BUILDING PERFORMANCE

Building and Construction Sector Trends

ANNUAL REPORT 2021

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

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MINISTRY OF BUSINESS,
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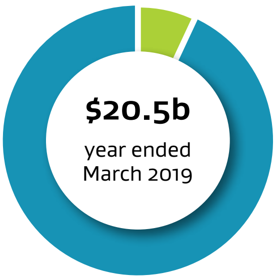
Executive summary

The purpose of this report is to provide an overview of the key trends in the building and construction sector, and covers the period from July 2020 to June 2021. The key trends are outlined below.

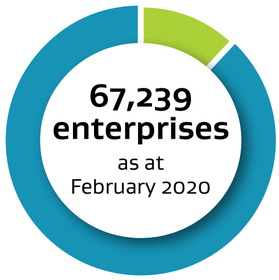
The building and construction sector is a major contributor to New Zealand's economy:

GDP **7%**



Employment **10%**

Businesses **12%**



The sector remained strong in the past year, despite challenges faced as a result of the COVID-19 pandemic:

- **Building consent numbers reached record-level highs.**
- **Size of the workforce grew and is becoming more diverse.**
- **Steady pipeline of domestic students training in construction or joining as apprentices.**
- **Pandemic impacted global supply chains, and its impact continues to be felt.**

The building landscape is also changing, with the introduction of innovative building designs, technologies, and materials. These present opportunities to:

- Introduce efficiencies and lower costs in the building process (to reduce the overall costs of building and to lift sector productivity).
- Increase worker health, safety, and well-being (and reduce the incidence of sector fatality and injuries).
- Improve the quality and durability of buildings (and enable New Zealanders to live and work in buildings that best meet their needs).
- Reduce the emissions and carbon footprint of buildings and help Government reach its climate change goals.

1.0 Introduction

The building and construction sector is a significant contributor to New Zealand's economy. It contributed 6.7 per cent of total GDP in 2019 [1], and was the fourth largest employer, employing 275,600 people in the year ended June 2021 [2]. In June 2021, the sector was the second-fastest growing industry in terms of employment, with 11,014 more filled jobs than in June 2020 [3].

1.1 Purpose of the report

The purpose of this report is to meet the requirements of section 169 of the Building Act 2004 [4]. Section 169 states that the: *"Chief executive must monitor current and emerging trends in building design, etc., and must report annually to Minister"*.

The aim of the report is to provide an overview, rather than an exhaustive compilation, of the key trends in the building and construction sector. Desktop research was undertaken between May and July 2021, with the relevant content sourced from publicly available data and information sources. The reporting period covered in this report is from July 2020 to June 2021. This report does not provide policy advice, solutions, or recommendations.

1.2 Report structure

The report is organised into the following sections:

› the context within which the sector is operating – **Section 2**

› key New Zealand trends on building and construction – **Section 3**

› key global trends on building design, technologies, and materials – **Section 4**

› conclusion – **Section 5**.

2.0 The wider context

The past year was unprecedented, and it is worth acknowledging the wider environmental context within which the building and construction sector operated. These are briefly discussed below.

2.1 COVID-19 pandemic

In late 2019, the first cases of an unknown viral disease was identified, and a global pandemic of the COVID-19 virus was declared by WHO in March 2020 [5]. As at 7th July 2021, more than 184 million cases had been identified, and around 4 million people had died from this virus globally [6].

The first known case of COVID-19 in New Zealand was reported on 28 Feb 2020 [7]. Since then, the New Zealand Government has applied measures to control the spread of the virus.

The pandemic and Government's measures impacted the sector in the past year. For example, work on the majority of building and construction projects paused during the national Alert Level 4 lockdown in 2020; while during Alert Level 3, social distancing restrictions and health and safety protocols did not allow multiple trades to work in the same space at the same time [8, 9].

These findings were supported by Stats NZ's 2020 Business Operations Survey which reported that: no businesses fully operated under COVID-19 Alert 4 levels; while this increased to 34%, 79%, and 96% under Alert Levels 3, 2, and 1, respectively [10].

Other reported impacts on the sector included [8, 11, 12]:

› supply chain issues
› rising construction costs
› businesses working for discounted rates
› reduced availability of skilled migrant workers due to border restrictions
› negative mental wellbeing impacts on workers in the sector
› concerns about the quality of the work

Stats NZ's Quarterly Building Activity Survey reported that two-thirds of respondents did not have the materials and equipment for their new-home projects, and that Auckland-based projects were affected more by COVID-19 compared to the rest of the country [13].

To mitigate the impact of the pandemic, the Government provided several financial support packages, including wage subsidies [14]. The construction industry was the largest recipient of wage subsidies among all industries (at 15 per cent) [15].

However, in spite of this, the first half of 2021 saw record high numbers of new homes consented [16]. In the March 2021 quarter, the sector was the largest contributor to GDP growth, rising 6.6 percent (or $268 million in 2009/10 prices) [17].

2.2 Climate change emergency

The changing climate will affect our economy, environment and way of life. By the end of this century, it is projected that New Zealand is likely to experience higher temperatures, rising sea levels, more frequent extreme weather events, and a change in rainfall patterns. All these changes will have an impact on our built environment [18].

At the end of 2020, the New Zealand Government declared a climate emergency, as a clear statement of intent to address climate change. As part of the overall response, the Government will develop policy over the next three years, to ensure the declaration is backed with action to bring emissions down [19].

In 2021, the Climate Change Commission provided their first set of independent advice to the Government. Their report, *'Ināia tonu nei: a low emissions future for Aotearoa* [20], detailed pathways for achieving our climate targets, including recommendations for the Government's first three emissions budgets.

As a contributor to greenhouse gas emissions, the building and construction sector and will play a key role in Government's overall climate change response. MBIE, as the central building regulator, has initiated a Building for Climate Change Programme, with goals to transform the sector to reduce greenhouse gas emissions and improve New Zealand's resilience to climate change [21]. The Programme will address two broad areas of actions:

› **Mitigation**
  – Lowering emissions from buildings (by improving the operational efficiencies of buildings, by reducing energy and water use and improving ventilation and building temperatures).
  – Reducing the whole of life embodied carbon footprint of buildings (which include greenhouse gas emissions generated from construction materials, processes, waste disposal, and disposal of buildings).
› **Adaptation**
  – Ensuring that the right buildings are built in the right places, and to help drive more resilience in buildings (such as insurance availability, provision of information and incentives).

3.0 New Zealand trends in building and construction

The building and construction sector played an important role in New Zealand's economy in the past year. An overview of the key trends in: economic performance; characteristics of the workforce; construction material and products; and the availability of materials and products are outlined in this section.

3.1 Economic performance

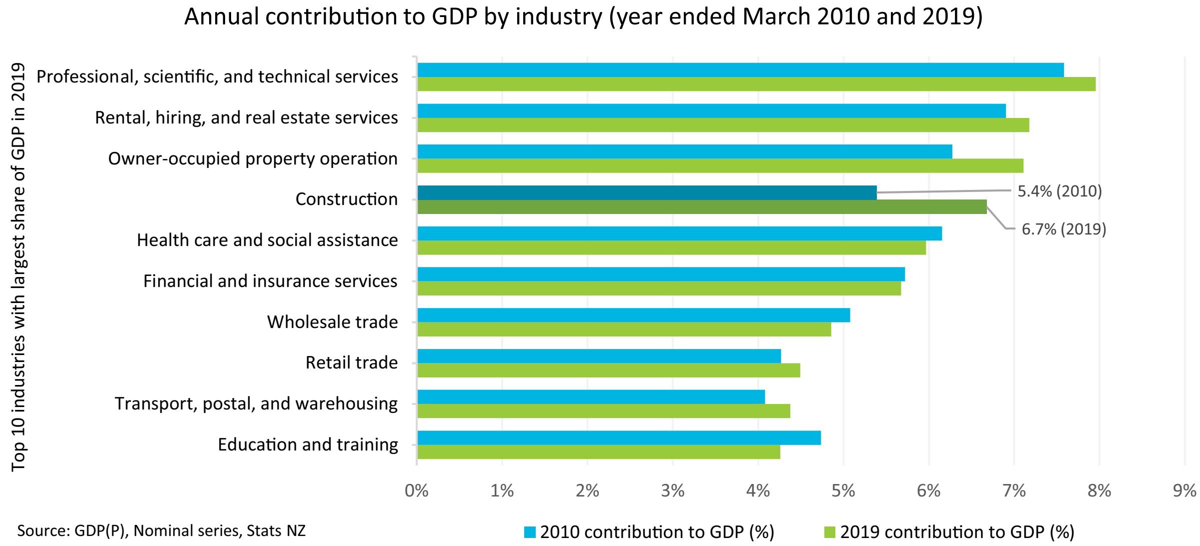
3.1.1 GDP

The key trend in the past year was that there was:

› Record falls in GDP in the June 2020 quarter, followed by rebounds since the September 2020 quarter.

The construction sector was the fourth largest employer, and contributed to 6.7 per cent of New Zealand's total GDP in 2019 (refer to **Figure 1**) [22]. Between 2010 and 2019, the sector saw strong growth in its GDP share. Out of 31 industries contributing to annual GDP, it ranked sixth in its share in 2010 (at 5.4%), however, by 2019, it ranked fourth (at 6.7%).

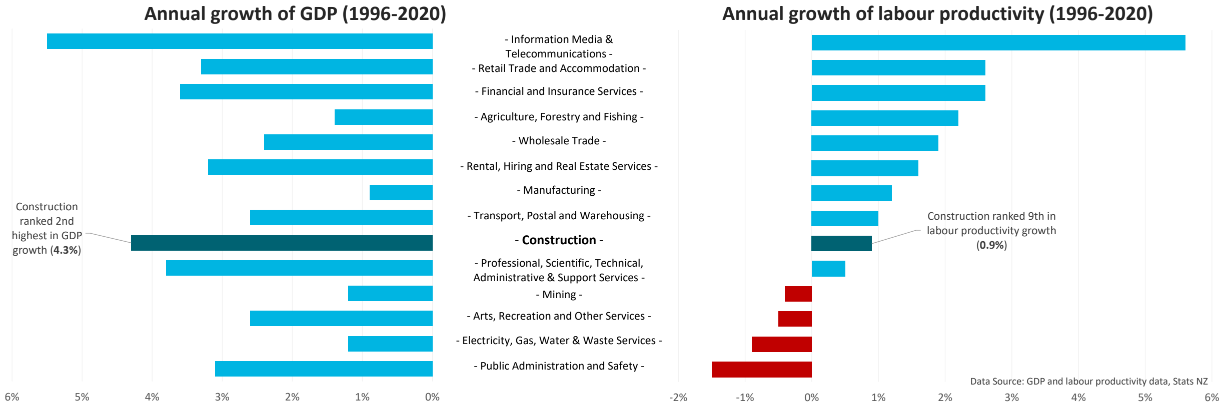
Figure 1



Source: GDP(P), Nominal series, Stats NZ

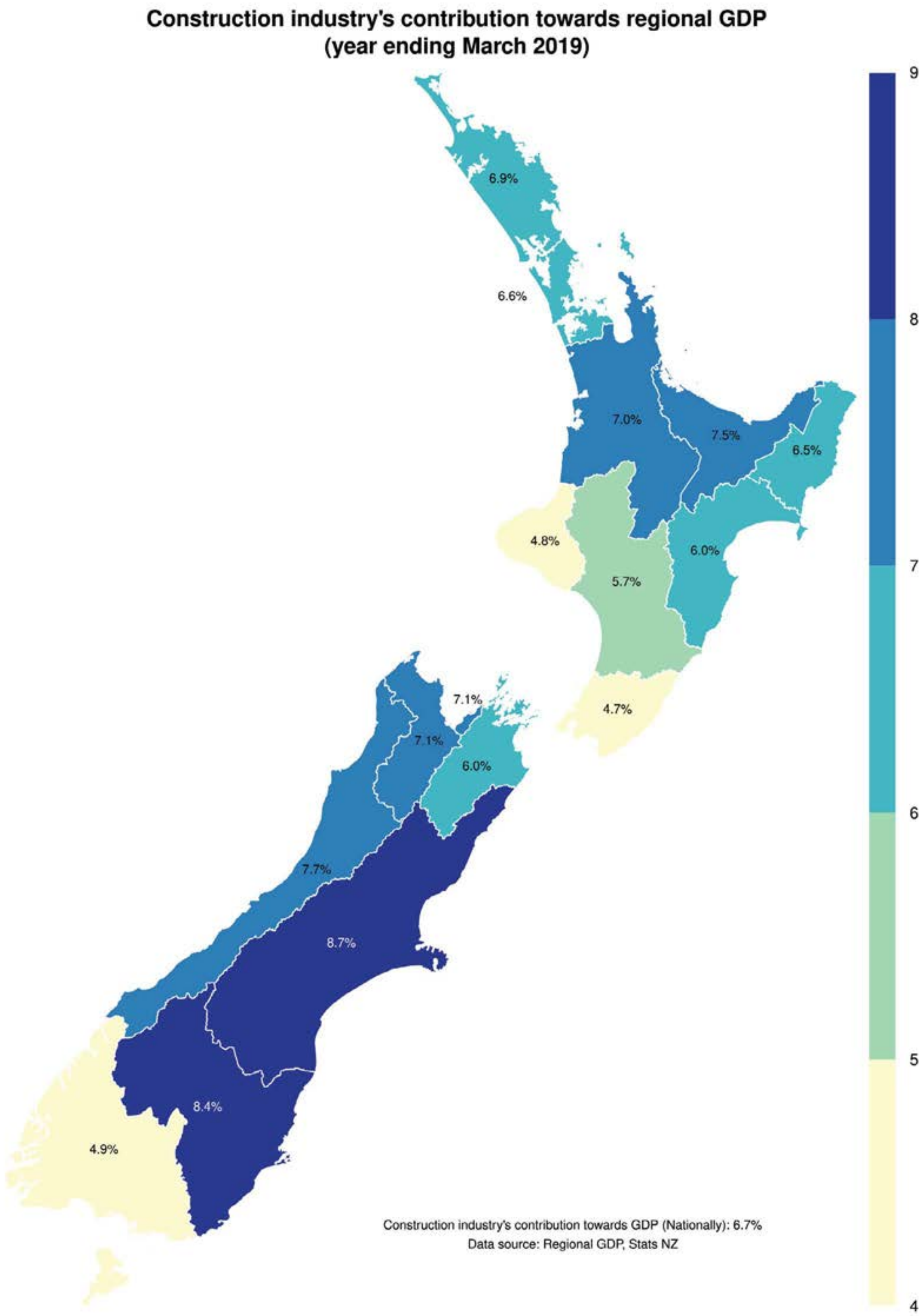
Additionally, between 1996 to 2020, the sector ranked second in terms of the compound annual growth rate of GDP, but ranked ninth in terms of the compound annual growth rate of labour productivity (refer **Figure 2**) [23]. From the year ended March 2016 to the year ended March 2021, the construction sector's contribution to GDP had grown 18 per cent in five years (in terms of 2009/10 prices).

Figure 2



The construction sector also played an important role in most of the New Zealand's regional economies. In the year ended March 2019, the sector's contribution towards Canterbury and Otago's regional GDP was 8.7 per cent and 8.4 per cent, respectively (refer to **Figure 3**) [24]. Only 3 out of 16 regions (Taranaki, Wellington and Southland) had contributions which were under 5 per cent.

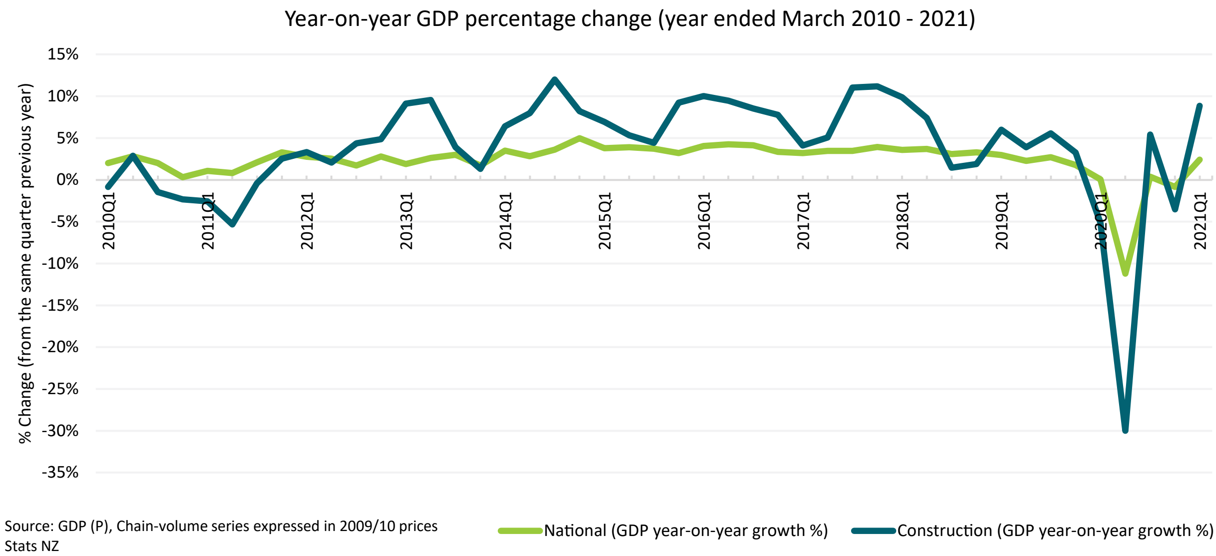
Figure 3



With the onset of the COVID-19 pandemic, New Zealand (as with the rest of the world) was impacted by this globally significant event (refer to **Figure 4**) [25]. Annual national GDP growth declined a record 2.9 per cent in the year to December 2020 [26]. The construction sector was the primary contributor to this decline.

However, by early 2021, a rebound was observed, whereby GDP increased by 1.6 per cent for the March 2021 quarter (after seasonal adjustment) [27]. Again, the construction sector was the main contributor to this, increasing by 6.6 per cent for the March 2021 quarter. Compared with the March 2020 quarter, the construction sector had grown by 8.8 per cent in March 2021 quarter, and outperformed the national GDP average of 2.4 per cent. This rebound demonstrated that New Zealand's economy was more resilient than previously predicted.

Figure 4



3.1.2 Buildings consents

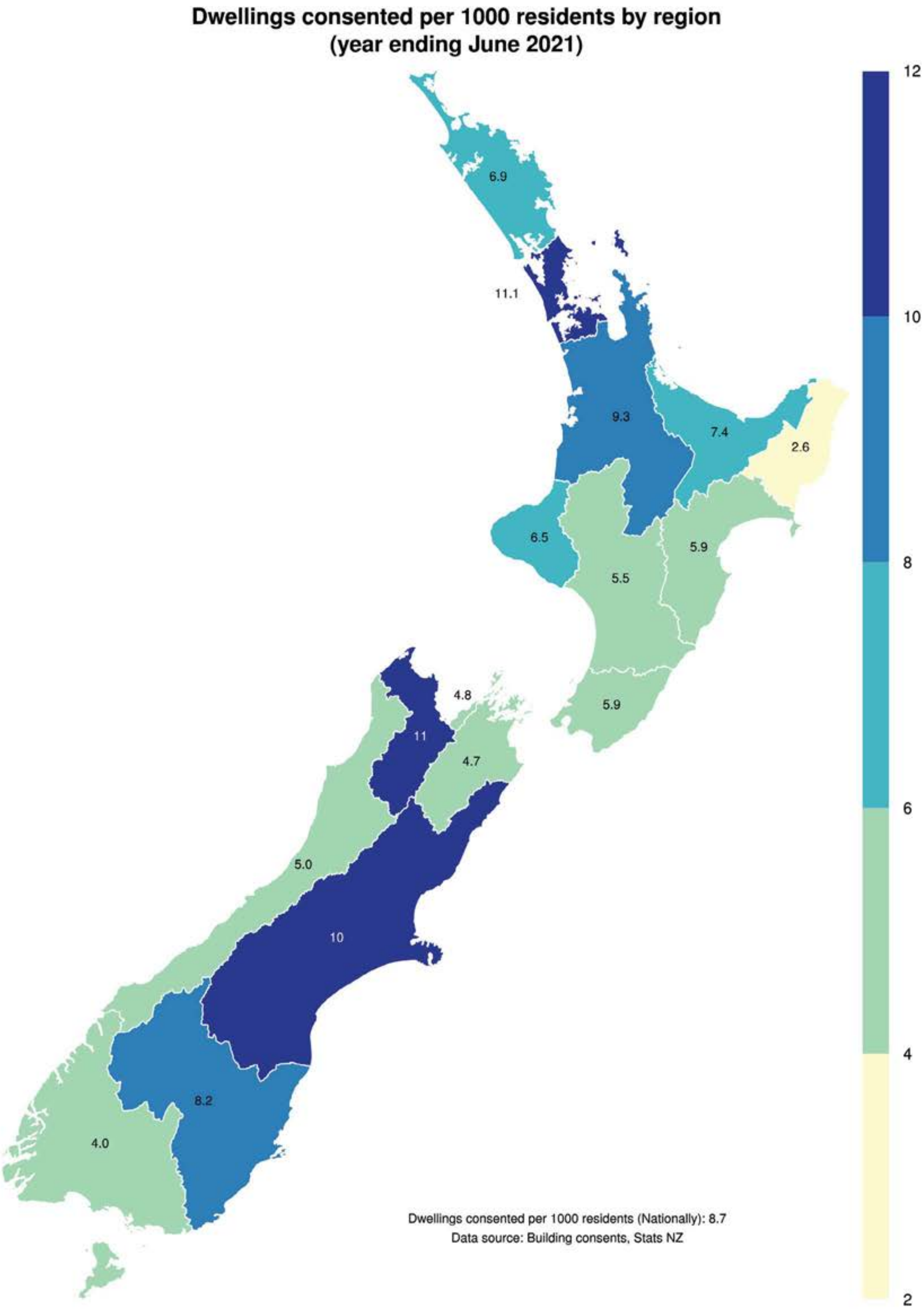
The key trends in building consents from July 2020 to June 2021 were:

› The number of residential building consents reached record highs.

› Multi-unit homes were the primary driver for the high building consent numbers. The number of building consents for new stand-alone housing has remained relatively flat since 2016, but the share has been declining.

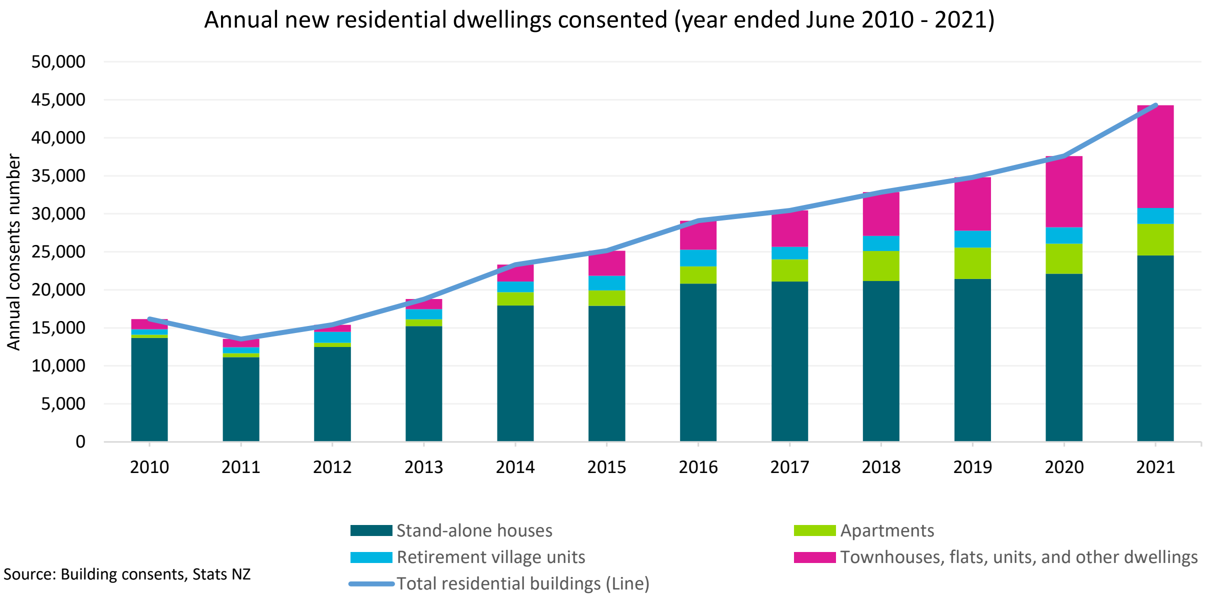
Residential building activity was at elevated levels in the past year, as a result of strong demand for housing throughout New Zealand. In the year ended June 2021, Auckland and Tasman regions had the highest number of consents per 1000 residents (at 11.1 and 11.0 respectively), while Gisborne region had the lowest consent numbers per 1000 residents (at 2.6) (refer to **Figure 5**) [28].

Figure 5



For the year ended June 2021, 44,299 building consents were issued for new dwellings, breaking the previous record of 40,025 consents issued for the year ended February 1974 (refer to **Figure 6**) [29]. Compared with the June 2020 year, the total number of multi-unit homes increased by 33 per cent, new homes by 18 per cent, and standalone houses by 11 per cent.

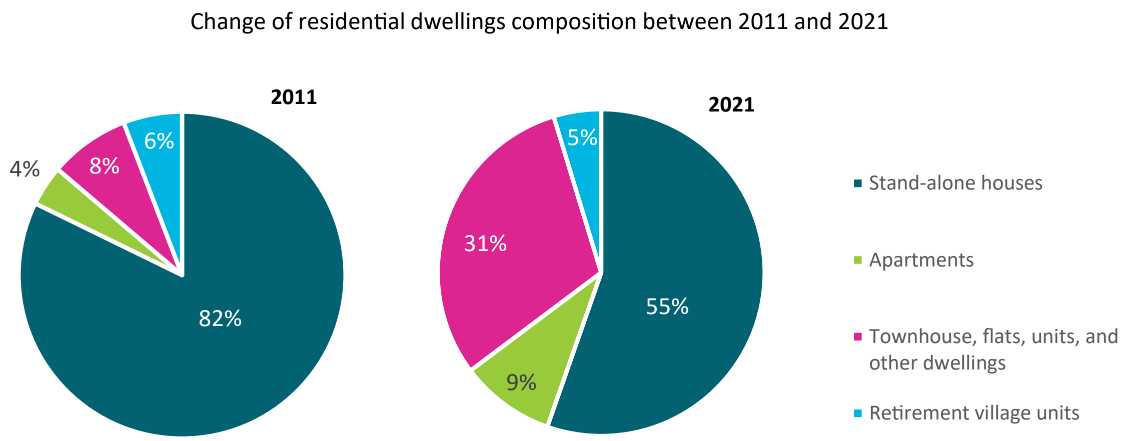
Figure 6



Source: Building consents, Stats NZ

The number of building consents for multi-unit homes (including apartments, townhouses, and flats) has increased significantly in recent years. Additionally, the share of stand-alone houses has been decreasing. In the past decade, the share of stand-alone houses consented dropped from 82 per cent in 2011 to 55 per cent in 2021. The share of multi-unit homes, however, increased from 12 per cent to 40 per cent during the same time period (refer to **Figure 7**) [29].

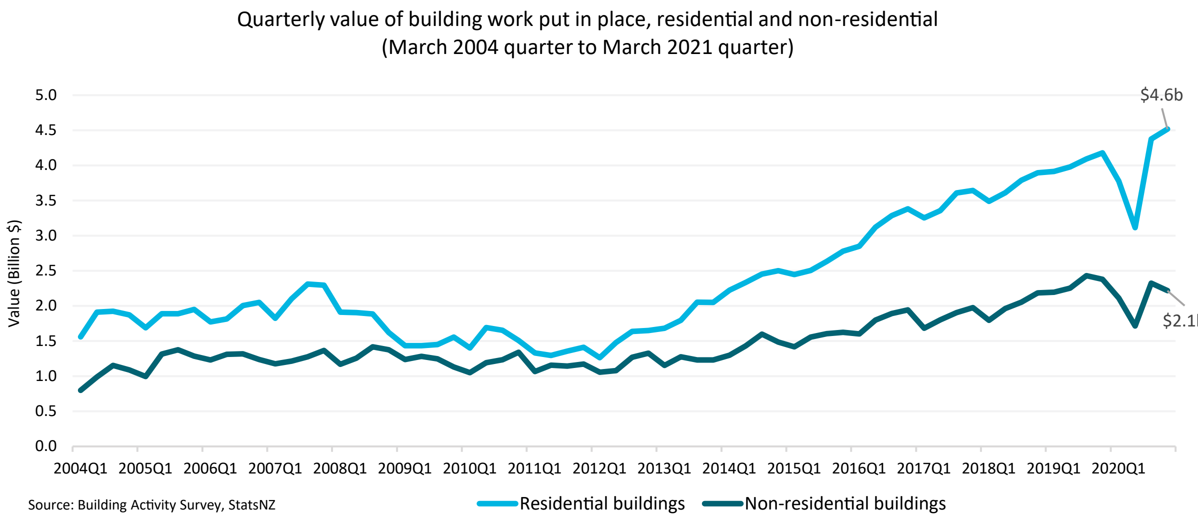
Figure 7



Source: Building consents, Stats NZ

Since 2012, the value of residential building activity has been growing at a greater rate than for non-residential building activity (refer to **Figure 8**) [30]. The value of building work was $6.7 billion in the March 2021 quarter, up 13 percent from the March 2020 quarter. Within this, residential building work rose 21 per cent to $4.6 billion, and non-residential work fell 0.6 per cent to $2.1 billion.

Figure 8



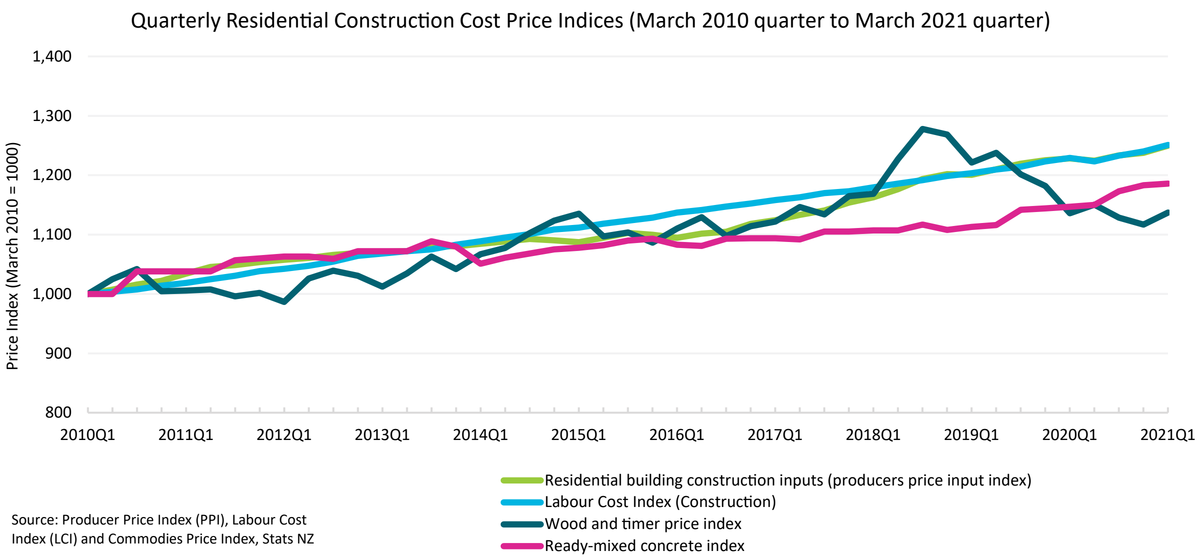
The COVID-19 pandemic, and specifically last year's nationwide lockdown, had a clear negative impact on both residential and non-residential building activity, where decreases in the value of building work were observed.

According to Stats NZ's Quarterly Building Activity Survey, 6 out of 10 home building projects in Auckland were negatively impacted by material and/or equipment availability [13]. This was also supported by findings from Stats NZ's Business Operations Survey 2020, which reported that COVID-19 had disrupted international and domestic material production and distribution.

3.1.3 Buildings costs

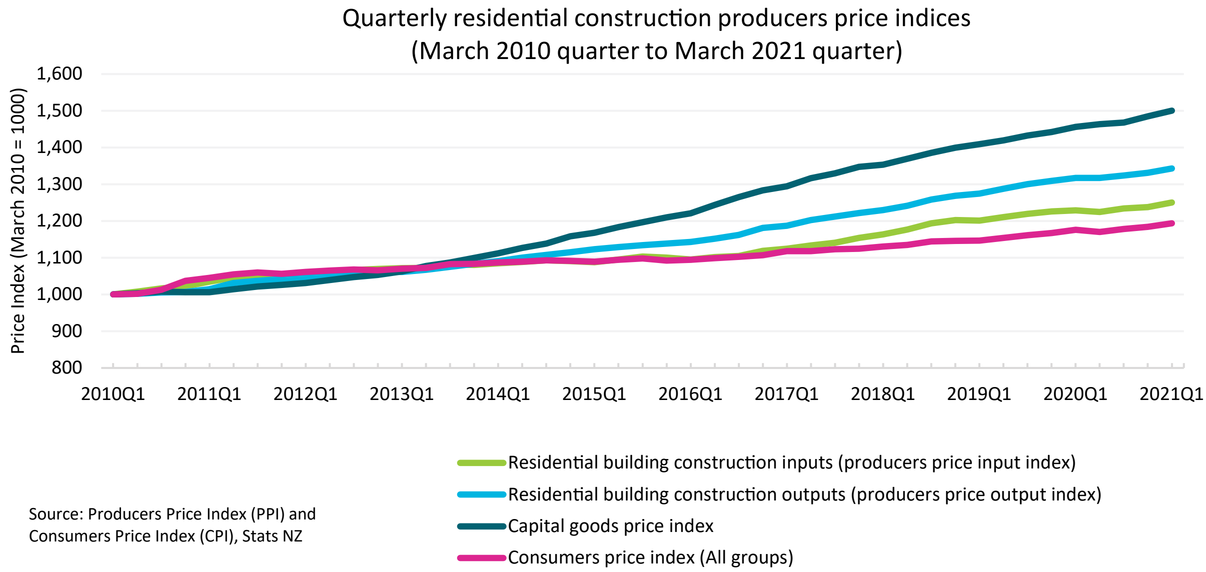
The costs associated with building activity have been steadily rising over the last decade (refer to **Figure 9**) [29]. From 2010 Quarter 1 to 2021 Quarter 1, prices paid by producers for inputs such as raw materials, fuel and services (excluding labour and capital cost) rose 25 percent across New Zealand. Additionally, labour costs rose 23 percent; while costs of materials, such as wood/timber and concrete, rose 14 and 19 per cent, respectively. Rising labour costs is one of the key contributors to increases in construction costs.

Figure 9



Output costs associated with residential construction rose at several times the rate of general inflation (refer to **Figure 10**) [31]. Since 2010, the output Producers Price Index rose more than 31 per cent (or 2.8 per cent each year), while the input Producers Price Index rose almost 22.5 per cent (2.5 per cent each year), and the Consumers Price Index by 20 per cent (or 1.5 per cent each year). The construction cost of an 'average house' (by building consent value) rose 35 per cent between 2010 and 2021 [31].

Figure 10



3.2 Construction workforce

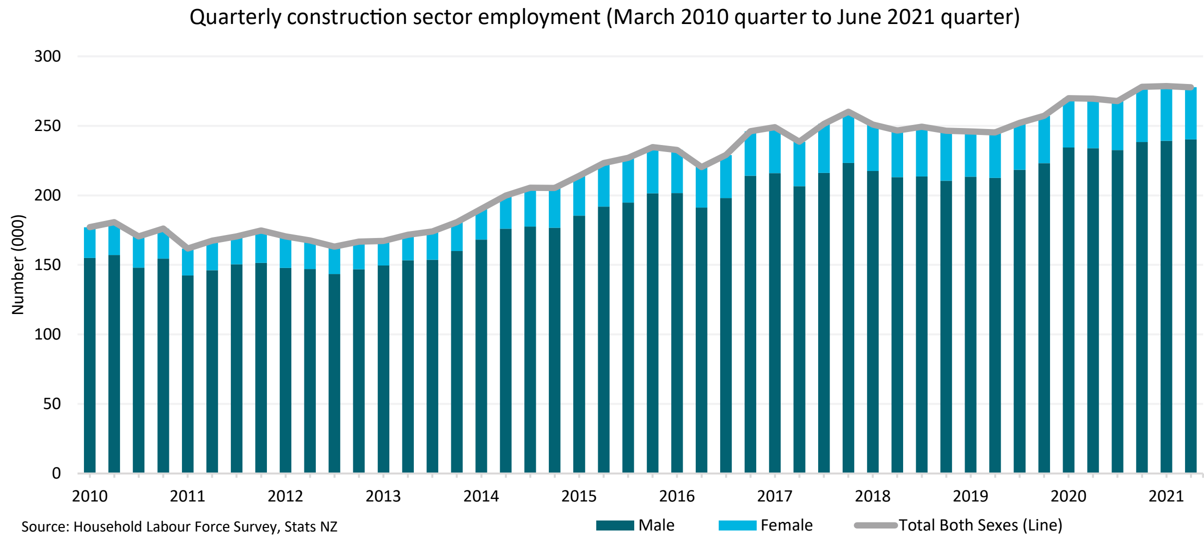
3.2.1 Demographic characteristics

The key demographic trends of the construction workforce were:

- The size of the workforce grew, reflecting the elevated levels of building activity around the country.
- It is also becoming more diverse. Female participation grew; there was increase in the numbers of workers of Māori, Pacific and Asian ethnicities; and it is youthful.
- Mean hourly earnings increased although gender pay gaps remain.

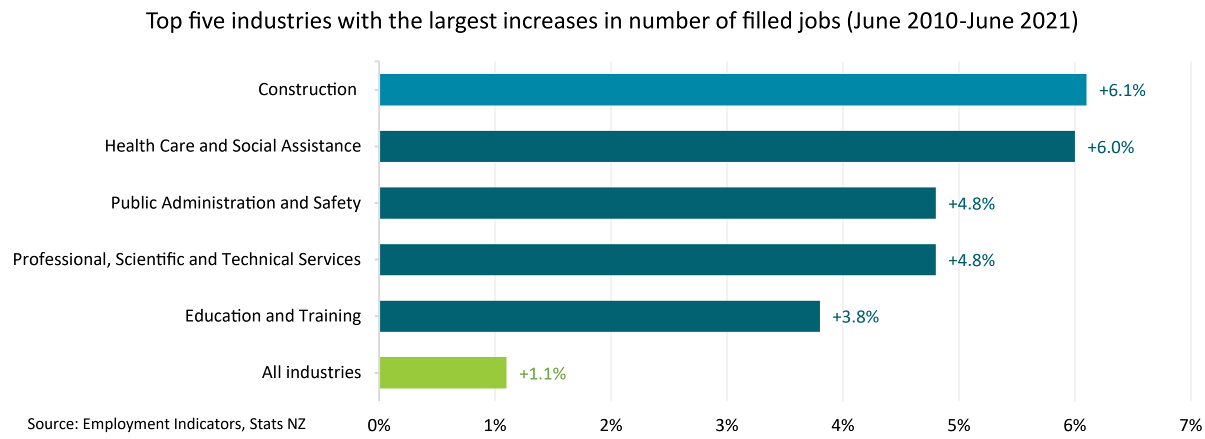
The building and construction sector is an important national employer. It has consistently employed approximately 10 per cent of New Zealand's total workforce. There were approximately 275,600 workers in the year ended June 2021 (c.f., 262,200 in 2020 and 170,800 in 2012) (refer to **Figure 11**) [32].

Figure 11



Compared with June 2020, there were 11,014 more jobs filled in the construction sector in June 2021, and it was the industry with the largest percentage increase. (refer to **Figure 12**) [32].

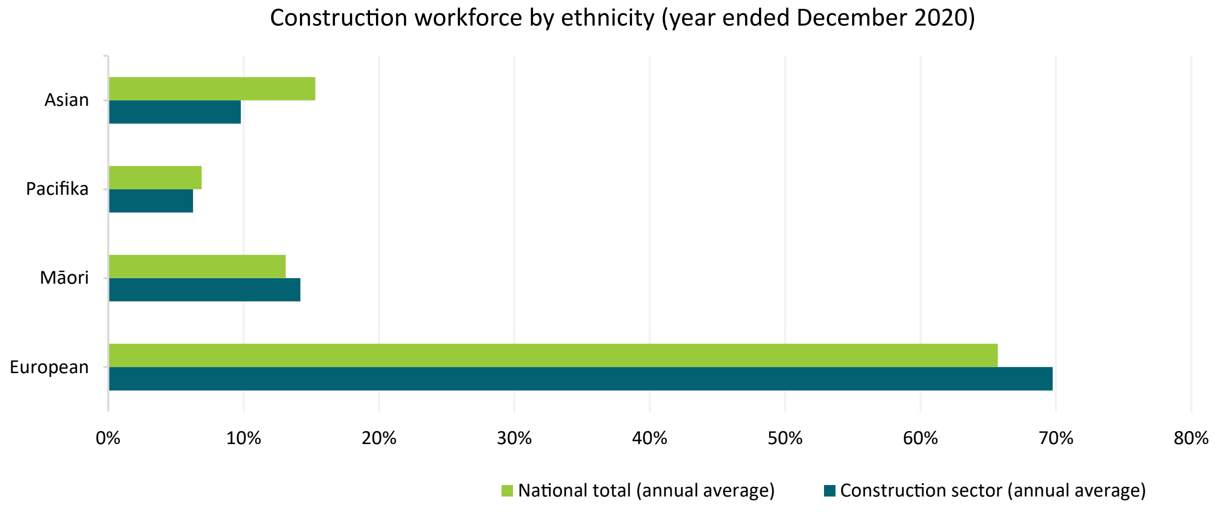
Figure 12



The construction workforce is becoming more diverse. Although there are fewer female workers, the number of female workers in the sector has been increasing. In the past decade, the number of female workers increased by 72 per cent (equating to 15,700 workers). This was comparatively higher than the 58 per cent growth in the number of male workers during the same time-period [32].

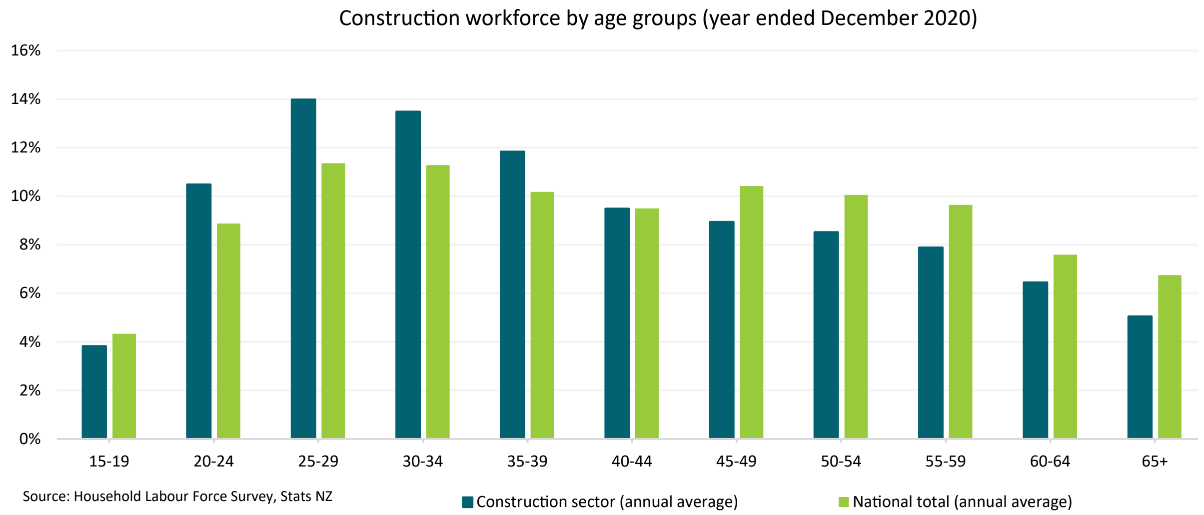
In addition to the increasing gender diversity, the sector is also becoming more ethnically diverse (refer to **Figure 13**) [33]. In 2020, one-third of the construction workforce identified as being of Māori (15 per cent), Pacific (7 per cent), or Asian (11 per cent) ethnicity, an increase of 2 per cent from 2018. The portion of those who identified as Māori or Pacific peoples were similar to that in the national population.

Figure 13



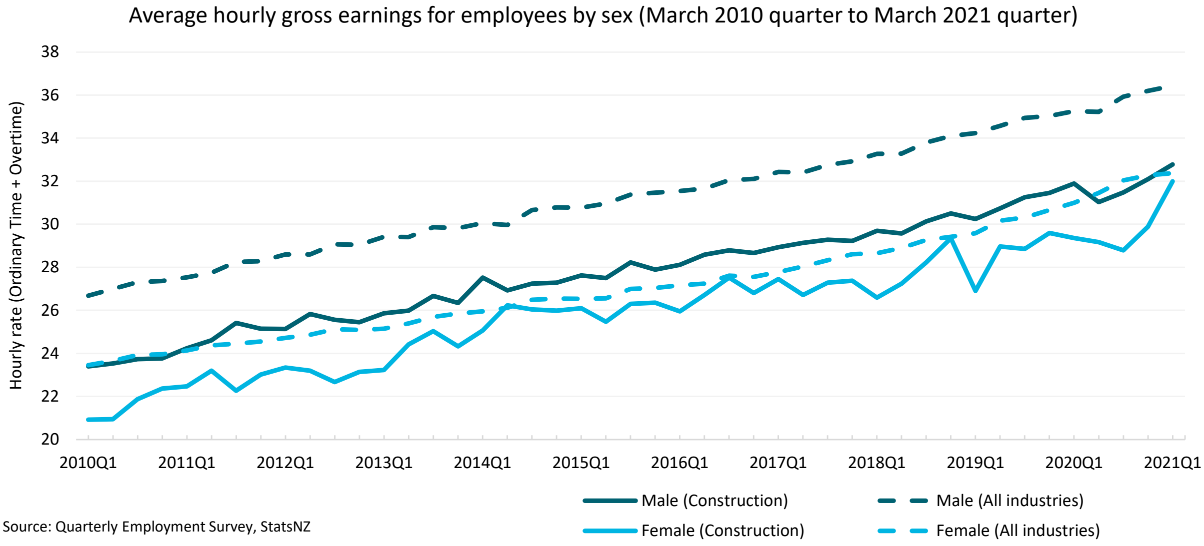
Workers in the construction sector tended to be younger in age when compared against the national population (refer to **Figure 14**) [33]. Just under half of the construction workforce (46 per cent) were aged between 15 – 39 years old.

Figure 14



In the past decade, the average hourly grown earnings has grown steadily (refer to **Figure 15**) [34], and is catching up with the national average. The average hourly rate was $32.09 in the year ending June 2021, which was an increase of almost $1.30 from the hourly rate of $30.79 in 2019. However, pay gaps between male and female workers remain.

Figure 15



Source: Quarterly Employment Survey, StatsNZ

3.2.2 Workforce pipeline

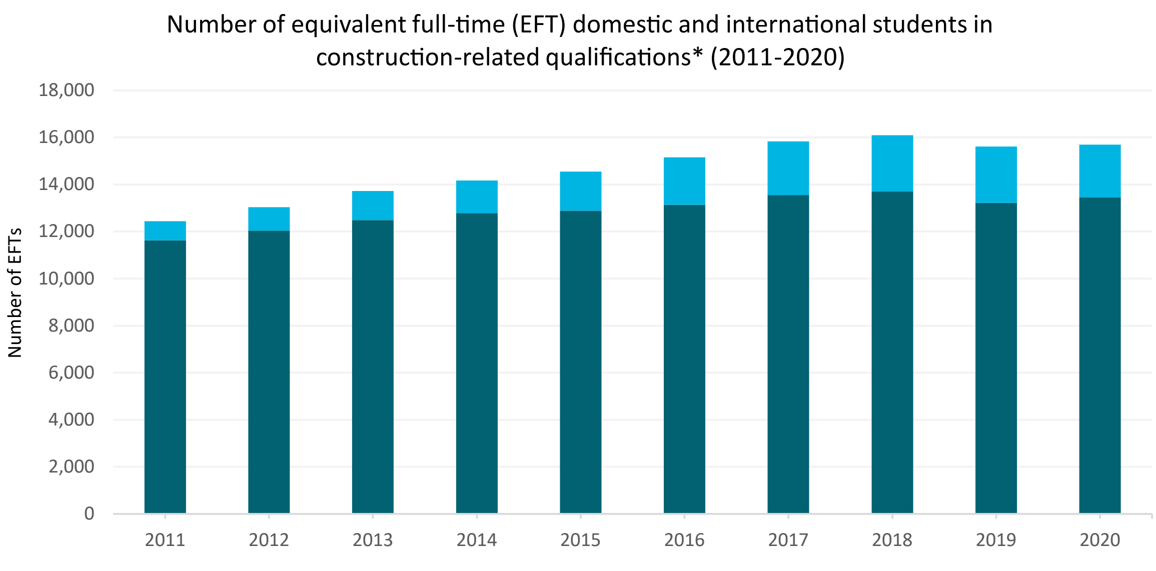
The key trends in the workforce pipeline were:

› In the past decade, there has been a steady increase in the number of workers training in construction-related qualifications and those joining apprenticeships.

› In the past year, there was ongoing concern around worker capacity and capability to meet the elevated demand of building activity.

Between the 2011 and 2020 calendar years, the total number of domestic and international students in construction-related qualifications increased 26 per cent (from 12,440 in 2011 to 15,690 in 2020; refer to **Figure 16**[1]) [35]. The largest increase was seen in the number of international students, which increased by 178 per cent during this period (805 in 2011 cf., 2240 in 2020) [35].

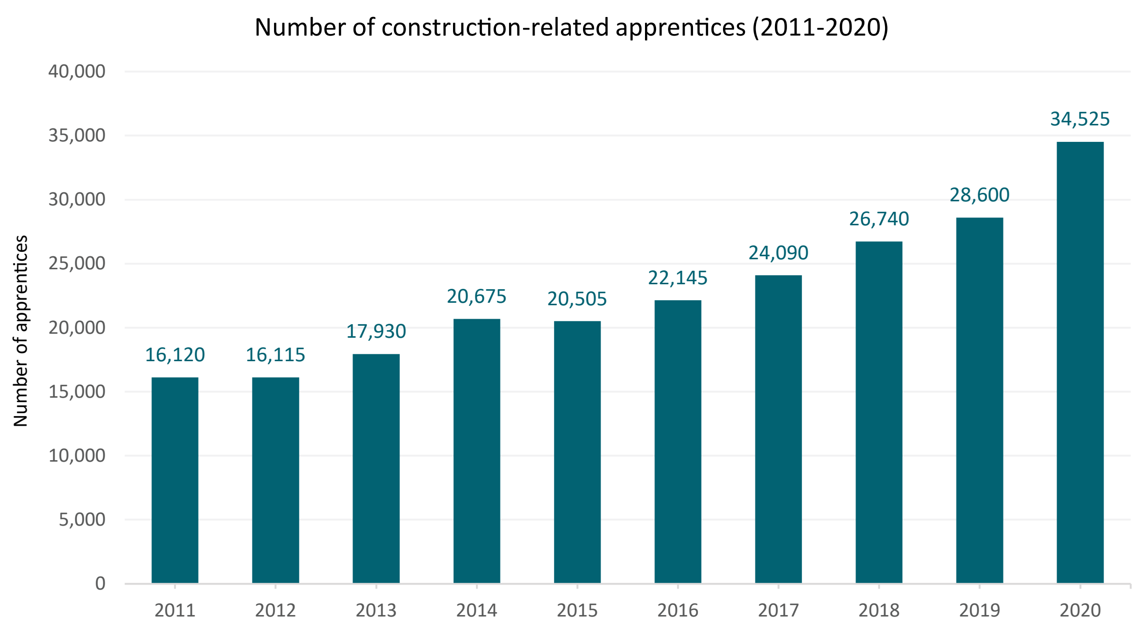
Figure 16



Source: Education Counts, Ministry of Education

The number of construction-related apprentices increased by 114 per cent from the 2011 to 2020 calendar years (refer to **Figure 17**) [36]. The largest increase occurred between 2019 and 2020, where a 21 per cent increase was observed.

Figure 17

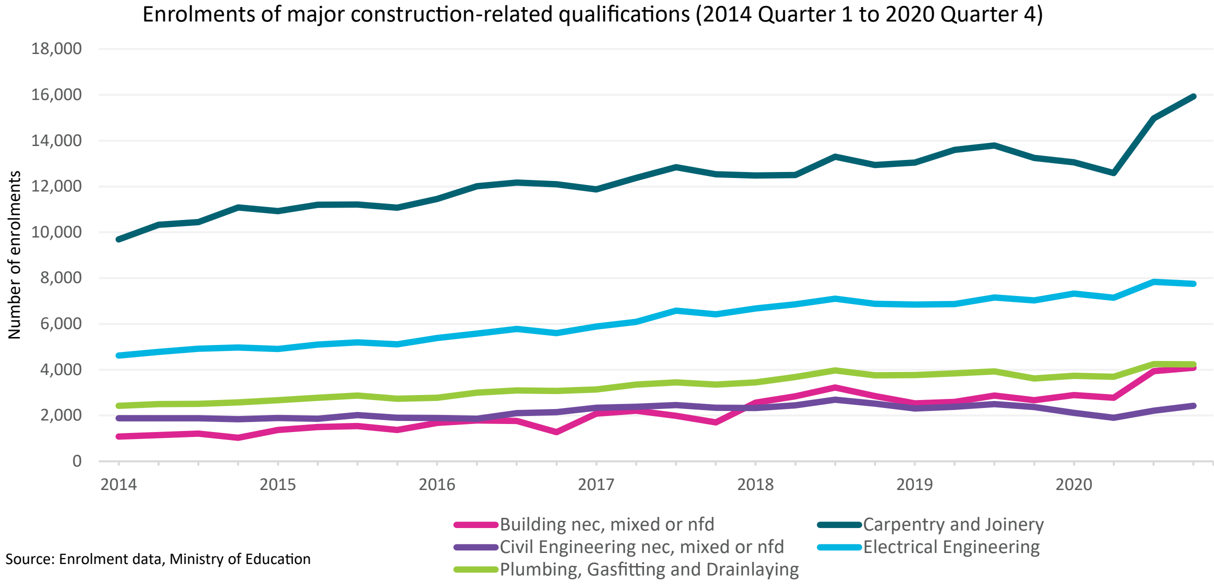


Source: Education Counts, Ministry of Education

[1] In Figures 16 and 17, construction-related qualifications were defined as those being in the "broad field of study" category in Architecture and Building, the "narrow field of study" category in Civil Engineering, and the "detailed field of study" category in Surveying, Electrical Engineering, and Refrigeration, Heating and Air Conditioning in the New Zealand Standard Classification of Education (NZSCED).

However, due to last year's border closures, the number of international students significantly decreased, while the number of domestic students increased sharply (refer to **Figure 18**) [37]. This could be attributed to Government schemes such as the Targeted Training and Apprenticeship Fund (TTAF)[2] [38] and Apprenticeship Boost[3]. Enrolments in carpentry and joinery had the sharpest increases in the past year, and remained the most popular construction-related courses for student enrolment.

Figure 18



Source: Enrolment data, Ministry of Education

With the elevated levels of building activity in the past year, there were ongoing concerns around the capacity and capability of the workforce to meet this demand. Stats NZ's Business Operations Survey 2020, reported that 76 per cent of construction businesses had experienced moderate to severe difficulty recruiting tradespersons and related workers (including apprentices) [39, 40].

3.2.3 Health, safety and well-being

The key trend in health, safety, and well-being was:

› Fewer deaths and injuries in the construction sector in the past year.

Six construction-related fatal incidents were reported in the year ended December 2020, which was at the same level reported in 2019 [41]. Injuries resulting in more than one week away from work also decreased in the year to December 2020 (5,346 cf., 5,517 claims in December 2019).

This declining trend could be attributed to the COVID-19 Alert Levels in the past year, which periodically restricted building activity. Now that building activity levels have increased again, five deaths were recorded from January to April 2021.

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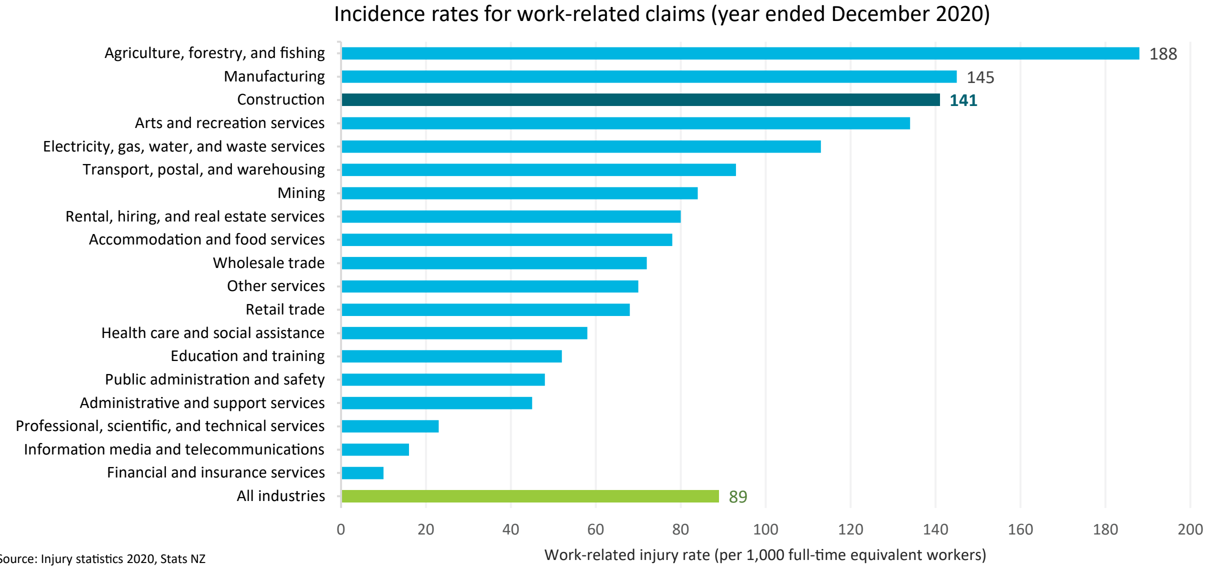
[2] TTAF supports learners undertake vocational education and training without fees, from 1 July 2020 until 31 December 2022.
[3] Since August 2020, Apprenticeship Boost has been providing employers with $1000 a month for first-year apprentices and $500 a month for those in their second year of training.

Additionally, the construction sector had the third highest incidence claim rate (141 claims per 1,000 FTEs), compared to a national rate of 89 claims (refer to **Figure 19**) [42]. The number of work-related injury claims in 2020 was 36,200 claims (which was 17 per cent of all claims, down 1,100 from 2019).

Figure 19



Source: Injury statistics 2020, Stats NZ

3.3 Construction materials and products

The key trends in the types of construction material in new housing in 2010-2019, as reported in BRANZ's New Dwellings Survey [43], is summarised below in **Table 1**. The table showed that in the past decade: sheet metal has become the most popular roof cladding material; weatherboards have become a popular wall cladding material; timber has remained the most popular material for wall framing and floor joists; and that fibreglass was the dominant insulation material for walls and ceilings.

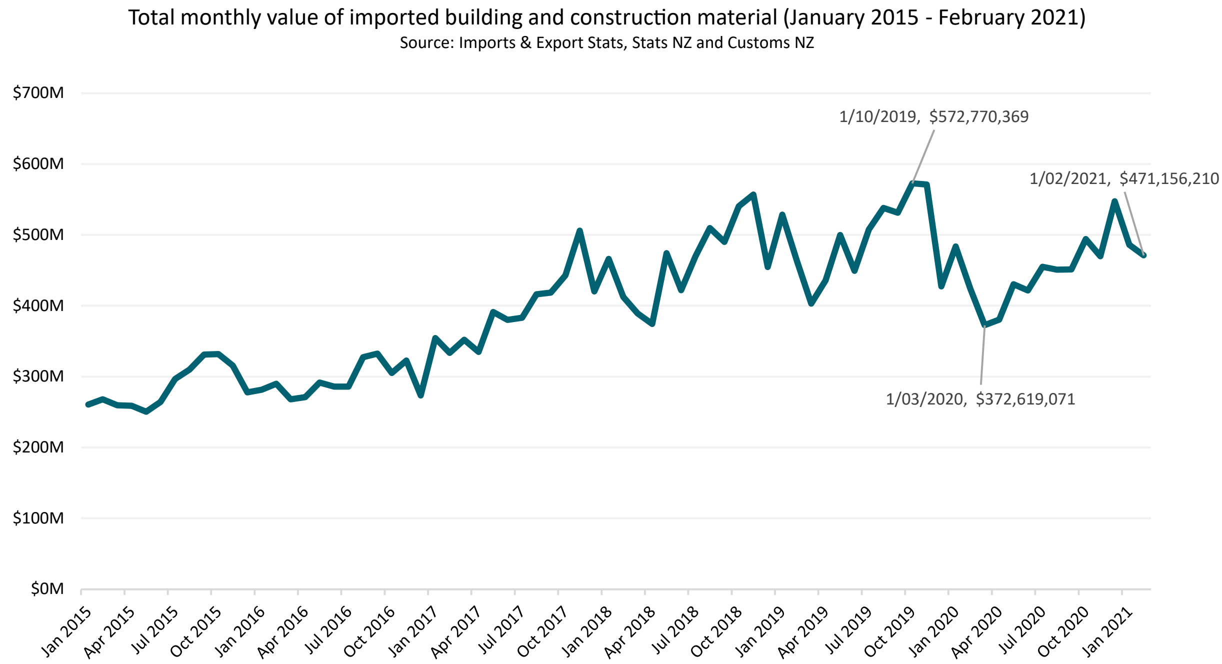
Table 1

Key trends in the types of construction material in new housing in 2010-2019	
Roof cladding: Sheet metal was the most popular roof cladding material in 2019. The percentage of houses with sheet metal roof cladding increased from approximately 55 per cent in 2010 to around 70 per cent in 2019. During the same period, the percentage of houses with metal/concrete tile roofs decreased from just under 40 per cent to under 20 per cent.	**Wall cladding:** Weatherboard (timber, fibre-cement, PVC) was the most popular wall cladding material in 2019 (43 per cent). This was a change from 2010 when finish bricks (both clay and concrete) were the most used wall cladding material. During the same period, a minor upward trend in other cladding types (such as AAC, fibre-cement sheet, plywood, EIFS, stucco, sheet steel) was also reported.
Wall framing: Timber remained the predominant structural material and was still the main wall framing material at around 90 per cent of houses. However, its use has been easing in the past 6 years. There has also been a rapid increase in the use of laminated veneer lumber (LVL)s, which comprised 12 per cent of timber framing in 2019.	**Flooring:** A downward trend in the use of concrete flooring, and an upward trend in all other flooring types (mostly particleboard and strand board) was reported. This could be attributed to the trends towards multi-storey buildings.
Floor joists: While solid timber was still the most common floor joist material, there has been a downward trend since 2017. During the same period, the use of "other" material (primarily consisting of wood and steel composite joists and traditional heavy-gauge steel joists) increased from, 26 to 45 per cent.	**Insulation:** Fiberglass was the dominant insulation material for walls and ceilings (at above 90 per cent) between 2010-2019. For under-floor insulation, more than three-quarters of new houses with timber floors used polystyrene, followed by fiberglass and polyester.

3.4 Availability of materials and products

A significant proportion of New Zealand's building and construction materials are imported. Notably, around the time of last year's national lockdown, the value of imported building and construction material fell to just over $372 million in March 2020. However, since then, the value has steadily increased and was over $471 million in February 2021 (refer to **Figure 20**) [44].

Figure 20



It is widely recognised that the COVID-19 pandemic has had a "devastating impact" on global supply chains [45]. In New Zealand, there were a number of media, industry and research articles which reported on the adverse impacts on construction goods/products supply chains in the past year (refer to [46-50]).

4.0 Global trends in building design, technology and materials

Each year, the construction sector welcomes new building design, technologies, and construction materials. In recent years, climate change, greater environmental awareness, and the need for increased efficiency and functionality, have been some of the key drivers behind these new trends. This section provides highlights of current and emerging building designs, technologies, and materials. Trend information has been provided where this is available. It is worth considering what potential implications these new innovations could have for New Zealand's building and construction sector.

4.1 Trends in building design

4.1.1 Tiny homes

Tiny homes are a relatively new house type which started in the late 1990s, however, at this point in time, there is no internationally consistent definition of what constitutes a tiny home [51]. Therefore, it is difficult to know how many tiny homes there are across the world. They are, however, increasing in popularity. For example, between 2016 and 2017, the US market experienced a 67 per cent increase in the number of tiny home sales [52], and it was estimated that their global market size could increase by USD $5.8 billion between 2020 and 2024 [52, 53].

Reasons for their rising popularity include: more affordable housing; lower living costs; more freedom and autonomy; a simpler lifestyle; and a lower carbon and ecological footprint [51, 52, 54-57]. However, countering this, some of the issues which have arisen include: overcrowding; isolated housing; poor workmanship; mouldy homes; and no tax contribution (as most homes do not have a permanent location) [58].

In New Zealand, dwellings that are 400 square feet (37.16 m^2) or less are categorised as a tiny home by the NZ Tiny House Association [59]. According to Census 2013, there were 5,586 privately occupied dwellings classified as "mobile dwellings not in a motor camp", some of which could be classified as tiny homes on wheels [60]. There is no accurate information about the number of tiny homes in New Zealand, however, this method of housing has become more popular in recent years.

4.1.2 Smart buildings

Smart buildings use Internet of Things (IoT) devices (such as sensors, software, and online connectivity) to monitor various building characteristics, and generate insights around usage patterns and trends to optimize the building's environment and operations [61]. The global smart (non-residential) building market has been projected to grow from $36 billion in 2020, to $42 billion in 2021, and $59 billion by 2025 [62].

Three key reasons for using smart building technology include: energy savings (through active management of spaces and appliances); water savings (through using water-efficient plumbing, smart irrigation management systems and monitoring software); and more human comfort (where occupants get their preferred comfort level without having to spend time and energy to control the building and/or its appliances) [63-65]. It has been reported that an upgrade to a smart building with integrated systems could save 30–50 per cent or up to 2.37 kWh/sq. ft. energy [63].

The type of areas where smart buildings could be useful include: improving air quality; controlling indoor temperature; controlling the intensity of the artificial and natural lighting; providing building security and safety systems; reducing plug power; and more effective management of waste [66-71].

In New Zealand, there are now several companies that offer smart building technology, and buildings which are equipped with various levels of smart technology. It may be worth considering how the use of this technology gets regulated, particularly regarding privacy issues with respect to user and building performance data collected by smart buildings [72].

4.1.3 Green buildings

Green buildings are those that preserve natural resources, reduce or eliminate negative impacts from the building process, and create positive impacts on the climate and natural environment [73]. The concept is about creating environmental-friendly and healthy buildings, and reducing the level of energy consumption and carbon emissions.

The importance of green buildings was highlighted during the global energy crisis in the 1970s, and more recently in the Paris Agreement in 2015 [74-76]. In 2002, the World Green Building Council (WGBC) was established with a mission to "transform the building and construction sector across three strategic areas: climate action, health and wellbeing, and resources and circularity" [77, 78]. The key drivers for green buildings include: client demand (34 per cent); environmental regulations (33 per cent); and having healthier buildings (27 per cent) [79].

Today, there are 70 Green Building Councils throughout the world [80]. The New Zealand Green Building Council (NZGBC) joined as the sixth member of WGBC in 2006 and has more than 520 members [81].

Globally, the green building industry is anticipated to be one of the fastest growing sectors [82]. In New Zealand, there are currently more than 3000 (mainly residential) green building projects and more than 25,000 projects in the pipeline [83].

4.1.4 Prefabrication

Prefabrication refers to standardised complete building or buildings components that are built off-site, and then assembled at the construction site. It is known as a solution in countries facing demand for new houses while facing skills shortages, and where there are severe weather conditions [84-88].

Prefabrication has been growing in popularity. With more public environmental awareness, climate change, and rapid increase in housing demand, prefabrication has become a trending construction method in many countries in recent years. For example, in Sweden, approximately 85 per cent of new homes were built using some type of modular engineering in 2018 [89]. The global modular and prefabricated construction market was forecasted to grow from USD $102 billion in 2020 to USD $173 billion by 2027 [89].

Some reasons for their popularity include [89, 90]:

- shorter construction time (for example, research has found that it can save between 30 to 50 per cent of time against traditional construction methods)
- fewer skilled people required
- better health and safety outcomes (for example, it was estimated that 80 per cent fewer accidents occurred during modular construction compared to traditional methods)
- less construction waste (for example, an international study found that through prefabrication, concrete wastage was reduced by 51-60 per cent, and 74-87 per cent by using steel formworks)
- being more environmentally friendly (due to less construction waste, dust and noise; and the ability to use low-embodied carbon construction material and tools).

Barriers include: the need for significant initial investment (to research, design, build, and market the products); potential regulatory barriers (regarding the need for a consistent approach towards prefabricated buildings); and social acceptance of these types of buildings [91, 92]. It may be worth considering how these types of construction methods could be supported.

4.2 Trends in building technologies

4.2.1 Green energy

Due to climate change, there is a growing trend towards adopting green energy. Renewable or green energy includes resources that rely on fuel sources that restore themselves over short periods of time, and include the: sun, wind, moving water, organic plant and waste material, and earth's heat [93].

In 2019, 39.5 per cent of New Zealand's primary energy supply came from renewable sources, and our share of renewable electricity generation was 82.4 per cent, which was the third highest in the OECD [94].

Residential consumers were responsible for 64.61 PJ (10.8 per cent) of the total energy demand, while building and construction sector consumers were responsible for 9.25 PJ (1.5 per cent) (refer to Table 2, calculations were based on [94]). The bulk of the energy used by the sector was from oil (at 79.9 per cent), while 70.5 per cent of residential consumers used electricity.

Table 2

Energy sources for residential and building and construction consumers in 2019						
		Energy source (%)				
Consumer type	Percentage of the total energy demand	Coal	Oil	Natural gas	Renewables	Electricity
Residential	10.8	0.4	6.0	10.6	12.5	70.5
Industrial: Building and Construction	1.5	-	79.9	5.3	-	14.9

Over the years, Census data from 2001, 2006, and 2013 showed a steady increase in the number of dwellings that used electricity and solar power for heating purposes, and a steady decrease in the use of main gas, bottled gas, wood, and coal [95]. In Census 2018, 52.5 per cent used gas, wood, pallet, or coal for heating purposes [96].

With the New Zealand construction sector committing to zero/low carbon emission by 2050 [21], there are a number of opportunities for the sector to reduce its carbon footprint and increase the use of green energy. This could include using green energy to produce and transport construction materials, and during the lifecycle of the construction process (from building through to demolition).

4.2.2 Artificial intelligence, machine learning, and robotics

Artificial intelligence (AI) is the *"study of how to make computers do things at which, at the moment, people are better"* [97], while machine learning (ML) is a subset of AI and is *"an evolving branch of computational algorithms that are designed to emulate human intelligence by learning from the surrounding environment"* [98].

While the pace of applying advanced technologies in the construction sector has been slower than other industries [99, 100], the use of AI (combined with other technologies such robotics, drones, and 3D printers) has become increasingly popular in the past decade. For example, the value of the construction robotics market was projected to grow globally from USD $2.45 billion in 2019 to reach USD $7.88 billion by 2027 [101].

Instead of taking humans out of the equation, these technologies allow workers to do their jobs more effectively [99]. It has been estimated that up to 30 per cent of business time can be saved by AI technology [102].

Machine learning is able to assist at the design, build, and post-construction stages of a project, and can be used to improve the safety, decision-making process, risk identification, and cost estimation of projects [99, 100, 103, 104].

Construction robots can also be employed to perform repetitive tasks (such as painting, bricklaying, wall construction, plastering, façade installation, cleaning, inspection, beam assembly, and earthworks) [105]. The advantage of using construction robots and AI technology include: fewer construction-related injuries; fewer skilled workers required; time savings; lower construction costs; increased accuracy and quality; easier access to high risk and inaccessible areas; and ability to work and manage remotely [101, 106-111].

However, despite developments in technology, and the advantages that these could bring, there is a view by some that due to the complex nature of construction site activities, it may take some time for these types of technology to be widely accepted by the sector [112].

4.2.3 The Internet of Things (IoT)

The Internet of Things is the *"concept of connecting any device (so long as it has an on/off switch) to the Internet and to other connected devices. . .. [and is] a giant network of connected things and people – all of which collect and share data about the way they are used and about the environment around them"* [113].

IOT technology works in complement with artificial intelligence, machine learning, robotics, and smart building technology, and is widely accepted by the construction sector. Its market size was projected to increase from USD $8 billion in 2019 to USD $19 billion by 2027 [114].

IoT devices may be attached to people (e.g., wearable devices), equipment, or vehicles; or installed in various spaces to collect data. The IOT technology enables the monitoring and tracking of people, plant, and machinery, ensuring a safer and more efficient worksites [115, 116]. IoT technologies and devices can help reduce the operating costs of buildings, and are key factors in smart buildings [115, 117].

4.2.4 Drones

Drones are aircrafts or flying robots which can be controlled remotely or fly autonomously through software-controlled flight plans [118]. They were initially invented for military purposes [119] but are now being used by businesses.

The global construction drone market size was valued at USD $4.80 billion in 2019, and was projected to reach more than $12.0 billion in 2027 [120]. The new generation of drones are now equipped with advanced technologies (such as Global Navigation Satellite Systems (GNSS), Global Positioning Systems (GPS), Geographic Information Systems (GIS), internet of things, and artificial intelligence), which in effect increases their functionality [120].

It was estimated that there were 15,322 drones used for business and scientific purposes in New Zealand in 2020 [121]. In a drone tracker survey completed in 2018, the construction industry was the second largest sector that received services from drone operators at 38 per cent (cf., 40 per cent by the real estate sector) [122].

The benefits of using drones for the sector include: increased speed safety, security and accessibility; and the potential to lower overall construction costs [123-125]. Where drones can be utilised include: land surveying; construction site and asset inspections; facilitating site security and safety; transportation of goods; assistance with record-keeping and management tasks (by providing real-time information on personnel, plant, and machinery); and performance of (high-risk) construction tasks (such as nailing roof shingles) [123-133].

In the UK, PriceWaterhouseCoopers (PwC) predicted that the savings and efficiency improvements associated with the use of drones will result in an £8.6 billion GDP uplift in their construction and manufacturing industry, and create net cost savings of around £3.5 billion by 2030 [127].

However, despite the benefits of using drones, they also bring some challenges. In addition to the costs and the ability to find skilled drone operators, the most significant challenge was being able to have secure data transmission [134]. In 2019, the US Department of Homeland Security warned American drone users about the risks of the data being saved on servers that could be accessed by manufacturers and foreign governments [135].

In New Zealand, construction-related businesses had the highest usage of drones in restricted airspaces in 2020 [121]. A discussion document by the Ministry of Transport stated that the misuse of drones was a matter which related to the Privacy Act 2020, the Conservation Act 1997, and the Department of Conservation (DOC) concession regime, the Summary Offences Act 1981, and the Crimes Act 1961 [136]. Suggestions for how they could be better regulated was also provided.

4.2.5 3D Printing

3D printing is a *"method of manufacturing in which materials, such as plastic or metal, are deposited onto one another in layers to produce a three-dimensional object"* [137]. It can be used to create [138-142]: affordable housing; office buildings; emergency and disaster shelters; landscape elements such as bus stops; small-scale infrastructure such as bridges; and construction of building and infrastructure in space.

The construction sector first started using 3D printing during 1986-2000 to make scale models of buildings at the design stage [143]. Since then, it has been gaining popularity and the application of this technology has significantly accelerated. 3D printing was projected to grow globally from USD $3 million in 2019 to more than USD 1.6 billion by 2024 [144]. Some highlighted projects from the past decade are outlined in **Table 3**.

Table 3

Examples of projects which used 3D printing	
2014: A private company in China built 10 detached single storey houses in a day. The cost of each house was under $5,000 [145]	**2016:** The world's first 3D printed pedestrian bridge, which was 12m long, was built in Madrid, Spain [146].
2019: The longest 3D printed concrete bridge (26.3m) in the world was built in 450 hours on an artificial river in Shanghai, China [147].	**2019:** A neighbourhood with fifty 3D printed houses was built as the first 3D printed neighbourhood in rural areas in Mexico [148].
2019: The world's largest 3D printed office building with the floor area of 640m^2 (and 9.5m long) was built in Dubai [149].	**2020:** The largest 3D printed house with the floor area of 176m^2 was built within 48 hours in the US, using less than $6000 worth of construction materials [150].

Common reasons for the popularity of 3D printing include: lower construction costs; reduced construction labour; limited construction waste; increased site safety; maximum design flexibility; and being more environmentally friendly [105, 139, 151, 152].

The disadvantages of this technology, however, are: the high cost of the automated machines; the reliance on skilled personnel to operate machinery; design limitations (regarding the building height, the need for the build to be at ground level, the reliance on using specific construction material e.g., concrete); and need to incorporate building elements manually (such as sanitary services) [105, 153, 154].

At this point in time, as most 3D printed buildings are only just a few years old, there is an absence of data on end-user feedback. Despite this, in 2020, NASA announced they were looking to "advance 3D printing construction systems for the moon and mars" [142]. Dubai also recently announced that 25 per cent of its city's new buildings will be made using 3D printers by 2025, and proposed to be the world's "3D-printing hub" by 2030 [138].

4.2.6 Building Information Modelling (BIM)

Building Information Modelling, also known as BIM, *"integrates structured, multi-disciplinary data to produce a digital representation of an asset across its lifecycle, from planning and design to construction and operations"* [155]. Using BIM technology, collaborative work on virtual buildings between architects, structural engineers, builders, subcontractors, and all other people who are involved in a construction project is made possible [156].

The global BIM market was USD $8.89 billion in 2020, and was projected to reach USD $23 billion by 2026 [157]. The application of BIM is growing in various countries, with some governments making its usage mandatory. UK companies were leading in this area, whereby 73 per cent of their construction companies used BIM [158].

The benefits of an architectural design model tied to a relational database have proven to be incredibly valuable [156]. Some of the benefits of using BIM include: faster cost estimation; increased cost and resource savings; improved quality of project management, communication, and risk mitigation; improved visualisation and the quality of the final product; improved site safety; reduced construction wastage; and more opportunities for prefabrication and off-site construction [159-161].

According to BIM NZ, five NZ universities and five polytechnics have currently included BIM-related courses in their construction-related programs [162], which means that the next generation of industry professionals will be able to use this technology in future building activities.

4.3 Trends in building materials

4.3.1 Smart glass (nanocrystal)

Smart glass technologies *"alter the amount of light transmitted through typically transparent materials, allowing these materials to appear as transparent, translucent, or opaque"* [163].

Although it is still expensive to buy and difficult to install [164], its application in the construction industry has significantly grown in recent years. The smart glass market size was projected to grow from USD $10.2 billion in 2020 to USD $14.2 billion by 2026 [165]. Several companies are now selling smart glass technology in New Zealand.

Multiple research projects have proved the significant role smart glass can play in reducing energy consumption in buildings [166-168], but at the same time being able to control the transparency level of the glass via an app, which means that curtains or blinds are no longer needed [169].

4.3.2 Engineered Living Materials

Engineered Living Materials (ELMs) are defined as *"engineered materials composed of living cells that form or assemble the material, or modulate the functional performance of the material"* [170]. As this is a new building material, no trend information was available.

A key benefit of ELMs is the ability to engineer living cells through genetic modification to adjust their properties [171]. Examples of these include materials which: self-heal (such as concrete which self-heals its cracks [171-173]); absorbs CO2 emissions over the life of the material (such as concrete [174-176]); and adjusts the properties of existing martials (for example, it strengthens them [177, 178]).

New Zealand's construction sector may benefit from these living materials, particularly due to the potential environmental benefits of using them.

4.3.3 Breathe Bricks

The Breathe Brick is a structural masonry component with an embedded cyclone separator [179]. Using a combination of wind and stack ventilation forces, polluted outdoor air passes through Breathe Bricks, which filters and cleans the air, before it reaches the interior spaces of the building [179]. It is a system designed for regions with elevated outdoor particulate matter (i.e., size PM 5 and above) [179, 180]. As New Zealand is not considered as a country with extreme air pollution, and as masonry construction is less popular as a construction method, the use of this material may not be as relevant for the sector. As such, trend information on its uptake in New Zealand was not available.

4.3.4 Laminated timber

Glulam (glue-laminated) timber was one of the first engineered wood products to be accepted as a viable structural material. It uses relatively low technology, to cut flaws from thin strips of wood and for these to be glued together, to form larger and stronger components [181]. In recent years, engineered wood products (such as laminated veneer lumber, cross laminated timber, laminated strand lumber, and parallel strand lumber) have become very popular in recent years, and have become widely available [182].

The reasons for their popularity include: the use of lower cost/flawed timber and small trees; enhanced strength and stiffness; seismic resistance of cross laminated timber; lighter buildings; lower carbon emission; more flexibility in shape and design; cleaner construction process; and shorter construction time [182-196].

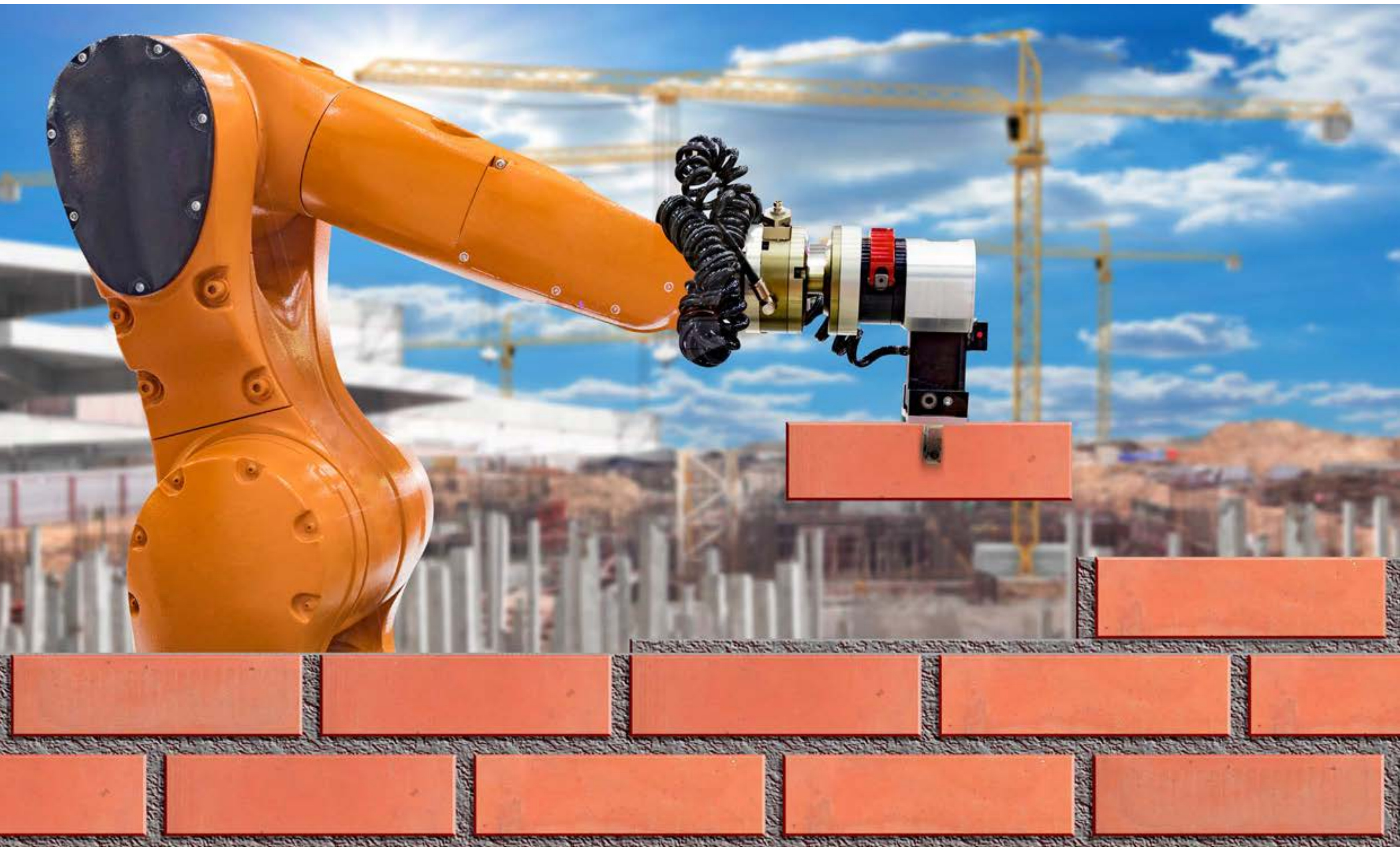
Results from the 2019 BRANZ research on the usage and uptake of engineered wood products found that around a quarter of respondents had used a significant amount of engineered wood products in more than half of their projects [197]. Cost, regulation and compliance, education, availability, and durability were the key barriers to engineered wood products usage [197].

4.3.5 Transparent solar cells

Photovoltaic or solar panels are a known technology, and are the most rapidly growing source of sustainable energy [198]. Recently, a group of international scientists have made “transparent” solar panels [199, 200]. It has been claimed that if this technology is used on the glass surfaces of all buildings in the US, it would be possible to generate 40 per cent of the U.S. energy demand, and that this could be increased to 100 per cent (provided that the technology was combined with rooftop solar units and that energy storage was improved) [201]. At this point in time, this technology is not yet commercially available.

4.3.6 Hazardous materials

In the Living Building Challenge (LBC) Red List, the International Living Future Institute (ILFI) provides an annual review of the “worst in class” materials, chemicals, and elements known to pose serious risks to human health and the greater ecosystem, that are prevalent in the building products industry [202]. A summary of the changes that occurred since 2019 is outlined in Table 4 in Appendix A.



5.0 Summary and conclusion

The building and construction sector is a significant contributor to New Zealand's economy. It contributed to 6.7 per cent of total GDP in 2019, and was the fourth largest employer, employing 275,600 people in the year ended June 2021 [1, 2].

With the onset of the COVID-19 global pandemic, the sector faced a unique set of challenges which impacted on how building and construction businesses operated in the past year. However, despite this, building activity remained high, particularly in the past six months, where the number of residential building consents reached record-level highs. There also appeared to be a steady workforce pipeline, due in part to an increase in the number of domestic students enrolling in construction-related qualifications. The cost of building, however, remained high, and appeared to be exacerbated by the global supply chain issues impacting a number of industries, including construction.

In addition to COVID-19, New Zealand is now on a pathway to achieve zero carbon emission by 2050, following the declaration of a Climate Change Emergency in 2020 [203]. As a contributor of greenhouse gas emissions, the building and construction sector has a key role to play in the Government's climate change response.

It is worth considering how new design approaches, technologies, and materials can be used to achieve the Government's climate change objectives. This report has provided examples of innovations that could be adopted, to reduce the emissions and carbon footprint of buildings, introduce efficiencies and lower costs in the building process, and increase worker health, safety, and well-being. There is unharnessed potential in these innovations, which could play a significant role in the future of the construction sector.

However, the building and construction sector currently has lower research and development expenditure, relative to other sectors ($12 million; cf., $836 million for manufacturing; cf., $258 million for wholesale trade; cf., $1,056 million for professional, scientific, and technical services in the year ended August 2020) [204]. It also has one of the lowest degrees of change in technology, with 93.4 per cent of businesses in the sector reporting that they had made no or minor changes in technology in the year ended August 2020 [205].

Going forward, the sector may want to consider how it adapts to the changing building landscape and adopts the opportunities these innovations present. Supporting this, building legislation will need to continue to evolve to ensure that the benefits of these can be reaped.

In conclusion, this report highlights that the sector currently remains strong in face of the COVID-19 pandemic. New building designs, technologies, and materials present significant opportunities to further lift sector productivity and safety, as well as assist Government reach its climate change goals, and ensure that New Zealanders have safe, healthy and durable buildings now and into the future.

Appendix A

Table 4 provides an outline of the "worst in class" materials, chemicals, and elements known to pose serious risks to human health and the greater ecosystem that are prevalent in the building products industry [202].

Table 4

The 2021 Living Building Challenge Chemical Class Red List changes (since May 2019)		
New additions to the "red list": › Antimicrobials (marketed with a health claim) › Chlorobenzenes › Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) › Monomeric, polymeric, and organophosphate halogenated flame retardants (HFRs) › Perfluorinated and Polyfluorinated Alkyl substances (PFAS) / Perfluorinated compounds (PFCs) › Polychlorinated biphenyls (PCBs) › Polycyclic aromatic hydrocarbons (PAHs) › Short-chain and medium-chain chlorinated paraffins › Wood treatments containing creosote or pentachlorophenol	**New additions to the "priority for red list inclusion":** › Alkylphenols and related compounds › Biphenol A (BPA) and structural analogues › Perfluorinated and Polyfluorinated Alkyl Substances (PFAS) / Perfluorinated compounds (PFCs) › Phthalates (orthophthalates)	**New additions to the "watchlist":** › California-banned solvents › Monomeric, polymeric, and organophosphate halogenated flame retardants (HFRs)

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