage bracket multiplied by incidents in the respective damage bracket), yields the commercial and industrial total cost figures reported in Table 20.

Robbins et al. (2008) address the CO_2 emissions associated with the replacement of a house structure. We acknowledge that this replacement cost would complement our damage estimate, however, this emissions estimate is reported in "New Zealand Ecopoints". Ecopoints are a metric for the measure of environmental related costs and benefits, with 100 Ecopoints representing the average yearly environmental impact of one New Zealander. However, Ecopoints are not directly translatable to GHG emissions, as such, we are unable to attribute these a monetary value.

Vegetation fire GHG emissions are estimated to cost $8.99 million

Deforestation fires are a particularly important contributor to climate change as these result in a long-term loss of carbon to the atmosphere. We use BERL's (2009) economic cost of wildfires and an MPI estimate of CO_2 emissions from wildfires to inform our estimation.

We use BERL's (2009) distributions, which are based on ten year averages of wildfires from 1991/92 to 2007/08, to categorise FENZ's vegetation fire data into grass (47.1 percent), scrub (45.2 percent), and forest wildfires (7.6 percent). These categories were multiplied by their respective carbon sequestration rates, assumed to be:

- 7 tonnes per hectare for grass fires (BERL, 2009),
- 34 tonnes per hectare for scrub fires (BERL, 2009), and
- 111 tonnes per hectare for forest fires (Holdaway, et al., 2014).

These assumptions were based on suggestions from Landcare Research, the Ministry of Agriculture and Forestry, and MPI modelling of tree mortality and subsequent growth and wood decay processes.

Additionally, we assumed 50 percent of carbon across all three categories is consumed in a fire – an assumption informed by SCION's recommendation in BERL.

Multiplying the total CO_2 emissions estimate with the cost per tonne of CO_2 results in total costs of $1.09 million for grass fires, $5.10 million for scrub fires, and $2.80 million for forest fires in 2019/20. These estimates can be seen in Table 20.

Table 20: GHG emissions from structure and vegetation fires

	GHG Estimate	GHG value estimate per unit (at $63.04 per tonne)	Number of fires per year	Total cost ($M)
Residential buildings	The complete fire loss of the exemplar house structure releases approximately 27 to 38 t CO_2 Equivalent.	$1,702 - $2,395 per house fire	2,679 fires p.a.	**0.93 - 1.31**
Commercial buildings (exc. industrial)	Assumed equal to residential buildings	$1,702 - $2,395 per house fire	190 incidents p.a.	**0.03 - 0.05**
Industrial buildings	1.9 times larger than residential buildings	$3,260 - $4,588 per house fire	161 incidents p.a.	**0.06 - 0.09**
Vegetation (tonnes of CO_2)	7 per ha for grass 34 per ha for scrub 111 per ha for forest	$441 per ha grass $2,143 per ha scrub $6,997 per ha forest	4,950 ha grass 4,751 ha scrub 799 ha forest	**8.99**
Total				**10.01 - 10.43**

Source: FENZ incident data, NZTA tool, Love et al. (2010), Holdaway et al. (2005), and Robbins et al. (2008)

There are some limitations to these estimates:

- An estimate of CO_2 emissions from industrial buildings has not been made in New Zealand. In the UK, Entec previously undertook an emissions inventory for the Fire Service College (this is referenced in the 2006 UK cost of fire study). This detailed the impacts to air from various burn activities and could potentially be used to estimate average emissions from fires in certain building types (office, industrial, dwellings) based on the types of materials likely to be found therein. It should be noted this might provide an approximate estimate for emissions in NZ, but it would be based on a number of assumptions and would relate to UK buildings.
- Malicious fires may be more harmful as they are likely to use accelerants like petrol. This has not been accounted for in the estimates above.

- The replacement of house structures was given in "Ecopoints". Given Ecopoints are not directly convertible to GHG emissions, we are unable to attribute a monetary value to the emissions from the replacement of a house structure.
- Could argue that over long run, emissions would be released anyway through demolition and replacement. This is about a point estimate of costs in a year attributable to fire.
- Cost of rebuild; replacement contributes to emissions (e.g. transport).
- We assume the GHG emissions from the contents and structure of a residential building are equal to an industrial building i.e. if the buildings had the same floor area, they would have the same emissions.
- GHG emissions from forests and natural landscapes will be highly variable from year to year. The figure used is an average, meaning it is highly likely there will be variation from this each year – the extent of this variation will be dependent on the number and scale of vegetation fires incidents.

Other harmful emissions

The 2006 UK study only notes the negative impacts of other harmful substances. However, the 2009 Australian study acknowledges atmospheric haze and the potential for it to exacerbate existing respiratory and cardiovascular illnesses e.g. bronchitis or pneumonia (Ashe, McAneney, & Pitman, 2009). These illnesses will directly impact costs through increased hospital/emergency room visits, and also indirectly through the opportunity cost of an individual's time i.e. time that would otherwise be spent working.

Recent examples of (relatively) large fires in New Zealand include the Port Hill fire in Christchurch or the Lake Ohau fire. However, because of their small size relative to Australia's large scale annual bush fires, the haze emitted was too small to cause any adverse health effects. If these negative health effects had occurred, they would have happened on a scale too small to accurately quantify, meaning atmospheric haze will not significantly influence findings.

3.6.2 Water consumption tackling fires

We have estimated the cost of water use using Watercare's domestic/commercial per litre rates and FENZ estimates of water use per fire. Watercare's per litre rates for domestic and commercial users is $1.706 per cubic metre of water. This is a comparatively low estimate (Waikato District charges $2.05 per cubic metre of water). We exclude costs of wastewater from our estimates given the majority of water used to fight fires runs into stormwater drains or is absorbed by the ground.[3]

To estimate the total cost of water consumption, we multiply this per litre rate by an approximation of annual water usage. The annual water usage figure is approximated using FENZ's data on the average water usage in different building types, with different levels of damage, and the average number of

[3] Watercare recommendation.

fires (ten year average) in a given year. To carry out this estimation, certain assumptions were implemented, including:

- Only the number of fires with structural damage were included – assumes fires with no structural damage require minimal water.
- The percent of damage is taken from FENZ's statistics – estimates are only as accurate as the officer doing the assessment.
- The quantities of water used are an approximation dependent on the building type and damage.

Data included water usage for eight locations,[4] whereby the water usage was dependent on the percent of the building damaged. Implementing these assumptions to the data provided yielded the following table on water usage:

Table 21: Water usage by location and damage

(cubic metres of water, m^3)	Small (20%)	Room (50%)	Firecell (10%)	Structure (20%)	Extend (5%)	Total
Assembly	7	101	338	2,700	1,013	**4,158**
Commercial	20	293	975	7,800	2,925	**12,012**
Education	6	90	300	2,400	900	**3,696**
Healthcare	3	50	166	1,328	498	**2,045**
Manufacturing	9	129	430	8,600	43,000	**52,168**
Primary industry	11	165	550	4,400	1,650	**6,776**
Residential	185	1,388	2,405	9,250	3,238	**16,465**
Storage	8	126	420	3,360	1,260	**5,174**
Total	**249**	**2,341**	**5,584**	**39,838**	**54,483**	**102,494**

Source: Watercare water rates, FENZ estimates.

Combining the total water usage of 102,494 cubic metres with our cost per cubic metre yields an annual cost of $174,855 for water usage.

3.6.3 Loss of Biodiversity

Fire can affect biodiversity in waterways and on landscapes.

Biodiversity losses to landscapes

Costs associated with biodiversity losses are highly site specific and are best captured qualitatively. For example, the UK study used short case studies to illustrate biodiversity losses in different landscapes.

Historical wildfire data reveal that very little indigenous forest has been damaged by fire over the last two decades (Holdaway, et al., 2014). Even species such as mānuka (Leptospermum scoparium) and

[4] Locations included assembly, commercial, education, healthcare manufacturing, primary industry, residential, and storage.

kānuka (Kunzea ericoides) that are considered highly flammable in New Zealand have low ignitibility on an international scale (Holdaway, et al., 2014). Some forest types – mānuka and kānuka in particular – do propagate fire well once the fire has become established (usually in surrounding grassland or shrubland), but this generally requires weather conditions that are favourable to fire spread. In other words, biodiversity loss in forest areas will predominantly be felt in planted forests, not native forests.

Biodiversity losses in waterways

Biodiversity losses as a consequence of fire on waterways are outlined in the NZ Fire pollution study from Landcare (Moore, Burns, O'Halloran, & Booth, 2007).

The study reflected the wide diversity of contaminants that can be carried by firewater from industrial complexes or vehicles, into stormwater systems and eventually to streams. Fire water can flood chemical storage containers and flush spilt contaminants or burnt material into stormwater systems.

Most of the fire-water pollution incident files obtained during this study described fire-water discharges that quickly reached small streams, although some of these receiving waters were close to the confluence with much larger rivers or estuaries, reflecting the proximity of Auckland urban areas to estuaries. Data showed that fire water is highly toxic to mayflies. Fire water could be hazardous even without any contaminants because of the potential heat of water draining from a fire scene. The potential for fire-water heat and toxicity to cause problems in receiving waters will relate to the concentrations of contaminants and the temperature of water leaving the fire scene, the duration of fire-water discharge, any dilution from other stormwater or groundwater sources, and the dilution provided by the receiving waters. The sensitivity of the receiving environment will also vary from place to place, depending on the quality of the habitat and the types of aquatic species present.

No quantifications in monetary terms are possible from this study.

The study is limited in that it only captures data from fires in industrial buildings (this is because all records the researchers extracted from Regional Council fires related to industrial buildings. No records were available from residential and other buildings).

We are also aware of increased runoff from fires affecting water quality. Vegetation removed from fire exposes soil to increased runoff, negatively affecting waterway quality. Evidence of this is anecdotal and any attempt to quantify this impact would be highly speculative. We therefore do not attempt to attribute a monetary figure to this loss.

3.6.4 Debris to landfill

Debris left in the aftermath of fire represents a significant environmental cost.

Buildings can get demolished after fires; an expert from FENZ estimates there could be 20-30 tonnes of waste generated for a house that goes to landfill. Using the CBAx database, this debris is valued at $63 per tonne. Borrowing the earlier assumption from GHG emissions, we assume a commercial fire incident is equal in size to a residential fire incident, and that an industrial fire incident is equal to 1.9 times a residential, implementing the assumption used in the industrial fire GHG emissions estimate.

Multiplying these debris estimates by the CBAx cost of debris results in the average landfill waste estimate per incident. To extrapolate this per incident estimate to all fires, we use a method similar to the GHG emissions – in each category, multiplying the median damage (from the damage bracket) by the number of incidents in each bracket. This multiplication results in the equivalent number of full structures damaged in the residential, commercial, and industrial categories. Multiplying these costs per fire with the respective incidents and summing the resulting figures yields our total cost of debris of $0.95 million.

Table 22: Total cost of debris

	Debris Estimate	Landfill waste estimate per incident	Equivalent number of full structures damaged	Total cost ($M)
Residential	25 tonnes	$1,575	546	**0.86**
Commercial	25 tonnes	$1,575	20	**0.031**
Industrial	48 tonnes	$3,016	19	**0.06**
Total				**0.95**

Source: CBAx database, FENZ consultation.

3.6.5 Environmental clean-up

Unlike the UK model we have not included a separate cost estimate for the long-term monitoring and control of contaminated waters. In serious cases, such costs would be covered by the insurance pay-outs that are already incorporated elsewhere into the model.

3.7 Criminal justice system costs

Costs to the criminal justice system include the costs associated with police, court and sentencing costs, and the costs of imprisonment. Data on the number of fire-related property offences is published by the Ministry of Justice ("All charges and convicted charges").

The focus is on:

- Offence type (ANZSOC division): 12: Property damage and environmental pollution
  - ANZSOC subdivision 121: Property damage
    - ANZSOC group: Property damage by fire or explosion

In 2019/20 (averaging 2019 and 2020) there were 285 charges (of which 157 cases resulted in convictions).

The costs to the criminal justice system of processing these cases were estimated by using cost data in a publicly available New Zealand Treasury working paper from 2004. That work shows core justice sector fiscal costs (net of court fines) and provides a fiscal cost per property damage incident recorded. That per incident figure is inflated using CPI, from $1,633 in 2004 to $2,316 in 2020. Applying this per incident cost to the number of charges identified above, results in an estimated cost of $0.66 million in 2019/20.

4. Costs in response

Costs in response are costs associated with responding to fire incidents. This section outlines the composition of costs in response, comprising:

- response resource costs
- firefighting capital costs
- the marginal cost of false alarms,
- volunteer costs.

4.1 Response resource costs

Response resource costs are the operating expenses of FENZ that relate to the capacity to respond fire-related incidents.

Response resource costs were highlighted by all studies as a significant cost in response to fire. These costs are generally associated with fire risk management e.g. the cost of paid and volunteer labour. However, many of these costs will be fixed, given the unexpected nature of fire incidents and the requirement for firefighters to be constantly on call. Data for response resource costs were provided by FENZ. These data were sectioned into structural, vegetation, and other costs. Structural costs include the resource costs of responding to commercial and recreational fires in buildings. Vegetation costs include the resource costs of responding to all vegetation fires (both large and small) e.g. the hire of aircraft. Other costs include all extra costs not covered under the other headings.

4.1.1 Direct resource response costs

Similar to fire safety activity, we include a cost for the transition to FENZ. We add a component of the transition to FENZ cost proportionate to the size of the other components i.e. fire safety activity, resource response costs, and reduced harm from activities costs. Since resource response costs makes up 58% of year-on-year outputs costs (2019/20), we add 58% of the transition to FENZ cost to the total resource response cost. This addition results in total resource response costs of $348.38 million.

Table 23: Fire resource response costs, 2017/18 – 2019/20

($M)	2017/18	2018/19	2019/20
Resource response costs			
Fire Response, Structural	107.15	128.47	181.38
Fire Response, Vegetation	63.94	64.73	23.76
Fire Response, Other	94.72	112.21	132.62
Sub-total	**265.81**	**305.41**	**337.75**
Proportion of year-on-year output	56%	55%	58%
Transition to FENZ	13.14	11.80	10.62
Total direct resource response costs	**278.96**	**317.21**	**348.38**

Source: FENZ data

Overall, resource response costs are increasing (relatively) steadily over time. However, fire responses to vegetation are understandably volatile, given their susceptibility to individual events that happen in a year. Structural and other resource response costs experienced relatively consistent increases over the two years, although given the magnitude of these, the costs will unlikely continue to increase at the same rate.

4.1.2 Indirect resource response costs

FENZ's GHG emissions were included as indirect response resource costs. As stated in Fire safety activity, FENZ's total GHG emissions were separated into the three scopes. In this case, Scope 1 and Scope 3 were included as indirect resource response costs. [5] These scopes were attributed to resource response costs because of the GHG emissions arising from FENZ's fire response activities e.g. from fire trucks on route to fires for Scope 1, or emissions from contracted helicopters for Scope 3.

Emissions for these two scopes totalled 10,620 tonnes of CO_2 equivalent. Combining this tonnage with NZTA's cost per tonne of $63.04 results in a total cost figure of $0.67 million. A caveat when using this is estimate is that these emissions were expended as part of a process to fight fires and reduce further emissions. Estimates of the emissions saved by FENZ's activities were unavailable and therefore not included in our model. This exemption is done in the belief that the relative cost of these emissions saved is small, meaning there will be no material change in findings.

Table 24: Total resource response costs

($M)	2019/20
Direct resource response costs	348.38
Indirect resource response costs	0.67
Total resource response costs	**349.05**

Source: FENZ data, Toitū Envirocare GHG emissions report

4.2 Firefighting capital costs

Firefighting capital costs were highlighted across all studies to be a significant cost in response to fires. For New Zealand, these capital costs are associated with the annual consumption of capital by FENZ e.g. fire trucks. Similar to both UK models, we class these as a cost in response to fires.

Data for these costs were provided by FENZ in two forms. The first includes the annual capital expenditure (CAPEX) for the 2019/20 period, split into the asset types of ICT, equipment, fleet, and property. The second includes asset values for these asset types and their respective lifetime estimates (upper and lower), also for the 2019/20 period.

Total firefighting capital costs amount to $102 million.

After consultation with FENZ, we deem annual capital expenditure as total firefighting capital costs. To portion out this CAPEX, we estimate depreciation for each asset type. To do so, we use the upper and

[5] Scope 1 - includes emissions from sources owned or controlled by FENZ. Scope 3 – includes emissions that occur from FENZ's activities, but from sources not owned or controlled by FENZ.

lower estimated life figures to calculate annual depreciation rates for each asset type i.e. an estimated life of 20 years would mean an annual depreciation rate of 5%. Combining these depreciation rates with their respective asset values generates an annual depreciation figure for each asset type – using the straight-line method of depreciation. These figures are shown in Table 25.

Table 25: Firefighting capital components

($M)	Expenditure	Consumption
ICT	17.52	26.26
Equipment	9.96	9.76
Fleet	29.36	14.44
Property (fit out)	-	0.87
Property (land and buildings)	44.98	14.09
Total	**101.82**	**65.42**

Source: FENZ data

When comparing the CAPEX and depreciation figures, depreciation can be seen as the average annual loss in assets, meaning the proportion of CAPEX that is depreciation, is the proportion spent on replacing the existing asset base. In this case, 64% of total CAPEX spending is for replacing existing ICT, equipment, fleet, and property. The remaining 36% can be seen as expenditure on

- improving the quality of existing capital, for example, modernising equipment,
- expanding the volume of FENZ's capital, for example, increasing the number of fire trucks in the current fleet, or
- deferred capital spending, for example purchasing a new fire truck today and annuitizing the cost over future years.

This theory can be extended for all individual asset types. Interestingly, ICT depreciation spending is greater than CAPEX, meaning FENZ's ICT assets decreased in the 2019/20 year. This deficit is likely caused by the nature of technology i.e. high deprecation rates and large on off costs. If these costs are not annuitized, there will be fluctuations in surpluses and deficits, as is the case for FENZ's ICT spending for 2019/20.

4.3 Marginal cost of false alarms

The cost of false alarms was highlighted across numerous studies to be a significant cost in response. We will follow the UK 2006 approach and observe the marginal cost of these. Marginal cost refers to the cost of each additional unit, the adverse of this is the average cost, referring to the total cost attributed to false alarms (by FENZ) divided by the total number of false alarms. In this case, it is more appropriate to investigate the cost of each additional false alarm, given fire crews and resources were already available to respond to fires, irrespective of whether there were any false alarms – meaning this fixed portion of costs should not be included in the cost of false alarms.

We note the exclusion of FENZ's costs of false alarms given these costs would be accounted for in response resource costs and response capital costs.

Data on the total number of false alarms were provided by FENZ and data on the cost were provided by BERL (2019). FENZ data included the total number of false alarm incidents, split into eight categories based on the cause of the false alarm. BERL's data included a time series of the GDP lost due to unwanted alarms for 2013 to 2018.

Our estimation involved using each year's total GDP loss figure and the number of false alarms to estimate a total cost per call. These five figures were averaged and inflated to 2021 dollars, resulting in an average GDP cost per false alarms. This average cost per false alarm was multiplied by the total number of false alarms in 2019/20 to estimate the total cost of false alarms at $8.90 million.

Limitations of this method

We acknowledge that this is an aggregate figure. Lack of granularity in the data meant we were unable to break the number of incidents down by building type and therefore estimate GDP loss per incident, in each building type. Instead, we had to rely on assumptions stated in the surrounding literature. Further research may wish to obtain more granular data to enable verification of our estimates.

We also acknowledge our estimate is a maximum. The total loss for a firm is likely to be less than the time lost multiplied by hours, due to the absorption of time by other company processes in place. For example, an hour lost due to a false alarm may mean an employee has to work an extra hour of overtime. However, this will not always happen, and the firm will lose the output value of time lost. Therefore, the true cost of false alarms is likely to sit between the lower input and upper output value of time.

4.4 Volunteer response costs

As mentioned in section 2.4 Anticipatory volunteering activity, volunteering costs were not present in the UK studies. We use a method similar to Ashe et al. (2009) by using the total number of volunteer hours to extrapolate a monetary figure for volunteer response costs.

The data for this section is provided from FENZ, and obtained from Stats NZ and NZTA. FENZ provided estimates of volunteer fire fighters' incident hours and the dollar value of incident reimbursement. Data on the earnings of New Zealanders were obtained from Stats NZ, and the value of travel time savings was obtained from NZTA.

Volunteers' time spent responding to incidents is split into work and leisure

We split volunteers' incident responsibility activity into work and leisure categories. As this distribution is unknown, we allocate 1/3 as working hours and 2/3 as leisure hours – assuming fire incidents are distributed evenly across the day.

The average New Zealander's hourly earnings is used to value work hours, and NZTA's value of travel time saving is used as a proxy for the cost of leisure.[6] In this instance, volunteers' hours spent firefighting represents an opportunity cost of work and leisure time.

[6] Definition of NZTA's value of travel time saving can be found in 2.4 Anticipatory volunteering activity.

Total volunteer response costs are estimated at $1.23 million

We value the cost of work hours lost at $0.76 million and the cost of leisure time at $0.47 million. Note FENZ provided incident payments that were omitted from this total because these payments were reimbursements for volunteers' loss of wages, meaning including these would be double counting a portion of the opportunity cost of time.

Table 26: The value of the opportunity cost of work and leisure

	Work	Leisure
Incident hours	23,224	46,448
Total cost ($M)	**0.76**	**0.47**

Source: FENZ data, Stats NZ earnings data, and NZTA monetised benefits and costs manual

5. Results

The headline result is that **the cost of fire in New Zealand is estimated at $2.008 billion** in 2019/20, with a plausible range being estimated at $1.598 to $2.435 billion (or ±21 percent). As a comparison to provide a sense of scale, this result is equivalent to 0.6 percent of GDP in 2019/20, with the range being 0.5 to 0.8 percent of GDP.

Table 27 presents the results by category and component. Costs in anticipation are the largest of the three main categories, accounting for $1.017 billion (i.e. 50.6 percent of the total), followed by costs as a consequence at $530 million (26.4 percent), and costs in response at $461 million (23.0 percent).

The uncertainty is higher within the costs in anticipation and costs as a consequence. Fire protection in buildings is estimated at $730 million, with the plausible range of $540 million (-26 percent) to $1,021 million (+40 percent). Damage to property is estimated at $417 million, with the plausible range of $273 million (-35 percent) to $534 million (+28 percent). In contrast, the costs in response are largely based on actual expenditure figures and so the uncertainty is lower.

Table 27: Estimated cost of fire – summary of results, 2019/20

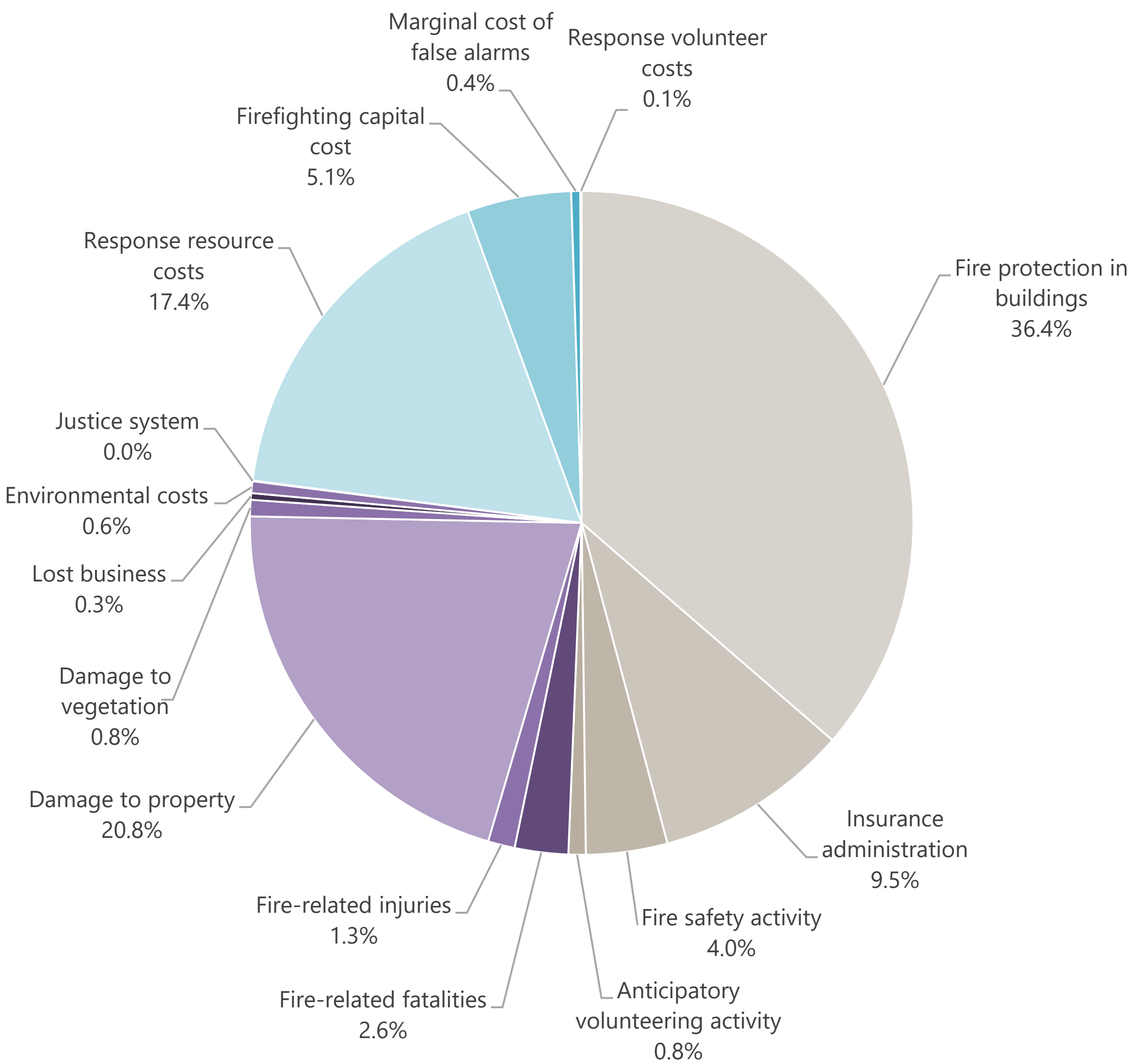
Category	Component	Result ($M)	Low ($M)	High ($M)
Costs in anticipation	Fire protection in buildings	730	540	1,021
	Insurance administration	190	175	205
	Fire safety activity	80	80	80
	Anticipatory volunteering activity	17	17	17
	Subtotal	**1,017**	**812**	**1,323**
Costs as a consequence	Fire-related fatalities	52	52	52
	Fire-related injuries	26	26	26
	Damage to property	417	273	534
	Damage to vegetation	16	16	16
	Lost business	7	4	10
	Environmental costs	11	11	12
	Justice system	1	1	1
	Subtotal	**530**	**383**	**651**
Costs in response	Response resource costs	349	349	349
	Firefighting capital cost	102	44	102
	Marginal cost of false alarms	9	9	9
	Response volunteer costs	1	1	1
	Subtotal	**461**	**404**	**461**
Total		**2,008**	**1,598**	**2,435**

Source: Sapere cost model

Figure 3 illustrates the relative shares of the categories of the estimated cost. Broadly, the costs in anticipation account for approximately half of the overall cost, with the categories of the costs as a consequence and costs in response each accounting for approximately one quarter.

Among the components, the overall result is dominated by three large components that together comprise three-quarters of the estimated total cost of fire. The largest component is fire protection in buildings (36 percent), followed by damage to property (21 percent), and resource response costs (17 percent). Other sizeable components include insurance administration (10 percent), the capital costs of the fire service (5 percent) and fire safety activities (4 percent).

Figure 3: Components of the estimated cost of fire, 2019/20



Source: Sapere cost model

6. Discussion

This chapter places the results in context and considers areas of uncertainty and possible extensions.

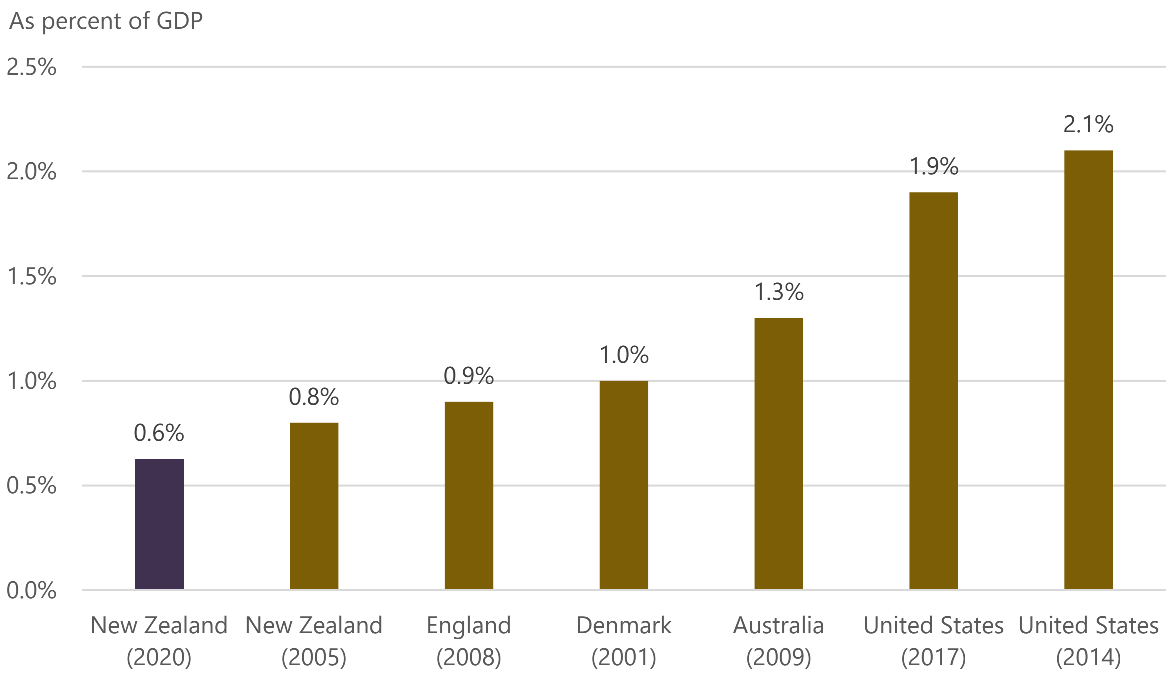
6.1 Comparison with prior studies

The results can be placed in the context of prior country-level studies into the cost of fire, as a test of reasonableness. Some caution is required as the results vary among the studies according to the differences in the scope of costs being quantified, the estimation method, and the potential for year-to-year variation in fire incidents to impact on costs as a consequence. Nevertheless, it is still of interest to compare the results with prior studies.

A simple approach is to place the results in the context of GDP at that time – as a reference for the scale of the costs being estimated. Figure 4 compares the results alongside that of six prior studies across five countries of Australia, Denmark, England, the United States as well as New Zealand. The results from prior studies range from 0.8 percent of GDP in New Zealand in 2005 to 2.1 percent of GDP in the United States in 2014.

It is noticeable that the prior estimate for New Zealand, undertaken by BERL for the New Zealand Fire Commission in 2005, was at the lower end of the range of results from prior studies. The result obtained for this work is slightly lower still, i.e. being 0.6 percent of GDP (with a range of 0.5 to 0.8). However, as the upper bound of our estimate overlaps with BERL's prior estimate i.e. both are 0.8 percent of GDP, it is useful to examine the possible reasons for this.

Figure 4: Comparison of results from prior studies as a percentage of GDP



Note: The result for England uses gross value added (GVA) as GDP data is not available at a lower level than the UK as a whole.

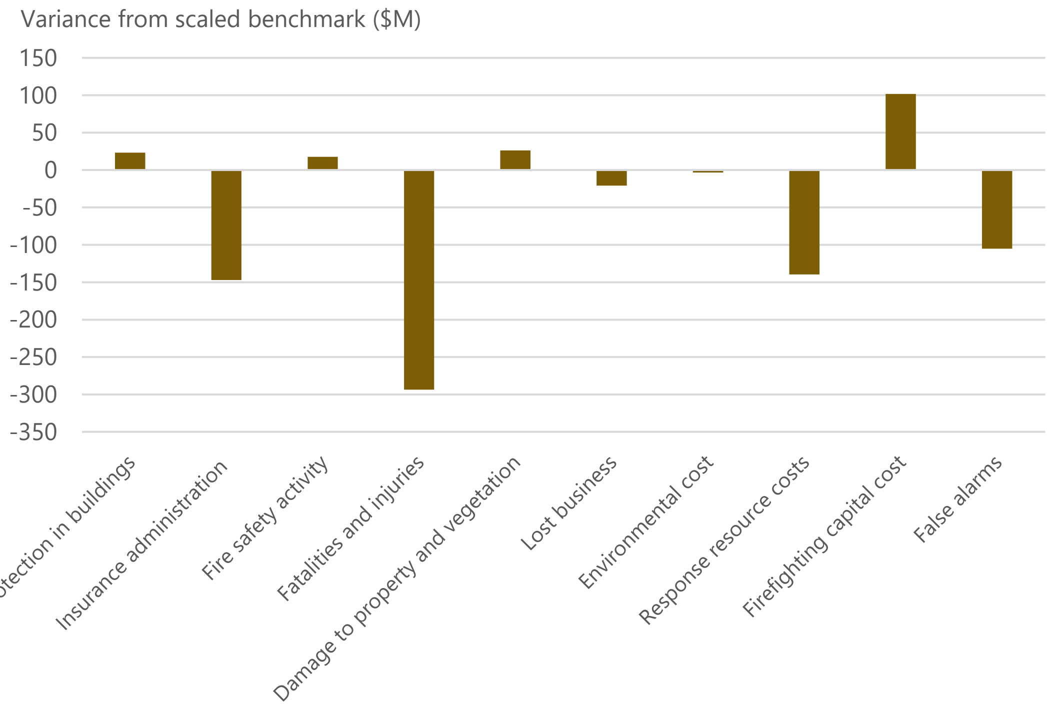
Source: BERL (2005), DCLG (2011a), Ashe et al (2009), Zhuang et al (2017), Hall (2014)

The approach is to take the result obtained in 2005 and to scale up the components of cost for the growth in GDP between 2005 and 2019/20. This scaled up result provides a benchmark of the costs of fire – if those earlier results had followed growth in the economy over time. Figure 5 shows how the results obtained in this work vary from that benchmark. It is noticeable that the two largest components have relatively small variances – i.e. fire protection in buildings (+$23 million) and damage to property and vegetation (+$26 million). These variances are due to differences in method used in each study and their relatively small size provides some measure of confidence in the results obtained for this work. The variances of two other components are of particular interest.

- Fatalities and injuries, combined here, have the largest variance relative to the benchmark, being $293 million lower. This is mainly driven by the number of fatalities in 2019/20 (11) being much lower than in 2005 (35) and also by the Value of a Statistical Life increasing more slowly than the growth in GDP over this period. These factors account for $190 million of this variance. A lower estimate cost for injuries accounts for the remainder.
- Resource response costs are lower than the benchmark, by $140 million, with the actual expenditure being a function of policy settings. Alongside this, expenditure on safety activities has grown more quickly, being slightly above the benchmark ($18 million).

These two components account for approximately 80 percent of total variance. If these components had grown with GDP, then the total result of this work would be similar to that obtained in 2005, as a percentage of GDP. However, some of the component costs of fire clearly increase more slowly than GDP over time. This finding is not unreasonable as some components are not necessarily linked to growth in the economy. This might be expected in the case of the resource response costs (where there may be capacity) and fatalities and injuries (where safety activities can make an impact).

Figure 5: Variance analysis – estimated cost of fire relative to scaled benchmark



Source: Sapere analysis

A further check on the reasonableness of the results is to compare the category and component shares with those in prior studies that used a similar framework of costs. Table 28 shows that the three categories of cost, as shares of total cost, fall within the ranges observable across the comparator studies. This is generally the case among the cost components, with the exception of fire safety activity and damage to property, which are higher than the ranges observable across the studies.

- Fire safety activity, largely reflecting actual expenditure, accounts for 4.0 percent of costs, compared with the range of 0.3-2.5 percent among other studies. Alongside this, it is worth noting that fatalities and injuries account for 3.9 percent of total costs, which is at the low end of the range of 3.1-19.6 percent; this may be due to the focus here on avoidable fire fatalities and it is possible that other studies include intentional fatalities (this is not stated).
- The component of damage to property (and vegetation) comprises 21.6 percent of total costs, whereas the range across other studies is 8.3-17.0 percent.

On a component share basis, the results of this work largely lie with the ranges observable in other studies, although this exercise also underlines the variability among the findings of those prior studies.

Table 28: Comparison with prior studies

Category	Component	NZ (2020)	NZ (2005)	UK (2006)	AUS (2009)
Costs in anticipation	Fire protection in buildings	36.4%	27.9%	31.1%	40.4%
	Insurance administration	9.5%	13.3%	6.4%	2.7%
	Fire safety activity	4.0%	2.5%	0.4%	0.3%
	Anticipatory volunteering activity	0.8%	-	-	-
	Fire safety in consumer items	-	-	-	13.5%
	Sub-total	**50.6%**	**43.7%**	**37.8%**	**57.1%**
Costs as a consequence	Fatalities and injuries	3.9%	14.7%	19.6%	3.1%
	Damage to property and vegetation	21.6%	16.1%	17.0%	8.3%
	Lost business	0.3%	1.1%	0.4%	0.4%
	Environmental cost	0.6%	0.6%	-	1.6%
	Justice system	0.0%	-	4.9%	-
	Community / heritage costs	-	-	-	0.4%
	Sub-total	**26.4%**	**32.5%**	**41.9%**	**14.0%**
Costs in response	Response resource costs	17.4%	19.3%	19.5%	28.9%
	Firefighting capital cost	5.1%	-	-	-
	False alarms	0.4%	4.5%	0.8%	-
	Response volunteer costs	0.1%	-	-	-
	Sub-total	**23.0%**	**23.8%**	**20.3%**	**28.9%**
Total cost of fire	**Sum of components**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Sapere, BERL (2005), DCLG (2011a), Ashe et al (2009)

6.2 Sources of uncertainty

An estimate of the annual cost of fire comes with some uncertainty as to the actual underlying cost. This is a point made in all the prior studies. A key source of uncertainty relates to the use of estimation in the absence of comprehensive data of the actual costs of fire. In particular, the need to estimate the largest components of cost – namely, fire protection in buildings and damage to property. The estimates of these costs have been included after comparing the strengths and weaknesses of the two methods and examining a plausible range with high and low assumptions. The cost of insurance administration is also a sizeable component where estimation has been necessary, and a plausible range identified has been identified for the results. Overall, the combined effect of the modelled uncertainty in these and several other smaller components is equivalent to ±21 percent of the reported total cost.

Another source of uncertainty is the year-to-year variation in the number of fire incidents. A given year could be high or low relative to other years, in terms of the frequency of incidents. The annual change in the number of structural fire incidents has been within ±7 percent over the period from 2015/16 to 2020/21. This variation in frequency directly affects some cost components, estimated below to account for approximately one-quarter of total costs, although the impact also depends on the type and scale of the fires, damage caused, and the number of fire-related injuries and fatalities. The above parameters suggest that the scale of uncertainty associated with variation in the frequency of fire incidents is likely to be lower than that associated with the reliance on estimation in the absence of data on actual costs.

6.3 Sensitivity to fire incident variation

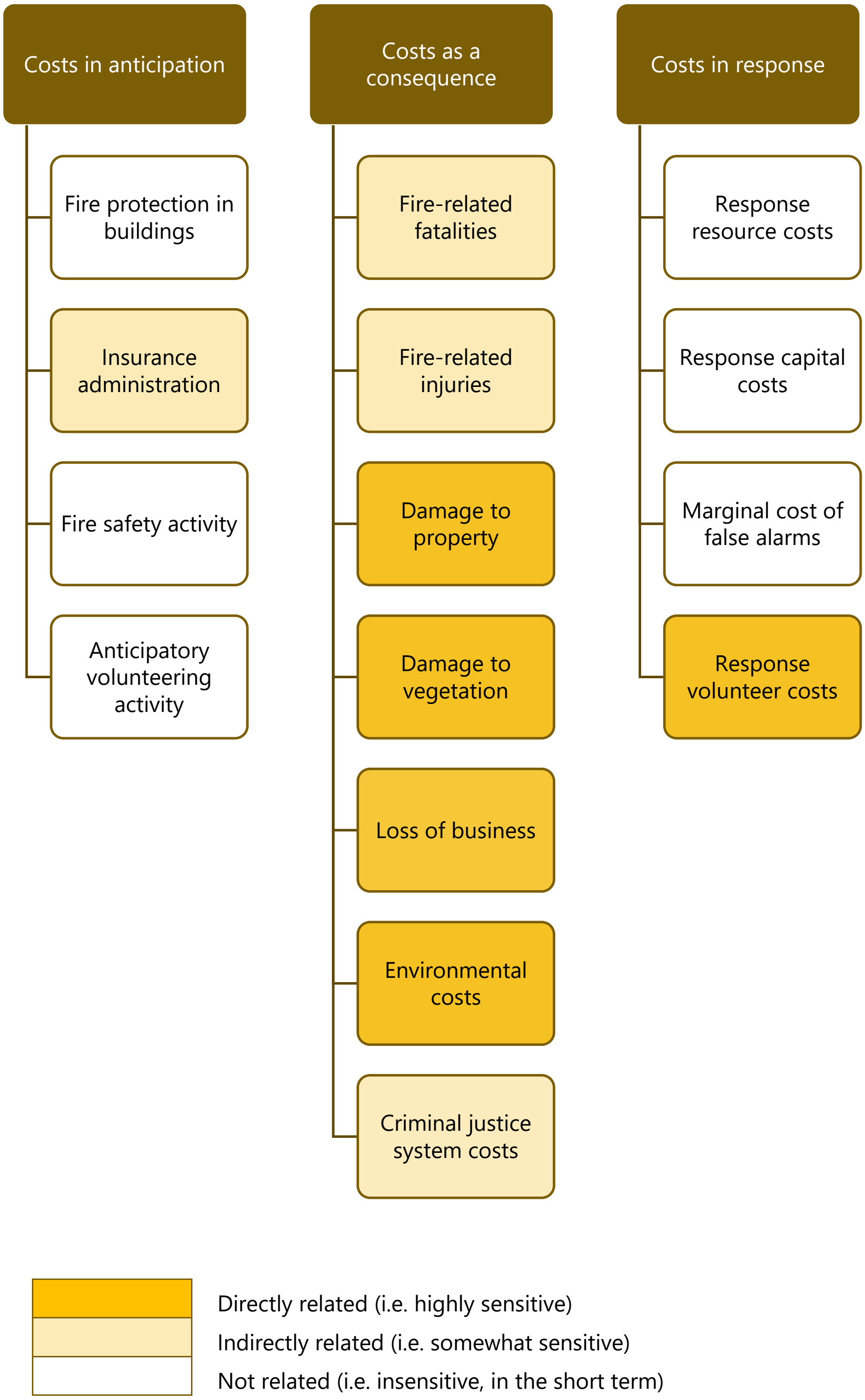
The components of cost can be categorised with respect to their sensitivity to annual variation in the fire incidents, being directly related (i.e. highly sensitive), indirectly related (i.e. somewhat sensitive), or not related (i.e. insensitive). This categorisation is for short-term sensitivity; in the longer term, all costs will be sensitive to trends or level shifts in fire incident numbers. Figure 6 illustrates the categorisation.

The following components are categorised as directly related (i.e. highly sensitive) to annual variation in fire incidents: damage to property, damage to vegetation, loss of business, environmental costs, and response volunteer costs. These costs account for 23 percent of the estimated total cost. A lower number of fire incidents in a given year would see these costs being lower, although the type and scale of fires are also factors.

Cost components that are categorised as being indirectly related (i.e. somewhat sensitive) to annual variation in fire incidents are insurance administration costs (a function of all insurance claims), fire-related fatalities, fire-related injuries, and costs to the criminal justice system. While these components are not as directly linked to variation in the number of fire incidents, they can be affected by increases or decreases in the number of incidents. These costs account for 13 percent of the estimated total.

Components that are categorised as being not related (i.e. insensitive) to annual variation in fire incidents are, in the main, determined by fixed budgets and regulatory settings: fire protection in buildings, fire safety activity, anticipatory volunteering activity, response resource costs, firefighting capital costs, and the marginal cost of false alarms. These costs account for 64 percent of the estimated total cost of fire.

Figure 6: Cost components categorised by sensitivity to variation in fire incidents



Source: Sapere

6.4 Unquantified costs

Several cost components have not been quantified due to an absence of data or their intangibility. The judgment here is that this work is better served by not attempting to make crude estimates of these costs, which may not withstand scrutiny.

Community costs are mentioned in most prior studies and refer to direct or indirect costs borne by communities as a consequence of fire, for example, the loss of heritage, and the decline in appearance affecting community wellbeing, property values, and the ability to attract investment. These costs are typically described qualitatively (DCLG 2011a; BERL 2012). The Australian study (Ashe et al, 2009) attempted to estimate heritage and cultural costs, using an extrapolation of two isolated incidents, we feel this approach was not appropriate in our case.

Other examples of costs not quantified in this work include the following.

- Costs of inconvenience – the lost time from fire drills or from dealing with secondary consequences of fire, for example, time spent on administrative activities to recover costs.
- Costs of lost productivity – associated with the costs of evacuation scheme approval and maintenance.
- Water use fighting vegetation fires – there was limited visibility of this water use and estimating this cost would mean relying on a set of anecdotal assumptions.
- Proximity costs – associated with being in the proximity of fire, for example, smoke and water damage to neighbouring buildings.
- Regulated costs for rental properties – i.e. smoke alarm installation and maintenance.
- Emotional costs – associated with personal emotional trauma, for example, from losing items of high intrinsic value.
- Business flow-on effects – associated with secondary business losses.

6.5 Concluding remarks

The cost of fire in New Zealand is estimated at $2.008 billion in 2019/20, with a range of $1.598 to $2.435 billion (or ±21 percent) being provided to represent the uncertainty inherent in an estimate.

The result is equivalent to 0.6 percent of GDP, which may appear to be on the low side, relative to prior studies, including one undertaken in New Zealand in 2005. A contributing factor is that the number of fatalities is much lower than those in the study in 2005. A further factor is that resource response costs appear to have increased at a lower rate than that of GDP since then. A comparison of the relative shares of component costs across studies shows that the results largely lie within the observable ranges, although this exercise also affirms the high variability in the mix of costs.

There were several limitations of this report. Lack of adequate communication with insurance companies meant we were unable to obtain up to date insurance data for insurance administration, damage to property, and lost business. In its absence, we used assumptions from the literature. We also acknowledge the limitations of the data provided from FENZ. These limitations meant several assumptions had to be made e.g. for volunteer training courses or for water usage in different building types. Improving the quality of data would reduce the need for these assumptions and likely improve the accuracy of estimates.

Several extensions to this work are possible. One step would be to improve the estimation of certain components if better data becomes available, for example, insights from the insurance industry, or data on the use of water in firefighting. Future work could also look to extend the scope of what has been quantified, for example, community costs and in safety costs, such as the cost of fire drills.

A next step would be to extend the cost model to examine the relationships between cost components over a multi-year timeframe. This would allow scenarios to be prepared to determine how changes in one area might affect downstream costs elsewhere, for example, the extent to which change in fire safety expenditure might impact components within costs as a consequence.

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Appendix A

Table 29: Mapping table for property damage

Building Type *Stats NZ consent data*	**General Property Use Name** *Fire and Emergency NZ fire incident data*
Houses	Single house Lifestyle block
Apartments	50% Flat, Apartment, Home unit Residential - not classified above
Townhouses, flats, units, and other dwellings	50% Flat, Apartment, Home unit
Hostels, boarding houses, and prisons	Boarding/Halfway house, Dorm, Homestay/Backpacker Prison, Correctional institution
Hotels, motels, and other short-term accommodation	Hotel, Motel, Lodge, Timeshare
Hospitals, nursing homes, and other health buildings	Doctors/Dentists emergency clinic, Medical centre Hospital, Hospice, Rest home, Rehab centre Laboratory, Research use
Education buildings	Educational, Health, Institutional - Other School: Pre-school through to Secondary/High University, Polytech, Other post-secondary venue
Social, cultural, and religious buildings	Church, Cemetery, Religious use Community hall Conservation, Recreation park, Reserve Library, Museum, Art gallery, Court etc Marae, Maori Culture use Recreational use, Theatre, Indoor sports, Pool, Park, Zoo, Aquarium Recreational, Assembly - not classified above Sports club, Health club Sports field, Stadium
Shops, restaurants, and bars	Restaurant, Pub, Tavern Shop, Mall, Supermarket, Gas station, Sales, Other
Office, administration, and public transport buildings	Communications, Research - not classified above Office, Bank, Embassy, Fire/Ambo/Police station Railway property Road, Street, Motorway Service/Repair, Dry cleaner, Laundry, Workshop Studio: Radio, TV Telephone exchange, Communications use, Data processing
Storage buildings	Storage, Warehousing
Factories and industrial buildings	Industrial, Manufacturing Power station
Farm buildings	Farming, Horticulture, Agricultural use Rural - not classified above

Miscellaneous buildings	Airport Commercial - not classified above Construction, Renovation - not classified above Construction, Renovation, Demolition site Defence, Military use Non-existent address Open land Passenger terminal Public Toilet Rubbish tip, Transfer station, Haz Waste disposal Stormwater, Harbour, Lake, River, Beach/Waterfront Unable to classify Vacant building, Section

Table 30: Mapping table for lost business

Business interruption type Insurance Council data	**Building Type** *Stats NZ consent data*
Manufacturing and industrial properties	Factories and industrial buildings
Public assembly, educational, intuitional, store, office	Education buildings Social, cultural, and religious buildings Shops, restaurants, and bars Office, administration, and public transport buildings
Residential, storage and special structure	Houses Apartments Townhouses, flats, units, and other dwellings Storage buildings
Vehicle and outdoor fires	
Unable to classify	Hostels, boarding houses, and prisons Hotels, motels, and other short-term accommodation Hospitals, nursing homes, and other health buildings Farm buildings Miscellaneous buildings

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Gary Blick
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Email: gblick@thinkSapere.com

Wellington	Auckland	Sydney	Melbourne	Canberra
Level 9 1 Willeston Street PO Box 587 Wellington 6140	Level 8 203 Queen Street PO Box 2475 Shortland Street Auckland 1140	Level 18 135 King Street Sydney NSW 2000	Level 5 171 Collins Street Melbourne VIC 3000	PO Box 252 Canberra City ACT 2601
P +64 4 915 7590 F +64 4 915 7596	P +64 9 909 5810 F +64 9 909 5828	P +61 2 9234 0200 F +61 2 9234 0201	P +61 3 9005 1454 F +61 2 9234 0201 (Syd)	P +61 2 6100 6363 F +61 2 9234 0201 (Syd)

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