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Near zero emission houses and offices

New Zealand Green Building Council

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Key findings

Constructing, maintaining, and operating houses, office buildings (offices), and other building types has a significant impact on climate change causing emissions of carbon. Worldwide, the construction and operation of buildings accounted for 39 percent of emissions in 2017. In New Zealand, the built environment is estimated to make up 20 percent of total emissions. This presents an opportunity to reduce emissions by building new homes and offices to standards that are greener and more sustainable, and that result in healthier, happier New Zealanders.

Despite the potential for new houses and offices to contribute to New Zealand's emission reduction targets very few near zero emission houses or offices have been built, and information on the impacts is limited. To fill this gap the New Zealand Green Building Council (NZGBC) developed specifications for five average buildings and worked with its members, Rawlinsons and BECA, to estimate the costs, electricity demand, and emissions for each.

Houses

- Just code compliant house: A typical 182m^2 stand-alone house constructed to meet the minimum requirements of the New Zealand building code H1 4th edition 2007.
- Low emission house: A 182m^2 stand-alone house constructed with a modified thermal envelope that minimises operational emissions and reduces embodied emissions.
- Near zero emission house: A 182m^2 stand-alone house constructed with a modified thermal envelope (including suspended floor) that minimises operational and embodied emissions.

Offices

- Standard office: A four storey office building covering a gross floor area of 9,424m^2 built to the minimum requirements of the building code.
- Low emission office: A four storey office building covering a gross floor area of 9,424m^2 built with low emission materials to reduce embodied emissions by 45 percent when compared to the standard office.

To understand the potential impacts of building low and near zero emission houses and offices this report was prepared by Business and Economic Research Limited (BERL) for the NZGBC. The report highlights some of the potential benefits that could be achieved by building homes and large offices to a near zero emission standard. Two scenarios are used to estimate the economic, emission, electricity demand, and health impacts that could be achieved by building near zero houses and large offices.

2025/2035 scenario

- Just code compliant houses and standard offices are built in 2023 and 2024. From 2025 to 2034 low emission houses and low emission offices are built. Finally, from 2035 to 2050 near zero emission houses and low emission offices are built. (A similar trajectory to the aims of the Ministry of Business, Innovation and Employment's building for climate change programme).

2030/2040 scenario

- Just code compliant houses and standard offices are built between 2023 and 2029. From 2030 to 2039 low emission houses and low emission offices are built. Finally, from 2040 to 2050 near zero emission houses and low emission offices are built.

Houses

Building near zero emission houses has the greatest economic impact, followed by the low emission house and the just code compliant house. The earlier these houses are built the greater the potential economic impact of construction, electricity savings and emissions avoided. Therefore, it stands that beginning construction of low emission houses in 2025, and near zero emission houses from 2035 delivers the greatest impacts.

Economic impact

The 2025/2035 scenario construction of low and near zero emission houses would result in an additional $42 billion direct contribution to GDP and an additional 369,000 years of direct full-time equivalent employment (FTE), compared to building just code compliant houses. When the indirect and induced impacts are included, the total GDP contribution is $141.5 billion, at an average of $5.1 billion per year. Total additional employment from lower emission houses, over 28 years, averages just under 41,000 additional FTEs per year. Over 28 years this totals over 1.1 million FTE years.

Economic outcomes of scenarios compared to building just code compliant houses

	GDP ($m)		Employment (FTE years)	
	Direct	Total	Direct	Total
2025/35 scenario	41,638	141,458	368,902	1,144,768
2030/40 scenario	34,342	115,836	304,759	937,342

Electricity demand

The superior thermal envelope of the low emission and near zero emission houses reduces electricity demand as less energy is required to keep the house warm. Compared to the just code compliant house, the annual reduction in electricity demand from the low emission house and the near zero emission house is 4,300 kilowatt hours (kWh) per year in the Upper North Island, and 9,400 kWh per year in the South Island. Building only low and near zero emission houses from 2025 to 2050 will result in electricity demand being 7,600 gigawatt hours (gWh) less in 2050 than if just code compliant houses were built. If low and near zero emission houses were built from 2030 to 2050 electricity demand in 2050 would be 6,200 gWh less than if just code compliant houses were built.

Embodied emissions

The low and near zero emission houses are deigned to reduce A1-A5 embodied emissions by 16 to 42 percent compared to the just code compliant house. As a result, in both scenarios from the time low emission houses are built embodied emissions from the construction period are significantly reduced. If low emission houses are built from 2025 to 2034 and near zero emission houses are built from 2035 onwards 2050 an annual average of 1.2 million tonnes CO_2-e emissions would be prevented each year, totalling almost 30 million tonnes CO_2-e by 2050.

Embodied emission (A1-A5) scenario comparison (kg CO_2-e)

Year	Just code compliant	2025/2035 scenario	2030/2040 scenario
2025	2,497,279	2,300,434	2,497,279
2030	2,768,121	2,549,928	2,549,928
2035	3,100,225	1,593,217	2,855,854
2040	3,423,752	1,759,479	1,759,479
Total 2023-2050	90,334,336	60,368,298	67,967,368

Offices

Building low emission offices will have a greater economic impact compared to continuing to build standard offices. The earlier lower emission offices begin to be built the greater the potential economic impact of construction, electricity savings and emissions avoided. Although this analysis looks at large offices, similar benefits would be expected if smaller offices were built to the low emission standard.

Economic impact

In the 2025/2035 scenario construction of low emission offices would result in an additional $1.57 billion direct contribution to GDP and an additional 14,600 years of full-time equivalent employment (FTE) compared to building standard offices. When the indirect and induced benefits that flow through the economy are included, the GDP contribution is $5.2 billion, at an average of $187 million per year. Total additional employment from building these offices over 28 years averages 1,550 additional FTEs per year. Over 28 years this totals to 43,400 FTE years.

Economic outcomes of scenarios compared to building standard offices

	GDP ($m)		Employment (FTE years)	
	Direct	Total	Direct	Total
2025/35 scenario	1,573	5,242	14,635	43,428
2030/40 scenario	1,270	4,234	11,820	35,077

Electricity demand

The superior performance of the low emission office building results in lower electricity demand. The annual reduction in electricity demand resulting from building a low emission office instead of standard offices is almost one million fewer kWh (one gWh). Building only low emission offices from 2025 to 2050 will result in electricity demand being 539 gWh less than if standard offices were built. If low emission offices are built from 2030 to 2050 electricity demand will be 435 gWh less in 2050 than if standard offices were built over the same period.

Embodied emissions

The low emission offices are designed to reduce embodied emissions by 45 percent compared to the standard office. As a result, in both scenarios, from the time low emission offices are built embodied emissions from the construction period are significantly reduced. If low emission offices are built from 2025 to 2050 an annual average of 46,200 tonnes CO_2-e emissions would be prevented each year, totalling 1.2 million tonnes CO_2-e by 2050. If they were built from 2030 the saving would be just under 970,000 tonnes.

Embodied emissions (A1-A5) compared to building standard offices (tn CO_2-e)

Year	2025/2035 scenario	2030/2040 scenario
2025	-46,178	0
2030	-46,178	-46,178
Total	-1,200,618	-969,730

Maximising the economic impact

The most ambitious scenario, which would see low emission houses and large offices built exclusively from 2025 and then low emission office and near zero emission houses exclusively from 2035 onwards until at least 2050, would contribute an additional $147 billion to New Zealand's GDP, and over 1.2 million additional FTE years, compared to the scenario where just code compliant houses and standard large offices are built over the same period.

Compared to the just code compliant houses and standard offices, the low emission and near zero emission houses and offices would reduce the expected electricity demand from new build houses and offices by over 8,000 gWh by 2050. As the population grows, and electricity replaces fossil fuels, electricity consumption is expected to increase. Limiting demand from the built environment will reduce the investment required to meet that growing demand, and reduce the chances of future electricity blackouts due to an inability to meet demand.

Across houses and offices almost 13 million tonnes of C02-e will be saved by reduced A1 to A5 embodied emissions during construction.

Health and well-being benefits

The impacts on health and well-being are difficult to measure accurately in a theoretical context. There are several factors that impact on health outcomes that are unique, and are likely to be highly dependent on contextual factors relating to building type, building characteristics, and the surrounding environment. Given these complexities we have not tried to quantify the estimated health benefits of New Zealand houses and offices becoming near zero emission.

Inadequately heated houses can have health consequences for occupants, particularly during winter periods. Cold indoor temperatures, dampness and mould have been linked to increased risk of respiratory symptoms. There is strong evidence for asthma exacerbation and respiratory infections, and also limited evidence for asthma development, in houses that are too cold, damp or mouldy.

Low and near zero emission houses will keep indoor temperatures at 20 degrees. International research, and domestic studies that address retrofit schemes, such as Warm up New Zealand: Heat Smart, and Warmer Kiwi Homes, provide an indication of the positive impact better quality housing is likely to have. Insulating houses led to a significantly warmer, drier indoor environment which resulted in improved self-rated health, and a reduction in wheezing, days off school and work, self-reported visits to general practitioners, as well as a trend for fewer respiratory hospital admissions.

In the office context, case study experiences indicate green buildings may positively affect public health. Improved indoor environmental quality contributes to reductions in perceived absenteeism and work hours affected by asthma, respiratory allergies, depression, and stress. However, the quality of the built environment can limit these impacts and improve productivity.

International studies have also shown a direct link between cognitive function and the indoor environment of green buildings, including improved focused-activity levels, information usage, and strategy and crisis-response. The results were consistent with earlier findings that suggested better air quality led to increased work performance, reduced sick building syndrome symptoms, reduced absence, and improved thermal comfort.

A new house or office built to the low emission, or near zero emission, standard is likely to be superior to retrofitting, therefore we expect the benefits of building near zero emission houses and offices in New Zealand would have similar, if not superior, results. The sooner these are built the sooner the benefits are realised.

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1 Introduction

Buildings are an essential part of life. They keep us and our loved ones warm and dry, provide shelter and sanctuary, and environments for learning and economic activity. However, constructing, maintaining and operating the built environment has a significant impact on climate change emissions. Worldwide, the construction and operation of buildings accounted for 39 percent of emissions in 2017. As New Zealand's population has grown, so have emissions from our houses and buildings. In New Zealand emissions from the construction industry have increased by 66 percent in the decade from 2007 to 2017.[1]

As part of New Zealand's commitment to address climate change the Government has set domestic targets under the Climate Change Response Act 2020 that include net zero emissions of all greenhouse gasses (GHG) other than biogenic methane by 2050, and a 24 to 47 percent reduction, below 2017 levels, of biogenic methane emissions by 2050.[2]

New Zealand has also signed up to international agreements to address climate change. These include a 2030 target to reduce net emissions to 30 percent below 2005 levels.

The built environment is regularly quoted as being responsible for two to five percent of New Zealand's carbon emissions, however this only considers the operational energy.[3] In 2018 Thinkstep prepared a report for the New Zealand Green Building Council (NZGBC) that estimated that if the full building cycle is considered, from material construction right through operation to demolition, the contribution of the built environment increases to 13 percent of domestic emissions.[4] If international trade is also included, Thinkstep estimates the built environment contributes one fifth of New Zealand's gross carbon footprint.[5] The 20 percent is comprised of 8.7 percent from building products, 8.6 percent from energy 2.1 percent from imported emissions, and 0.5 percent from building and garden waste. Thinkstep stated "[t]hese figures suggest that the built environment offers greater opportunities to reduce New Zealand's carbon footprint than is typically assumed."[6]

Emissions for the built environment can be split into two broad areas, embodied emissions and operational emissions. Embodied emissions are the emissions that occur during the manufacture and construction of a building and its materials. Operational emissions refer to the emissions that are generated from powering houses and buildings, including lighting, space and water heating, ventilation and appliances.

This report was prepared for the NZGBC and attempts to estimate the economic, emissions, electricity demand, and health benefits that could be achieved if all New Zealand's new build houses, and large commercial office buildings (offices), were to become zero carbon under two scenarios:

- Zero operational carbon, and a halving of embodied carbon, for new houses and offices from 2025. Plus zero carbon for new houses and offices from 2035.
- Zero operational carbon, and a halving of embodied carbon, for new houses and offices from 2030. Plus zero carbon for new houses and offices from 2040.

[1] New Zealand Green Building Council (2022). *Climate change & building pollution*.
[2] Ministry for the Environment (2022). *Greenhouse gas emissions targets and reporting.*
[3] Productivity Commission (2018). *Low-emissions economy*.
[4] Thankstep (2018). *The carbon footprint of New Zealand's built environment.*
[5] Ibid.
[6] Ibid.

1.1 Background

The Intergovernmental Panel on Climate Change states that the world needs to achieve net zero carbon emissions by 2050, and to reduce emissions by 50 percent by 2030, if we are to avoid a range of climate change impacts.[7]

The Government has committed to a vison that, "[b]y 2050 New Zealand's buildings are using as little energy and water as possible. They are warmer, drier and better ventilated, and provide a healthier place for us all to work and live."[8]

The Ministry for Business, Innovation and Employment (MBIE) launched its Building for Climate Change Programme in mid-2020. The objective of the programme is to transform the building and construction sector to reduce its emissions and improve climate resilience.[9]

In announcing the programme, the Minister for Building and Construction, Jenny Salesa, stated "[t]o help us reach this new state, changes will be made to current building laws, targets will be set for energy use and carbon emissions, and incentives will be introduced to encourage people to think innovatively about the construction, design and operation of buildings"[10]

Reducing the emissions associated with the construction sector would have benefits for many New Zealanders. Warmer, healthier houses would reduce household bills, and have health benefits. High rates of respiratory disease are estimated to cost the country $6 billion per year.[11]

Greener offices offer benefits for government and businesses because of reduced energy bills and increased productivity.

The construction sector is aware of its need to improve its environmental performance. Early responses from MBIE's consultation on its Building for Climate Change programme found that 92 percent of respondents agreed that the construction sector needs to take action to reduce emissions. However, 79 percent also said that there are barriers preventing or discouraging them from taking action.[12]

95 percent of respondents either agreed or strongly agreed that the programme should include measures to improve operational efficiency, and 87 percent of the survey responses agreed that the programme should include initiatives to reduce whole of life embodied carbon.[13]

Climate Change Minister, James Shaw, has acknowledged that improving our housing and building stock will not just have environmental benefits, but also economic impacts. "We owe it to future generations to design and build better and more climate-friendly buildings. This [Building for Climate Change] Programme will not only realise the full potential of the building and construction sector to help meet our climate change targets but help create new jobs in communities all across the country".[14]

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[7] Intergovernmental Panel on Climate Change (2022). *The evidence is clear: the time for action is now. We can halve emissions by 2030.*

[8] Ministry of Business Innovation and Employment (2020). *Building for Climate Change: Transforming the Building and Construction Sector to reduce emissions and improve climate resilience.*

[9] Ibid

[10] Salesa J., Shaw J. (2020). *Building a more sustainable construction sector.*

[11] Supra n 8.

[12] Supra n 8.

[13] Supra n 8.

[14] Supra n 10.

1.1.1 About the New Zealand Green Building Council

The New Zealand Green Building Council (NZGBC) is a passionate advocate for better buildings. The NZGBC recognises that better buildings mean healthier, happier Kiwis. It was established by the construction sector in 2005 and is Aotearoa's leading sustainable building not-for-profit. In 2006 the NZGBC became the sixth member of the World Green Building Council.[15] The NZGBC has since grown to over 700 members, including large government departments, banks, energy companies, insurers, property and construction companies, architects, developers, designers, and tertiary education providers. In addition, 60 percent of New Zealand is represented by local authority members.[16]

NZGBC's vision is for New Zealanders to live, work and play in healthy, efficient, and productive buildings in a sustainable built environment. NZGBC works to achieve this by promoting the benefits of sustainable buildings through creating a common language, demonstrating their value, assisting the property and construction sector to acquire the skills and knowledge to be able to deliver a sustainable built environment, and by encouraging and rewarding the sustainable development and operation of buildings across New Zealand.

To enable New Zealanders to be safe, healthy, and happy the NZGBC:

- Connects the people who can make a difference
- Inspires the market to build quality, efficient buildings
- Campaigns for regulatory reform and policy change
- Collaborates with industry to create best practice green building rating tools
- Provides education and training
- Holds events around New Zealand to share local and international expertise
- Supplies access to networks, information, and resources about green building for its members.

The actions and initiatives taken by the NZGBC, and its members, have led to changes in the New Zealand building code, and have helped to ensure hundreds of projects are designed and built better.

1.1.2 What is a green building?

A green building is one that is designed, built, and operated to reduce or remove any negative impact on the environment and the people using it. Green buildings make more efficient use of resources such as energy and water, and provide healthier environments for people to live and work in. Green building practices can also reduce construction and operation costs.

The World Green Building Council defines a net zero carbon building as one that is "highly efficient, with all remaining energy from on-site and/or off-site renewable sources". The NZGBC has taken this definition one step further. In the case of new buildings, the NZGBC thinks that the carbon emitted during construction (embodied emissions) should also be included in calculations.

An example of a net zero carbon building combines an energy efficient building design, which includes fixed appliances, with a solar energy system to help reduce running costs, increase comfort, and curb carbon emissions. It is designed to produce enough renewable energy to off-set

[15] There are now 70 green building councils around the world, representing over 36,000 members.
[16] New Zealand Green Building Council (2022). *Our vision.*

the annual greenhouse gas emissions of its estimated energy use. The need to for on-site renewable energy in New Zealand is less than other countries given our high proportion of our energy is generated from renewable sources. This proportion is predicted to get even greater with the Climate Change Commission advising the government it should aim to reach 95 to 98 percent renewable by 2030.[17] Therefore, we have focussed on fully electric buildings with very low energy demand.

The benefits of a net zero carbon building include lower energy bills, increased comfort and quality, reduced carbon emissions and improved wellbeing.

This report focuses on two types of emissions:

- Operational emissions – Energy and water used in the day-to-day operations of houses and buildings, including heating and appliances.
- Embodied emissions - Greenhouse gas emissions generated by building materials, construction processes and disposal of materials, also known as whole of life embodied carbon.

1.2 Scope of the assessment

Business and Economics Research limited (BERL) was engaged by the NZGBC to produce an authoritative, independent report detailing the impacts a zero-carbon built environment will have on New Zealand's economy by 2050, based on the two scenarios.

The assessment will show the impact on expenditure, gross domestic product (GDP), and jobs between 2023 and 2050 under each scenario, and put a dollar value on the benefits a transition to a zero-carbon built environment are likely to bring. Given the variety in New Zealand's built environment this assessment only focuses on average houses and large offices.

This assessment should be considered as indicative of the potential impact of a transition to a zero-carbon built environment would have on the New Zealand economy. As there is a wide variation in the design and construction of houses and offices this assessment is only intended to inform policy influencers, and decision makers, of potential impacts as they determine the future of New Zealand's built environment, and New Zealand's climate change initiatives.

1.3 Approach

The approach used existing publicly available data complemented with data provided by NZGBC and its members. After an initial desktop review, it was determined that the assessment would focus on residential houses and large offices. This excluded industrial, retail, and ancillary buildings where data was considered insufficient to allow an accurate assessment of the impacts. The approach included four stages:

Stage one: Establish the baseline data available

Limited information was available on net zero carbon emissions construction and building. During conversations with NZGBC and its members it was identified that there have been very few net zero emission houses and offices constructed. As a result, there was a lack of publicly available information on the costs of constructing houses and offices to net zero carbon emission standards. Previous reports have focused on specific projects that have sought to make houses warmer and dryer.

[17] He Pou a Rangi Climate Change Commission (2022). *Ināia tonu nei: a low emissions future for Aotearoa*.

Stage two: Additional data collection from NZGBC members to fill gaps in existing data

NZGBC worked with BECA and Rawlinsons to develop specifications and costs for average offices and average houses built to the New Zealand building code H1 4th edition 2007 standard, and as close to net zero emission as possible.[18]

Stage three: Forecast the future stock of houses and offices

Using Statistics New Zealand housing data, the BRANZ building and energy use study (BEES), the BRANZ Household Energy End-use Project (HEEP), the BRANZ National Construction Pipeline Report, population estimates, building consents, and historic trends, future demand for houses and large offices out to 2050 was forecast.

Stage four: Estimate the economic benefit, emissions impact, and other benefits

Stage four brought together the findings of the first three stages to estimate the economic impact of new build houses and offices being built to a near zero emission standard. At this stage the impacts on energy demand and emissions were estimated. Finally, we highlight existing evidence from previous studies addressing the impact of healthier houses to understand the potential impact improved housing standards are likely to have on health and health services.

1.3.1 Assumptions made in the assessment

BERL used averages and made several assumptions in assessing the scenarios. The assumptions throughout all calculations and estimates are:

- "Average" houses and offices have been used to represent New Zealand's future new build houses and large offices.
- All costs, electricity demand and emissions are taken from the specifications developed by NZGBC, assessed by BECA, and costed by Rawlinsons. These are included in Appendix A (houses) and Appendix B (offices)
- The base for the stock of offices is taken from the BEES.[19]
- The base for the stock of housing has been taken from Statistics New Zealand[20]
- Future construction of houses and buildings will be consistent with New Zealand's historic economic performance and growth of houses and buildings, based on building consents granted[21] and population growth, both historic[22] and forecast[23], and BERL's economic forecasts.
- 80 percent of new houses are additions to the housing stock. The remaining 20 percent will replace existing houses.
- Five percent of all commercial consents and seven percent of offices are large offices.
- 60 percent of offices are additional stock and 40 percent are replacing existing large offices.

Additional assumptions have been made in sections of this report. Where made they are identified.

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[18] Specifications available in Appendixes A and B.

[19] Amitrano, L. (Ed.), Isaacs, N., Saville-Smith, K., Donn, M., Camilleri, M., Pollard, A., Babylon, M., Bishop, R., Roberti, J., Burrough, L., Au, P., Bint, L., Jowett, J., Hills, A. & Cory, S. (2014). *Building energy end use study (BEES) Part 1: Final Report, BRANZ Study Report 297/1.*

[20] Statistics New Zealand (2020). *Housing in Aotearoa: 2020.*

[21] Statistics New Zealand (2021). *Building consents issued.*

[22] Statistics New Zealand (2021). *Estimated population of New Zealand*.

[23] Statistics New Zealand (2020). *National population projections: 2020(base)–2073.*

2 Buildings and scenarios used in this assessment

This assessment uses three house specifications and two office specifications to reflect the houses and offices that would be built to enable New Zealand to meet, or get as close as possible to, NZGBC's operational and embodied emissions targets.

Full specifications of the houses are included in Appendix A, and full specifications of the offices are in Appendix B.

2.1 Houses

To meet the targets and illustrate the impacts of the transition to the near zero emission-built environment, three specifications for a typical 182m^2 stand-alone house were produced and then costed by Rawlinsons. The three specifications were: a just code compliant house, a low emission house, and a near zero emission house.

2.1.1 Just code compliant house

For comparison against the houses that reduce emissions Rawlinsons created a specification for a typical 182m^2 stand-alone house constructed to meet the minimum requirements of the New Zealand building code H1 4th edition 2007. This house has three bedrooms and a study and assumes a typical set point temperature for New Zealand houses of 18 degrees.

The construction cost of the just code compliant house is $545,000

2.1.2 Low emission house

The low emission house, and the near zero emission house both use the same base specifications as the just code compliant house but with a modified thermal envelope to achieve that exceeds building code requirements, minimises operational emissions, and reduces embodied emissions in the Upper and Lower North Island, and the South Island. The total energy, and total heating energy (all electric in this case), excluding appliances, uses no more than 15 kWh/m2/yr.

Both the low emission house and the near zero emission house have full mechanical ventilation with a heat recovery system. This saves energy, but the primary benefit is better indoor air-quality.

The difference between the low emission house and the near zero emission house is the substructure. The low emission house has a concrete slab floor made from eco-concrete to reduce the embodied emissions from concrete. This provides a solution to reducing embodied emissions, without the additional cost required to reduce embodied emissions further.

The construction cost of the low emission house is $626,800 in the Upper North Island, $646,000 in the Lower North Island and $655,000 in the South Island.

2.1.3 Near zero emission house

The near zero emission house uses the same base specifications as the just code compliant house, with the same modified thermal envelope as the low emission house to minimise operational emissions. To reduce embodied emissions as far as possible the concrete substructure is replaced by a suspended timber floor. This comes at an additional cost and reduces embodied emissions but does not reduce annual operational energy demand.

Consistent with the low emission house is keeping total energy and total heating energy (all electric in this case), excluding appliances use, to no more than 15 kWh/m^2/yr.

The construction cost of the near zero emission house is $663,000 in the Upper North Island, $682,000 in the Lower North Island and $695,000 in the South Island.

2.1.4 Housing scenarios

Three scenarios are used in the assessment of housing. These scenarios are intended to align with the scenarios proposed by NZGBC. However, technology, materials, and New Zealand's current reliance on fossil fuel for a proportion of electricity supply, do not yet allow for a house that is 100 percent net zero emission without use of carbon offsets.

Just code compliant scenario

This represents the status quo if all houses continued to be built to the minimum requirements of the New Zealand building code H1 4th edition 2007, and illustrates the likely impact if changes are not made to encourage emission reduction. This scenario assumes that just code compliant houses will be built from 2023 to 2050.

2025/2035 scenario

This scenario represents achieving as close as currently possible to zero operational carbon, and a halving of embodied carbon, for new houses by 2025, and near zero emissions by 2035. This scenario assumes that just code compliant houses will be built in 2023 and 2024. From 2025 to 2034 low emission houses will be built. Finally, from 2035 to 2050 near zero emission houses will be built.

2030/2040 scenario

This scenario represents achieving as close as possible to zero operational carbon, and a halving of embodied carbon, for new houses by 2030, and near zero emissions by 2040. This scenario assumes that just code compliant houses will be built between 2023 and 2029. From 2030 to 2039 low emission houses will be built. Finally, from 2040 to 2050 near zero emission houses will be built.

2.2 Offices

To illustrate the impacts of the transition to a near zero emission built environment NZGBC engaged BECA to design two specifications for a theoretical four storey office with a gross floor area of 9,424m^2. One built to the minimum requirements of the New Zealand building code (standard office), and the second one built as close to near zero emission as possible (near zero office). These two office buildings were then costed by Rawlinsons.

2.2.1 Standard office

The standard office will be built to the New Zealand building code standard and will have four stories covering a gross floor area of 9,424m^2. The bottom floor is assumed to be retail with the upper three floors as office space. The construction cost of the standard office is $53 million.

2.2.2 Near zero office

The near zero office uses the same base specification as the standard office. However, substitution to low emission materials means the total embodied emissions are 45 percent less than the standard office. One of the biggest reductions in embodied emissions comes from replacing standard office structural steel frames with mass timber, although for the theoretical building layout this results in reduced amenity of the space. The construction cost of the near zero office is $63 million.

2.2.3 Why there are only two office specifications

It is not possible to reduce embodied emissions further with current materials and technology. A 45 percent reduction in emissions was the best that could be achieved. Further substitution would be possible. However, the structural efficiency and practicality of the solutions are currently not pragmatic. Any future reductions to embodied emissions from new build offices will need to come from innovations that reduce emissions from concrete, aluminium and steel production, and improvements to emissions from transporting materials.

BECA noted in their assessment of embodied emissions that "large-scale reductions in embodied carbon of open plan (retail and office space) multi-storey buildings in New Zealand may not be easily achievable. Seismicity of building location and proposed building height can preclude some of the most effective embodied carbon reduction strategies". Reducing emissions by more than 20 percent per square metre appears to require widespread material substitution as an alternative to current industry norms.[24]

2.2.4 Office scenarios

Standard scenario

This represents the status quo if all buildings were built to the minimum requirements of the New Zealand building code and illustrates the likely impact if changes are not made to encourage emission reductions. This scenario assumes that standard offices will be built from 2023 to 2050.

2025/2035 scenario

This scenario represents achieving as close as possible to zero operational carbon and halving embodied carbon for new offices by 2025, and near zero emissions by 2035. This scenario assumes that standard offices will be built in 2023 and 2024. From 2025 near zero emission offices will be built.

It is not possible to reduce embodied emissions further with current materials and technology and so this scenario does not consider a near zero embodied emission situation.

2030/2040 scenario

This scenario represents achieving as close as possible to zero operational carbon and halving embodied carbon for new offices by 2030, and near zero emissions by 2040. This scenario assumes that standard offices will be built from 2023 to 2030. From 2030 near zero emission offices will be built.

As in the 2025/2035 scenario, it is not possible to reduce embodied emissions further with current materials and technology.

[24] BECA Limited (2022). *NZGBC zero carbon research project. Embodied carbon reduction assessment.*

3 Building forecasts

To establish the impact of transitioning to a near zero emission built environment the first step was to estimate the current and future stock of New Zealand's houses and offices.

Using Statistics New Zealand housing data, the BRANZ building and energy use study (BEES), population estimates, building consents, historic trends, and the National Construction Pipeline Report 2021, BERL has forecast future demand for construction and building.[25] This included forecasting the housing and office stock for each year between 2023 and 2050.

3.1 Houses

At the start of 2023 New Zealand's residential housing stock will be just under 2.04 million houses. This is shown in Figure 3.1. Between 2017 and 2020 New Zealand is estimated to have averaged just under 36,000 new build houses per year, of which just over 29,000 houses were additional stock. The remainder were replacing existing houses. BERL estimates that in 2023 just under 44,000 new houses will be built, with over 35,000 additions to the stock. As New Zealand goes through a period of low economic growth between 2023 and 2025 this slows to 37,000 in 2025 before increasing to reach 59,000 by 2050.

As New Zealand's population grows and more houses are required for the increased population, New Zealand's housing stock is expected to increase to almost 3.1 million houses by 2050.

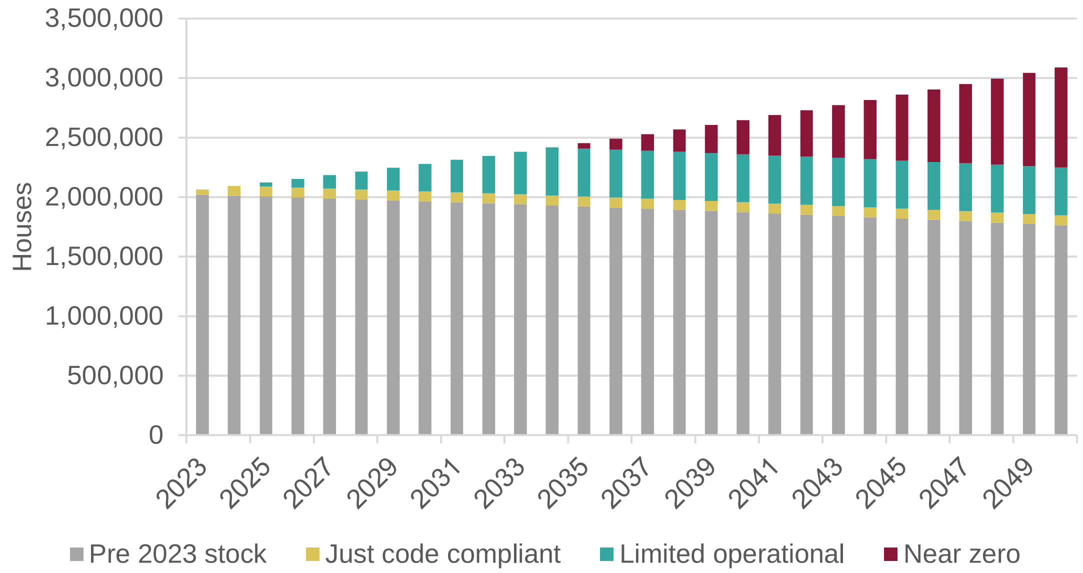
As Figures 3.1 and 3.2 show, by 2050 New Zealand will have almost 1.8 million houses that were built before 2023. Between the start of 2023 and the end of 2050 New Zealand will need to build almost 1.3 million new houses.

3.1.1 2025/2035 scenario

Figure 3.1 shows that in in the 2025/2035 scenario New Zealand will build almost 84,000 just code compliant houses in 2023 and 2024. From 2025 to 2034 New Zealand will build over 403,000 low emission houses, before over 840,000 zero emission houses are built from 2035 to 2050.

[25] Ministry of Business Innovation and Employment (2021). *National construction pipeline report 2021.*

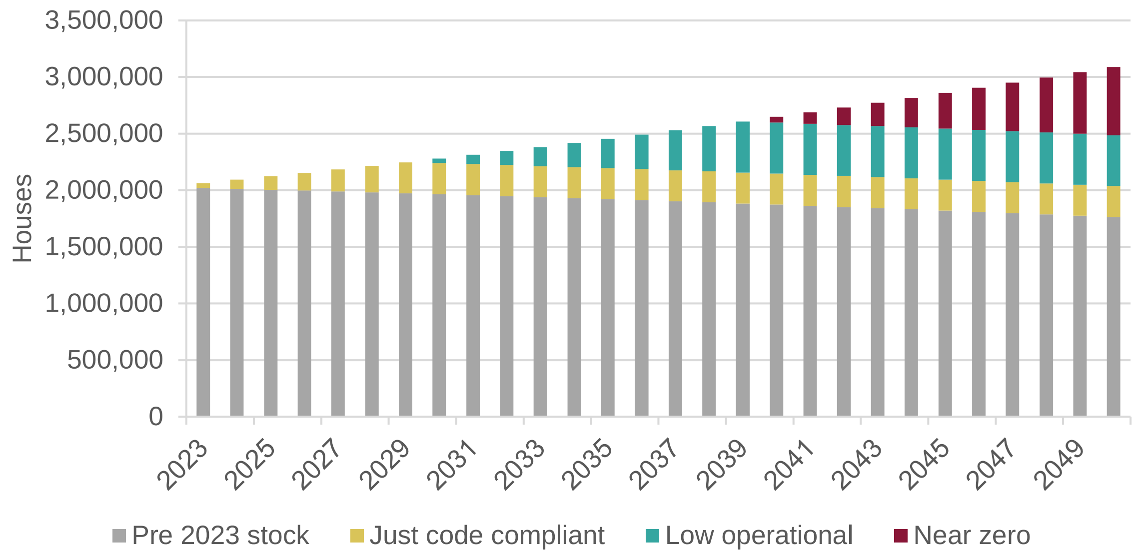
Figure 3.1 New Zealand housing stock 2025/2035 scenario



3.1.2 2030/2040 scenario

Figure 3.2 shows that from 2023 to 2029 New Zealand will build over 274,000 houses that are just code compliant standard, and then from 2030 to 2039 New Zealand will build 450,000 low emission houses. By 2050 there will be almost 603,000 near zero emission houses in the total national stock.

Figure 3.2 New Zealand housing stock 2030/2040 scenario

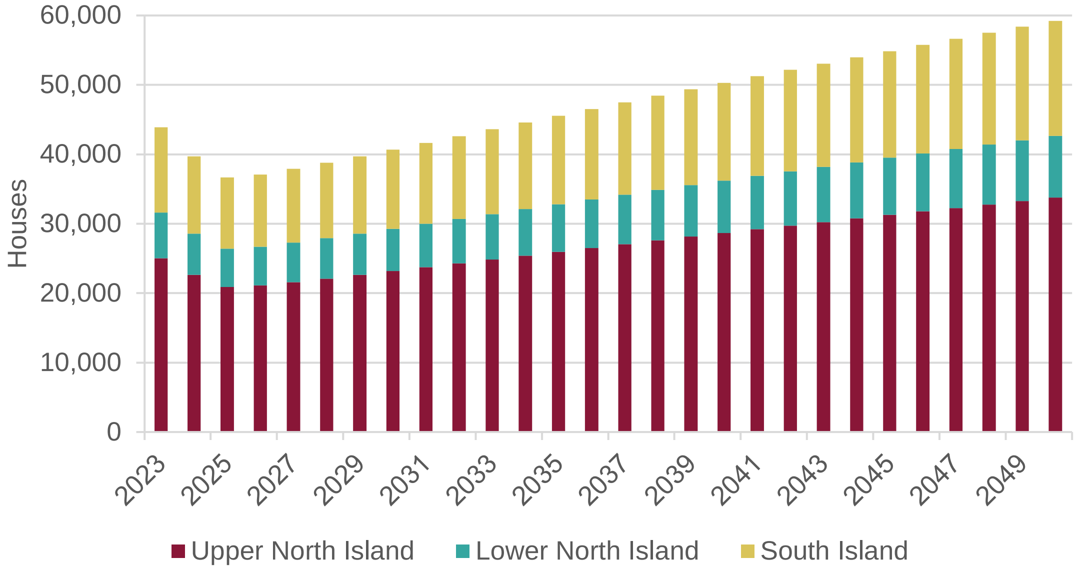


3.1.3 New builds by region

Meeting housing demand will require an extensive programme of building which will see 1.3 million new houses built between 2023 and the end of 2050. As Figure 3.3 shows, these will be spread with 57 percent in the Upper North Island, 15 percent in the Lower North Island and the remaining 28 percent in the South Island. To meet expected demand the total number of houses built per year will need to grow by 35 percent from almost 44,000 in 2023 to just over 59,000 houses in 2050. In 2050 this would see just almost 34,000 new houses in the Upper North Island, just under 9,000 in the Lower North Island and almost 17,000 in the South Island.

By 2025, when the first scenario will require low emission houses to be built, almost 37,000 houses will need to be built. In 2030, when the second scenario would require all houses to be low emission, just under 41,000 houses will need to be built. Looking out to 2035, when the first scenario will see all houses required to be near zero emission, the number of new build houses constructed will need to increase to almost 46,000. By 2040, when the second scenario would require near zero emission houses, the number built each year will be just over 50,000. By 2050 just under 59,200 new houses will be required each year.

Figure 3.3 New Zealand new build houses by region

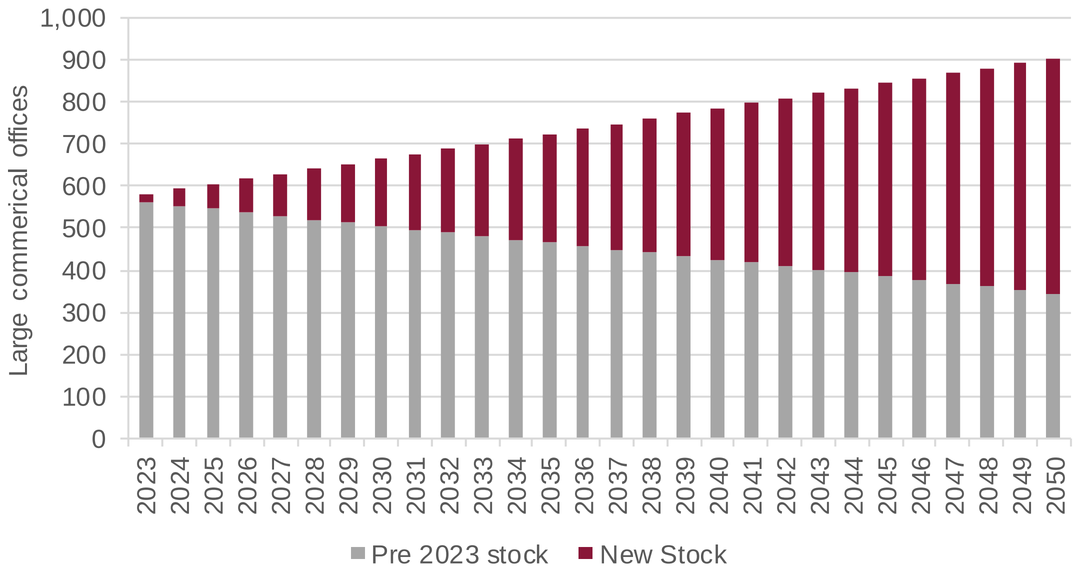


3.2 Offices

BERL estimates that at the start of 2022 New Zealand's office stock was just over 8,700 buildings. For the purposes of assessing the impact of transitioning to near zero emission buildings the focus is on large scale offices of at least 3,500m^2, of which there are estimated to be 581 in 2023. This is forecast to grow to 905 by 2050.

We estimate that between 2023 and 2050 New Zealand will construct 20 new large offices per year. As Figure 3.4 shows, from the reducing number of pre 2023 stock, eight of the new build offices will be replacements for existing offices. The remaining 12 of the 20 will be new buildings on currently vacant land, or on existing sites where they replace a different building type.

Figure 3.4 New Zealand office stock and forecast new builds



4 Economic impact of house construction

This section estimates the economic impact of house construction using multiplier analysis based on the 2019 Statistics New Zealand input output tables, and using the costs of construction for each of the three house specifications (just code compliant, low emission, and near zero emission) across the three regions, Upper and Lower North Island, and the South Island. The impact of a single house was then multiplied by the number of houses built in the region to estimate the impact of all house building in a region. The regional totals were then added together to estimate the national impact. The economic impact is measured by three indicators:

- Expenditure
- Gross domestic product (GDP)
- Employment

The economic impacts in this section are presented as direct impacts and total impacts. The direct impact is the impact of the initial spending on construction. Total impacts include the direct impacts as well as the indirect and induced impacts. Indirect impacts are the additional inter-industry spending resulting from the direct expenditure, for example payments made down the supply chain to suppliers. Induced impacts are the impacts of additional household expenditure resulting from the direct and indirect impacts. For example, the impact of house building employees, and the employees of suppliers, spending their salaries and wages throughout the economy.

All values used in this section are calculated in fixed 2022 dollar values and include GST.

Section 4.1 addresses the economic impacts of residential houses for the 2025/2035 scenario and section 4.2 outlines impacts for the 2030/2040 scenario.

Tables showing the annual direct, indirect, induced, and total expenditure, GDP, and employment impacts generated by each of the three house specifications across New Zealand are included in Appendix E.

Expenditure

Expenditure is the value of production, which is built up through the national accounts as a measure of gross sales or turnover. Table 4.1 shows the direct expenditure impact of each of the three house specifications in each of the regions. The contribution to total expenditure is least for the just code compliant house at $1.43 million. The near zero house results in $1.73 million of total expenditure when built in the Upper North Island, and $1.82 million when built in the South Island.

Table 4.1 Total expenditure impact per house ($m)

	Just code compliant	Low emission	Near zero emission
Upper North Island	1.43	1.63	1.73
Lower North Island	1.43	1.69	1.79
South Island	1.43	1.71	1.82

Gross Domestic Product

Gross Domestic Product (GDP) is the increase in output generated along the production chain. This is the sum of:

- Compensation of employees (i.e. salaries and wages)
- Income from self-employment
- Depreciation
- Profits
- Indirect taxes less subsidies.

Table 4.2 shows the total GDP impact of each house specification in each region. The GDP impact is linked to expenditure. Therefore, the contribution to total GDP is least for the just code compliant house at $540,000. The near zero house results in $650,000 of total GDP impact when built in the Upper North Island, and $680,000 in the South Island.

Table 4.2 Total GDP impact per house ($m)

	Just code compliant	Low emission	Near zero emission
Upper North Island	0.54	0.62	0.65
Lower North Island	0.54	0.64	0.67
South Island	0.54	0.64	0.68

Employment

The volume of employment is expressed as Full-Time Equivalents (FTEs). These are the number of full-time employees, working proprietors and part-time employees, converted to an annual basis. For example, four full-time jobs running for three months, or three part time jobs running for a year, would be shown as a single FTE.

As Table 4.3 shows the employment impact is lowest for the just code compliant house which generates 4.39 FTEs and greatest for the near zero emission house in the South Island which will generate total employment of 5.56 FTEs.

Table 4.3 Total employment impact per house (FTE)

	Just code compliant	Low emission	Near zero emission
Upper North Island	4.39	5.03	5.32
Lower North Island	4.39	5.18	5.47
South Island	4.39	5.25	5.56

4.1 2025/2035 scenario

In this scenario, as Table 4.4 below shows, just under 83,600 just code compliant, 403,300 low emission, and 840,300 near zero emission houses will be built across New Zealand between 2023 and 2050.

Table 4.4 2025/2035 scenario new build houses by specification and region 2023-2050

	2023-2024	2025-2034	2035-2050
	Just code compliant	Low emission	Near zero emission
Upper North Island	47,652	229,853	478,953
Lower North Island	12,540	60,488	126,040
South Island	23,408	112,910	235,275

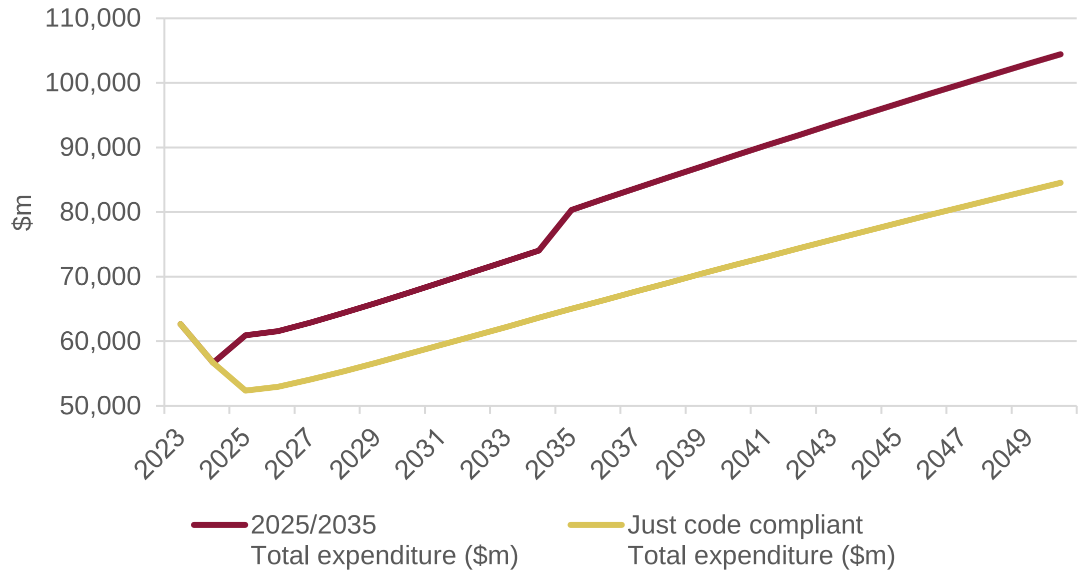
4.1.1 2025/2035 scenario expenditure

Direct expenditure on housing between 2023 and 2050 in this scenario is more than $871.3 billion. This includes $488 billion in the Upper North Island, $132 billion in the Lower North Island and $252 billion in the South Island. When the indirect and induced impacts are included, the total expenditure generated in the economy from the building of new houses totals $2.3 trillion.

As Figure 4.1 shows if New Zealand built just code compliant houses until 2050 total expenditure generated from house building would increase from $63 billion, for almost 44,000 just code compliant houses in 2023, to $85 billion for over 59,000 just code compliant houses in 2050. Over the period direct expenditure of $723 million would multiply up to total expenditure generated over the period of $1.9 trillion.

As the house specification changes from the just code compliant house to the low emission house, annual total expenditure increases from just under 40,00 houses built with total expenditure of just under $57 billion in 2024, to $61 billion in 2025 from the construction of almost 37,000 low emission houses. Finally, construction transitions to near zero emission houses in 2035. At this point total expenditure jumps from $74 billion for just under 45,000 houses in 2034, to $80 billion for just over 45,500 houses in 2035. By 2050 annual total expenditure generated from house building is $104 billion from just over 59,000 houses.

Figure 4.1 2025/2035 scenario total annual expenditure 2023-2050



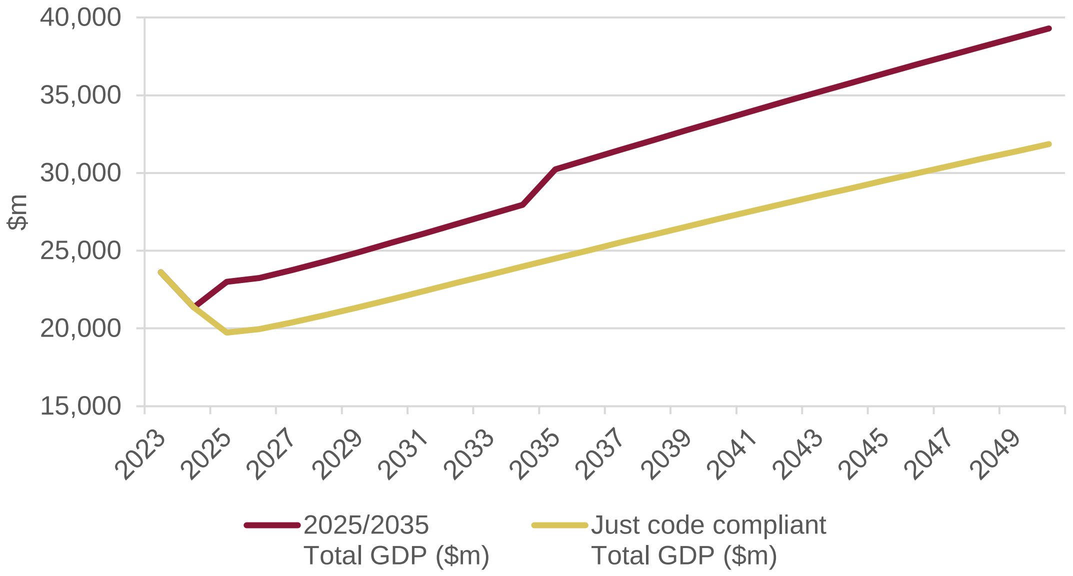
4.1.2 2025/2035 scenario GDP

Because of the link between expenditure and GDP the impact of house building on GDP follows a similar pattern to the impact on expenditure. As Figure 4.2 illustrates, there is a jump in the GDP impact when the house specification changes, and the cost of building these houses increases. Over the period from 2023 to 2050 the direct GDP impact will be $246 billion. When indirect and induced impacts are included, the total impact is $855 million.

In 2024 the direct GDP impact of the 39,700 just code compliant houses built will be $6.1 billion. If New Zealand were to continue to build just code compliant houses out to 2050 the direct GDP impact would be $205 billion. This would result in a $714 billion total GDP impact.

However, in this scenario, in 2025 New Zealand will transition to building 36,700 low emission houses, with a total GDP impact of $23 billion. Low emission houses will continue to be built until 2034 when 45,000 houses are built contributing $28 billion to GDP. In 2035, when just over 45,500 near zero houses are built, the total GDP impact will be $30 billion. As more houses are built each year this increases to reach $39 billion in 2050.

Figure 4.2 2025/2035 scenario total annual GDP impact 2023-2050



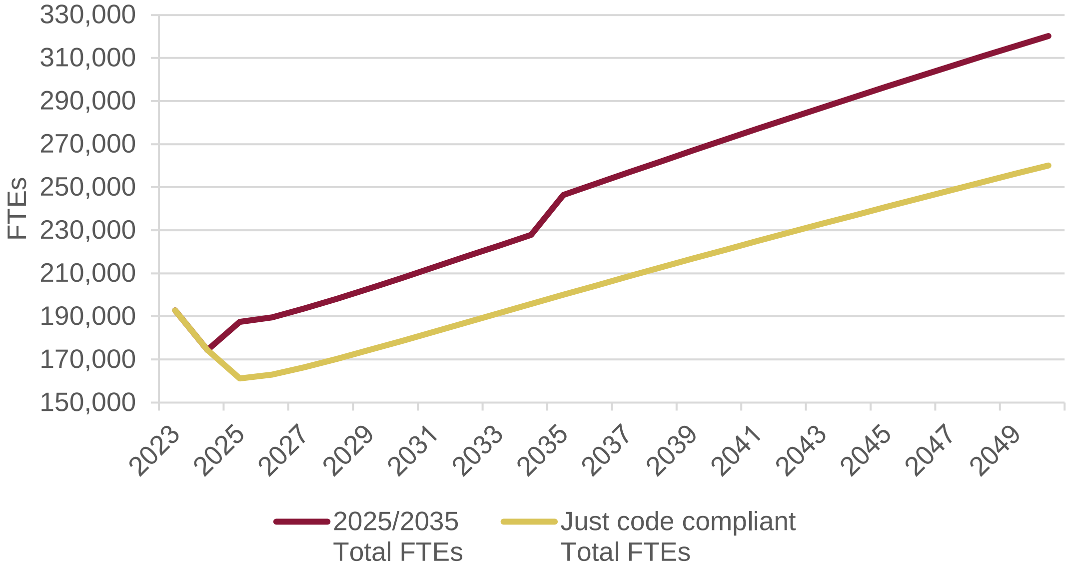
4.1.3 2025/2035 scenario employment

Employment also follows a similar track to expenditure and GDP. As Figure 4.3 shows, there is a jump in employment when the house specification changes. Over the period from 2023 to 2050 direct annual employment will grow from 64,000 FTEs to 105,000 FTEs. When indirect and induced impacts are included, the total employment generated from building new houses is 193,000 FTEs in 2023 and 320,000 in 2050. The direct employment years over the period total 2.3 million FTEs, at an average of 82,000 FTEs per year. This increases to almost 7 million total FTE years when indirect and induced impacts are included, an average of 249,000 FTEs per annum.

In 2024 the total employment impact of the 39,700 just code compliant houses built is just over 174,000 FTEs. If New Zealand were to continue to build just code compliant houses out to 2050 the direct impact would be 1.9 million FTE years, averaging 68,700 per year. This would result in a total of 5.8 million FTE years over the period from 2023 to 2050, at an average of slightly over 208,000 FTEs per year.

In 2025, when New Zealand will transition to build low emission houses, 37,000 will be built with a total employment impact of 188,000 FTEs. Low emission houses will continue to be built until 2034 when 45,000 houses are built supporting total employment of 188,000 FTEs. In 2035, when just under 46,000 near zero houses are built, the total employment impact will be 246,000 FTEs. As more houses are built each year this increases to reach 320,000 FTEs in 2050.

Figure 4.3 2025/2035 scenario total employment impact 2023-2050



4.2 2030/2040 scenario

As Table 4.5 shows, just under 274,000 just over code compliant houses, 450,000 low emission houses, and almost 603,000 near zero emission houses will be built between 2023 and 2050.

Table 4.5 2030/2040 scenario new build houses by specification and region 2023-2050

	2023-2029	2030-2039	2035-2050
	Just code compliant	Low emission	Near zero emission
Upper North Island	156,040	256,733	343,685
Lower North Island	41,063	67,561	90,443
South Island	76,651	126,114	168,828

Tables showing the annual direct and total expenditure, GDP, and employment impacts generated by each of these house specifications in each of the regions are included in Appendix E.

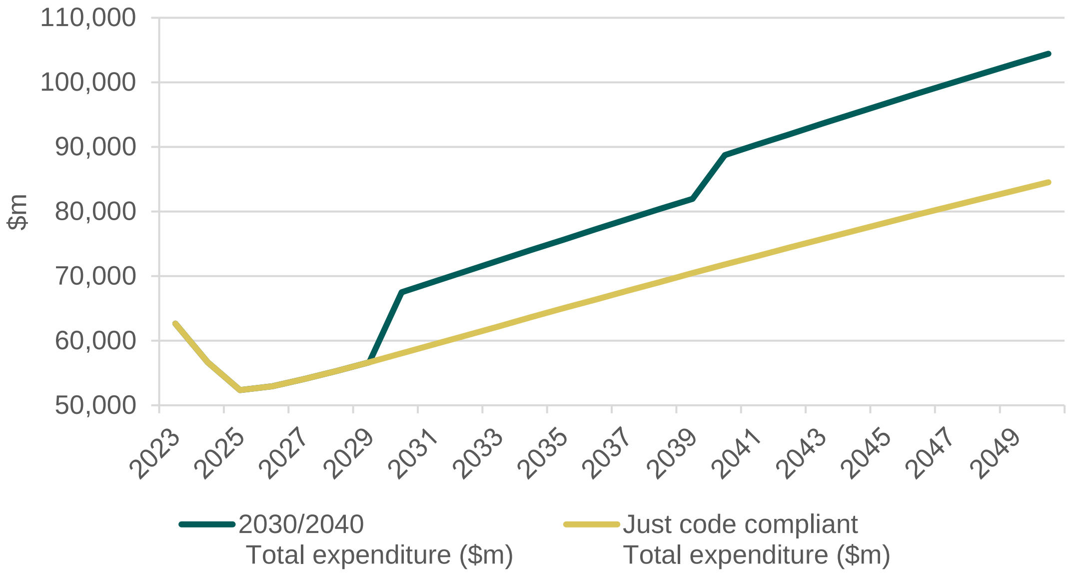
4.2.1 2030/2040 scenario expenditure

Direct expenditure on housing between 2023 and 2050 in this scenario is more than $845 billion. This includes $474 billion in the Upper North Island, $128 billion in the Lower North Island and $243 billion in the South Island. When the indirect and induced impacts are included, the total expenditure generated in the economy from the building of new houses totals $2.2 trillion.

As in the 2030/2040 scenario, Figure 4.4 shows if New Zealand built just code compliant houses until 2050, annual total expenditure generated from house building would increase from $63 billion in 2023 to $85 billion in 2050.

In 2030, when the house specification changes from the just code compliant house to the low emission house, annual total expenditure increases from almost $57 billion for 40,000 houses built in 2029, to $68 billion in 2030 from building 41,000 low emission houses. Finally, in 2040, when near zero emission houses are built, expenditure jumps from $82 billion for 49,000 houses in 2039, to $89 billion for 50,000 houses. As in the 2030/2040 scenario annual total expenditure in 2050 is $104 billion.

Figure 4.4 2025/2040 scenario total expenditure 2023-2050

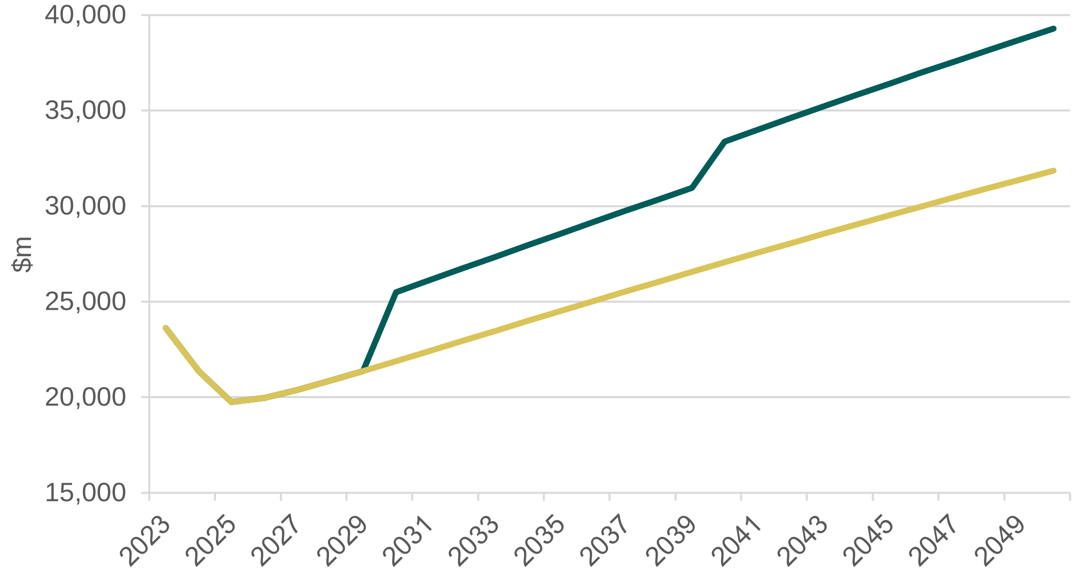


4.2.2 2030/2040 scenario GDP

Over the period from 2023 to 2050 the direct GDP impact will be $239 billion. When indirect and induced impacts are included, the total impact is $830 billion.

As Figure 4.5 illustrates there is a jump in the GDP impact when the specification changes in 2030 and 2040. In 2029 the total GDP impact if 40,000 houses are built to the just code compliant standard is $21 billion. In 2030, when 41,000 low emission houses will be built, the total GDP impact will be $25 billion. Low emission houses will continue to be built until 2039, when 49,000 houses are built contributing $31 billion to GDP. In 2040, when over 50,000 near zero houses are built, the GDP impact will be $33 billion, and this increases to reach $39 billion in 2050.

Figure 4.5 2030/2040 scenario total GDP impact 2023-2050

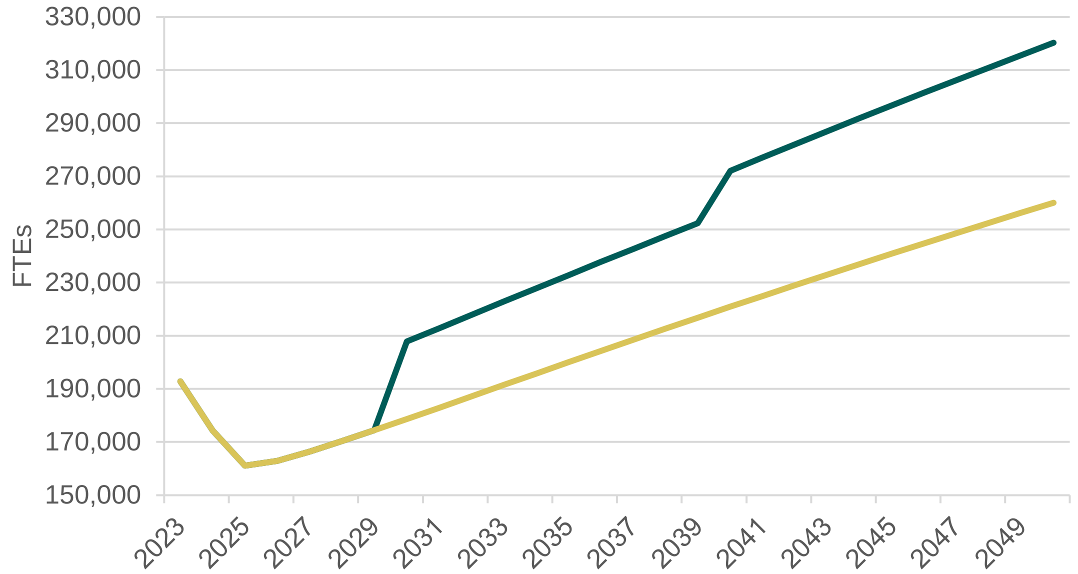


4.2.3 2030/2040 scenario employment

Direct employment years over the period is 2.23 million FTEs at an average of 80,000 FTEs per year. This increases to 6.77 million FTE years when indirect and induced impacts are included.

In 2029, the last year just code compliant houses are built, 40,000 will be built with a total employment impact of 174,000 FTEs. In 2030 the number of houses built will increase to 41,000 requiring 69,000 direct FTEs. This will generate 208,000 total FTE years across the economy. Low emission houses will continue to be built until 2039 when 49,000 houses are built, supporting total employment of 252,000 FTEs. In 2040, when over 50,000 near zero houses are built, the total employment impact will be 272,000 FTEs. As more houses are built each year this increases to reach 320,000 FTEs in 2050.

Figure 4.6 2030/2040 scenario total employment impact 2023-2050



4.3 Scenario comparisons

The 2025/2035 scenario has the greatest impact on expenditure, GDP, and employment. As table 4.6 shows, the total direct expenditure in the 2025/2035 scenario is $870 billion. This is $146 billion greater than the just code compliant scenario. When direct and indirect impacts are included, the total impact is $377 billion greater than the just code compliant scenario.

Direct GDP of $246 billion multiplies to $855 billion of total impact, which is $141 billion greater than the just code compliant scenario. Direct employment between 2023 and 2050 is 2.3 million FTE years, and when indirect and induced impacts are included the total employment impact on the economy is 6.97 million FTE years. Over 1.1 million FTE years more than the just code compliant scenario.

The 2030/2040 scenario did not have the same size impact as the earlier starting 2025/2035 scenario. However, the impacts were greater than the just code compliant scenario. The total expenditure impact was $308 billion greater than building just code compliant houses until 2050. The total GDP impact was $116 billion greater, and the total employment impact was over 937,000 FTE years more.

Table 4.6 Houses scenario comparison

	Expenditure ($m)		GDP ($m)		Employment (FTE years)	
	Direct	Total	Direct	Total	Direct	Total
Just code compliant	723,280	1,894,416	204,690	713,967	1,923,884	5,828,515
2025/35 scenario	869,686	2,271,191	246,328	855,425	2,292,786	6,973,283
2030/40 scenario	843,247	2,202,332	239,032	829,803	2,228,643	6,765,857

5 Economic impact of office construction

This section estimates the economic impact of large office construction. As in section 4, this section uses multiplier analysis based on the 2019 Statistics New Zealand input output tables. The impact of a single office was multiplied by the number of buildings completed nationally to estimate the direct and total impacts on expenditure, gross domestic product, and employment

Section 4.1 addresses the economic impacts of offices for the 2025/2035 scenario and section 4.2 outlines impacts for the 2030/2040 scenario.

Standard office

Table 5.1 shows the direct and total impacts of the standard office on expenditure, GDP, and employment. The standard office costs $53 million to construct and generates $135 million of expenditure in the national economy. Direct contribution to GDP is $16 million which multiplies to $53 million of total GDP impact. Direct employment to construct the building is 138 FTEs, which generates total employment of 420 FTEs.

Table 5.1 Standard office economic impacts

	Direct	Total
Expenditure ($m)	53.1	135.0
GDP ($m)	15.7	52.7
Employment (FTEs)	138	420

Near zero emission office

Table 5.2 shows the direct cost of the near zero emission building is $63 million and generates $161 million of expenditure in the national economy. Direct contribution to GDP is $19 million which multiplies to $63 million of total GDP impact. Direct employment to construct the building is 166 FTEs, which generates total employment of 504 FTEs.

Table 5.2 Near zero emission office economic impacts

	Direct	Total
Expenditure ($m)	63.3	161.0
GDP ($m)	18.7	62.8
Employment (FTEs)	166	504

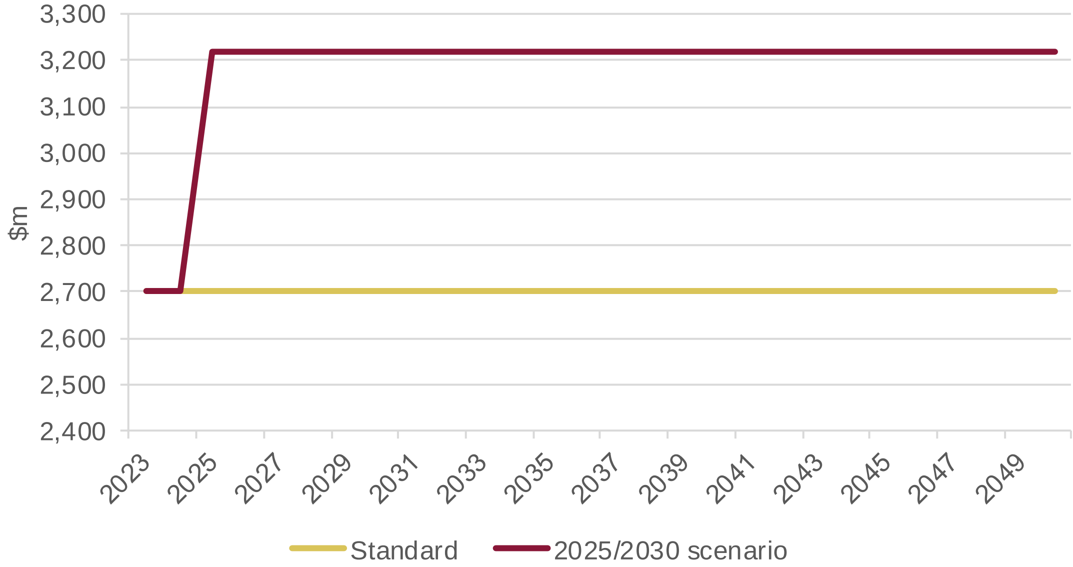
5.1 2025/2035 scenario

Section 5.1 summarises the total impact new large offices will have between 2023 and 2050. Standard offices will be built until 2024, and then low emission offices are built from 2025 to 2050. Large offices are just one percent of commercial consents and there is little fluctuation between years. We estimate 20 offices will be built in each year from 2023 to 2050.

5.1.1 Expenditure

Direct expenditure in 2023 and 2024 of $1.1 billion multiplies up to $2.7 billion of total expenditure in the economy. Direct expenditure in 2025 is $1.3 billion when 20 near zero emission offices are built. As figure 5.1 shows, when indirect and induced impacts are added to direct expenditure the total expenditure in 2025 is just over $3.2 billion.

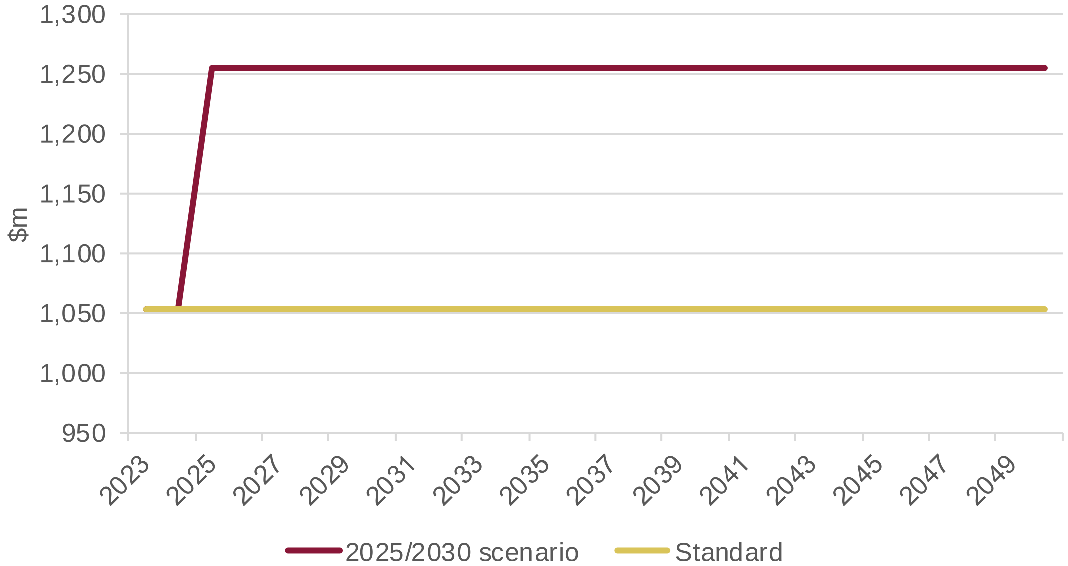
Figure 5.1 2025/2035 scenario office total expenditure 2023-2050



5.1.2 GDP

Like the housing scenarios, GDP for offices follows the same pattern as expenditure, increasing when the building specification changes from the standard office to the near zero emission spec in 2025. Direct GDP in 2023 and 2024 is $314 million and, as shown in Figure 5.2, multiplies up to $1.1 billion of total impact. In 2025 the direct impact of $375 million multiplies to a total impact of $1.3 billion where it stays until 2050.

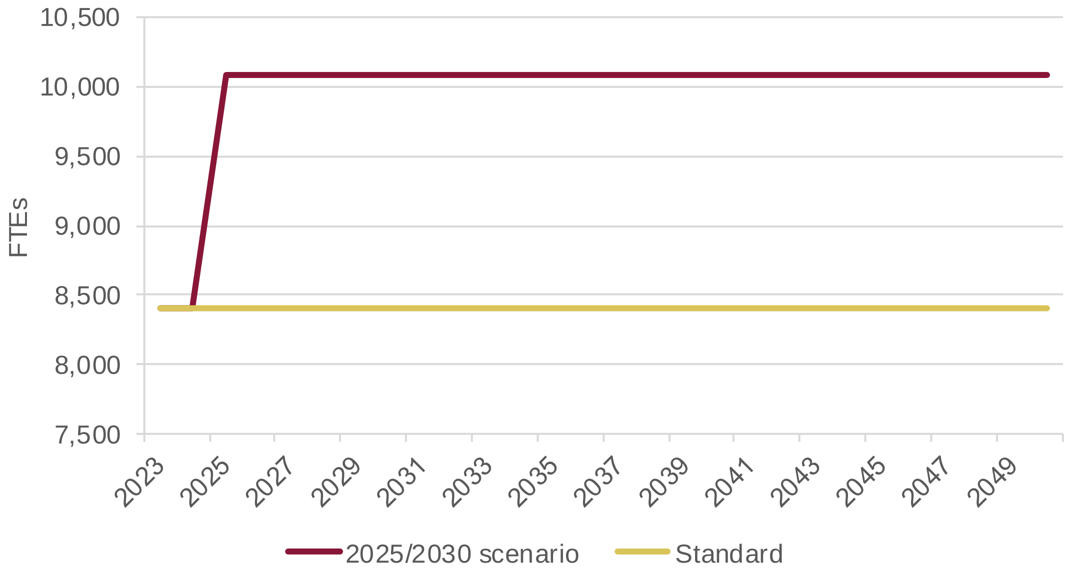
Figure 5.2 2025/2035 scenario office total GDP 2023-2050



5.1.3 Employment

In 2023 and 2024, direct employment is 2,800 FTEs. As Figure 5.3 shows, the total employment impact in each of these years is just above 8,400 FTEs. When near zero emission buildings are built in 2025 direct employment of 3,300 FTEs multiplies to a total employment impact of 10,000 FTEs.

Figure 5.3 2025/2035 scenario office total employment 2023-2050



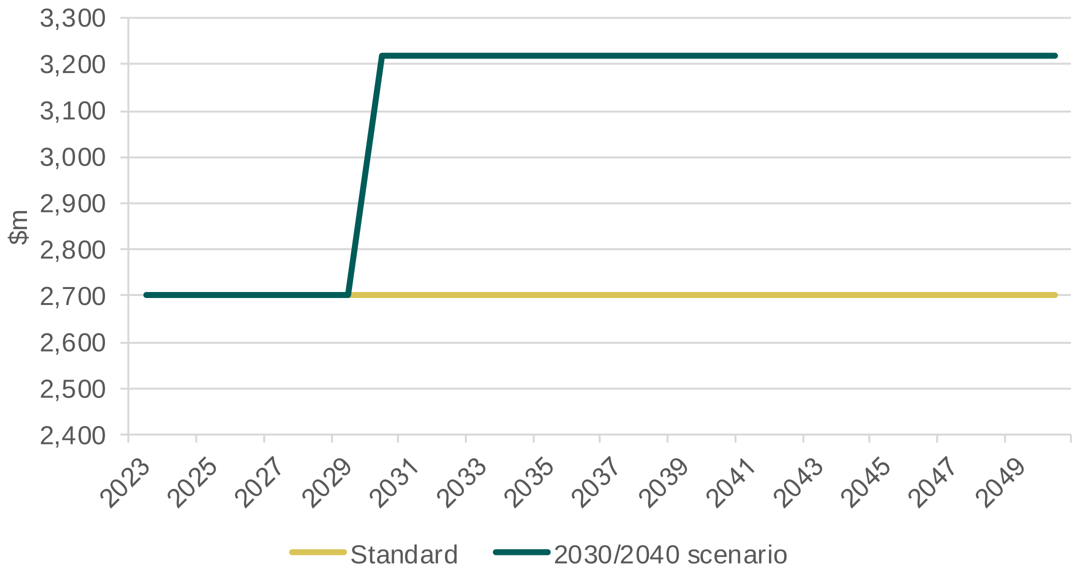
5.2 2030/2040 scenario

Section 5.2 summarises the total impact new large offices will have between 2023 and 2050 when standard offices are built until 2029, then low emission offices are built from 2030 to 2050.

5.2.1 Expenditure

As in the 2025/2035 scenario direct expenditure in 2023 and 2024 of $1.1 billion multiplies up to $2.7 billion of total expenditure in the economy. In this scenario the same level of expenditure continues each year until 2029 while standard offices are built. As figure 5.4 shows, in 2030 when near zero spec offices are built total expenditure in this scenario increases to just over $3.2 billion. This then continues each year to 2050.

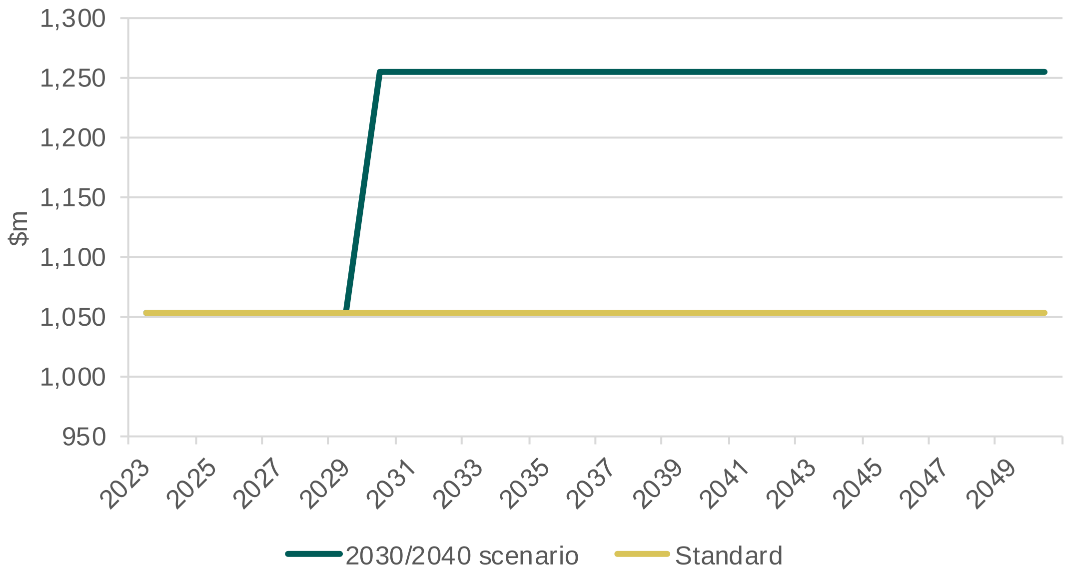
Figure 5.4 2030/2040 scenario total expenditure impact 2023-2050



5.2.2 GDP

Direct GDP in 2023 and 2024 is the same as the standard and 2025/2035 scenarios, $314 million of direct expenditure which multiplies up to $1.05 billion of total impact. As Figure 5.5 shows, in this scenario this continues until near zero houses are built in 2030 when the direct impact increases to $375 million, which multiplies to $1.25 billion of total impact per year.

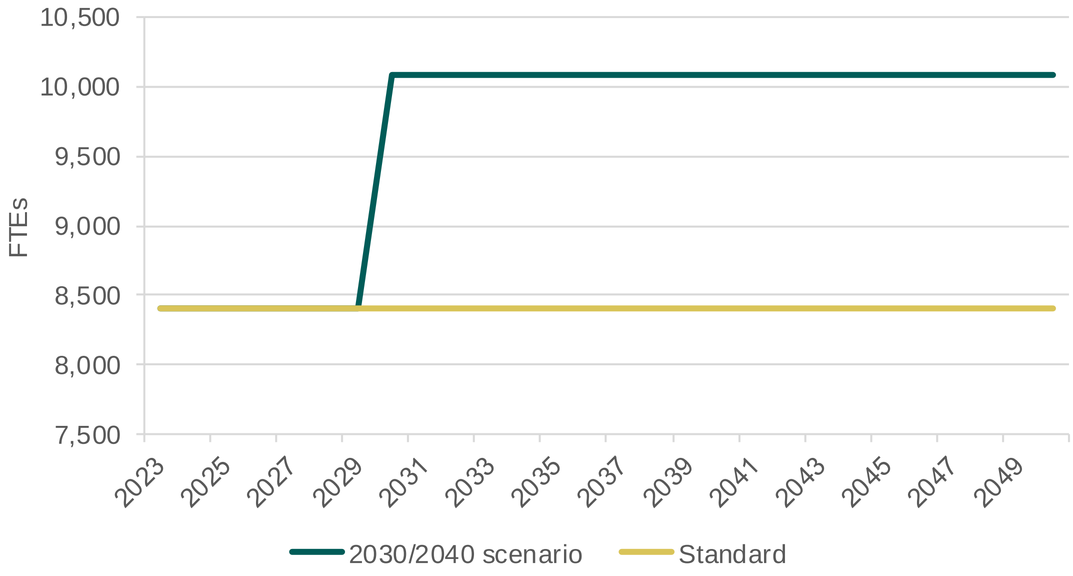
Figure 5.5 2030/2040 scenario office total GDP 2023-2050



5.2.3 Employment

From 2023 to 2029 direct employment on construction of new build offices is 2,800 FTEs. As Figure 5.3 shows, the total employment impact in each of these years is just above 8,400 FTEs. When near zero emission buildings are built from 2030 to 2050 direct employment of 3,300 FTEs multiplies up to generate a total employment impact of just over 10,000 FTEs.

Figure 5.6 2030/2040 scenario office total employment 2023-2050



5.3 Scenario comparison

The 2025/2035 scenario has the greatest impact on expenditure, GDP, and employment. As table 5.4 shows the direct expenditure in the 2025/2035 scenario is $35 billion over the 2023 to 2050 period. This is $5.3 billion greater than the direct expenditure in the standard scenario. When indirect and induced impacts are included, the $89 billion total expenditure impact of the 2025/2035 scenario is $13.5 billion greater than the standard scenario.

Because of the relationship between expenditure, GDP, and employment these two impacts are also greatest for the 2025/2035 scenario. Direct GDP of $10.4 billion multiplies to $34.7 billion of total impact, which is $5 billion greater than the standard scenario.

Direct employment between 2023 and 2050 is just under 92,000 FTE years, and when indirect and induced impacts are included the employment impact on the economy is almost 279,000 FTE years. This is over 43,000 FTE years more than the standard scenario.

The 2030/2040 scenario did not have the same size impact as the earlier starting 2025/2035 scenario. However, the impacts were greater than for the standard scenario. The total expenditure impact was $11 billion greater than building standard offices until 2050. The total GDP impact was $4 billion greater, and total employment was 35,000 FTE years more.

Table 5.3 Offices scenario comparison

	Expenditure ($m)		GDP ($m)		Employment (FTE years)	
	Direct	Total	Direct	Total	Direct	Total
Standard office	29,743	75,624	8,796	29,498	77,346	235,433
2025/2035 scenario	35,042	89,125	10,369	34,740	91,980	278,862
2030/2040 scenario	34,023	86,529	10,066	33,732	89,166	270,510

6 Energy demand impact

This section considers the impact the transition to a near zero built environment will have on electricity demand. The low emission, and near zero emission, houses and buildings used in this analysis all require less energy to operate and heat, while keeping indoor temperatures warmer than the just code compliant house and the standard office. Less energy demand results in lower energy costs, as well as reduced emissions if electricity generated from fossil fuels can be reduced or replaced with renewable electricity.

This section focuses on operational energy from houses and offices, and emissions from offices. Embodied emissions from houses and offices and operational emissions from houses are addressed in section 7.

6.1 Houses

To understand the impacts on annual electricity demand, electricity used by household appliances was excluded. Appliances vary between households and often change, as old appliances are replaced, or new residents bring their appliances with them, with limited ability for builders or developers to influence this decision.

The 2005 BRANZ report titled, Energy Use in New Zealand Households-Report on the Year 10 Analysis for the Household Energy End-use Project (HEEP), provides an estimate for the average household energy demand per occupant per year (kWh/occupant/yr).[26] When removing the 13 percent consumption attributed to household appliances the average demand nationally is 2,340 kWh per year. With 2.9 residents per household this totals to 6,787 kWh per year.

Auckland's average demand of 2,390 kWh per occupant is the lowest per occupant, however its houses have 3.3 occupants meaning the average demand per household, excluding appliances, is greater than the national average. Annual kWh demand in Auckland, excluding appliances, is 6,945 kWh per year.

Wellington has a higher demand per occupant than Auckland but only three occupants per household. As a result, the total household demand was 6,812 kWh per year. Christchurch also had three occupants per household, but with greater demand per occupant the total annual electricity demand is 7,569 kWh.

The estimates in the HEEP study are consistent with the most recent energy, and annual electricity generation and consumption data from MBIE. This dataset calculates the average electricity consumption per unique Installation Control Point (the number identifying a connection to the New Zealand electricity network) was 7,468 kWh in 2021. Excluding 13 percent for appliances this number reduces to 6,497 kWh.[27]

6.1.1 Just code compliant house

As shown in Table 6.1, the annual electricity demand of the just code compliant house, excluding appliances, varies from 35.3 kWh/m^2/yr in the Upper North Island, and 66.3 kWh/m^2/yr in the South Island. As a result, annual energy demand excluding appliances, of the just code compliant house is

[26] Isaacs NP, Camilleri M, French L, Pollard A, Saville-Smith K, Fraser R, Rossouw P and Jowett J. 2006. *Energy Use in New Zealand Households: Report on the Year 10 Analysis for the Household Energy End-use Project (HEEP)*. BRANZ Study Report 155.

[27] Ibid

6,425 kWh in the Upper North Island, 9,118 kWh in the Lower North Island and 12,067 kWh in the South Island.

Table 6.1 Just code compliant house annual energy demand

	Auckland	Wellington	Christchurch
Total energy- excluding appliances (kWh/m2/yr)	35.3	50.1	66.3
Size (m2)	182	182	182
Household energy (kWh/year)	6,425	9,118	12,067
Cost per kWh ($)	0.30	0.30	0.30
Annual cost ($)	1,953	2,771	3,667

Source: NZGBC, Ministry of Business Innovation and Employment

6.1.2 Low emission house and near-zero emission house

As noted in section 2, emissions from the low emission house and the near zero emission house are assumed to be relatively similar given the only difference is the substructure. As table 6.3 shows, annual electricity demand for the low emission house and the near zero emission house ranges from 11.5 kWh/m^2/yr in the Upper North Island to 14.9 kWh/m^2/yr in the South Island. As a result, the average annual energy demand of the low emission and near zero emission house ranges from 2,093 kWh per year in the Upper North Island to 2,712 kWh in the South Island.

Table 6.2 Low emission house and near zero emission house annual energy demand

	Auckland	Wellington	Christchurch
Total energy- excluding appliances (kWh/m2/yr)	11.5	13.9	14.9
Size (m2)	182	182	182
Household energy (kWh)	2,093	2,530	2,712
Cost per kWh ($)	0.30	0.30	0.30
Annual cost ($)	636	769	824

Source: NZGBC, Ministry of Business Innovation and Employment

6.1.3 Annual electricity saving

Across all three regions the low emission house and the near zero emission house save at least 2,093 kWh of electricity compared to the just code compliant house. Savings are 67 percent in the Upper North Island, 72 percent in the Lower North Island and 78 percent in the South Island. As table 6.3 shows, in the South Island a low emission/near zero emission house will save $2,843 per annum, when compared to a just code compliant household assuming an electricity cost of $0.304 per kWh.[28]

Table 6.3 Annual electricity demand and operational cost saving by house specification

	Auckland	Wellington	Christchurch
Just code compliant house (kWh)	6,425	9,118	12,067
Low emission / near zero emission house (kWh)	2,093	2,530	2,712
Operational cost saving ($)	1,317	2,002	2,843

[28] Average electricity cost for the four quarters of the year ended March 2022. Ministry of Business Innovation and Employment (2022). *Sales-based electricity costs for residential. Residential sales-based electricity cost data March year 2006 to March year 2020.*

Given the operational cost savings each year, assuming the price of electricity remains similar to March 2022 and all other things remain equal, the repayment period for a near zero house will be:

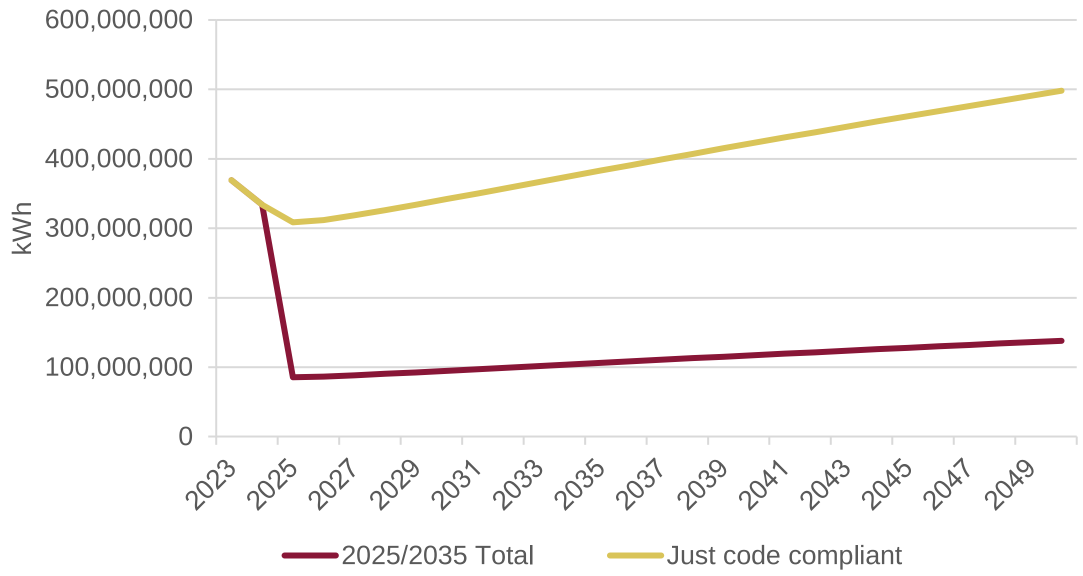
- Upper North Island - 67 years
- Lower North Island - 44 years
- South Island - 31 years.

6.1.4 2025/2035 scenario

As Figure 6.1 shows, there is a significant difference in the annual electricity demand from new build houses built to the just code compliant standard, when compared to those built to the low emission or near zero emission standard. In 2024 electricity demand from the 40,000 houses new build houses built to the just code compliant standard is 334 million kWh. In 2025 the annual electricity demand from the 37,000 new low emission houses is 86 million kWh.

As housing stock grows by 46,000 new build houses in 2035 the difference in electricity demand between the just code compliant scenario and the 2025/2035 scenario grows. The just code compliant scenario houses built will require 383 million kWh, compared to just 106 million kWh for houses built to the near zero standard. By 2050 the total annual electricity demand from near zero emission houses is 138 million kWh. The difference in electricity demand between new build just code compliant houses and newly built near zero emission houses in 2050 is 360 million kWh.

Figure 6.1 2025/2035 scenario electricity demand from new build houses 2023-2050

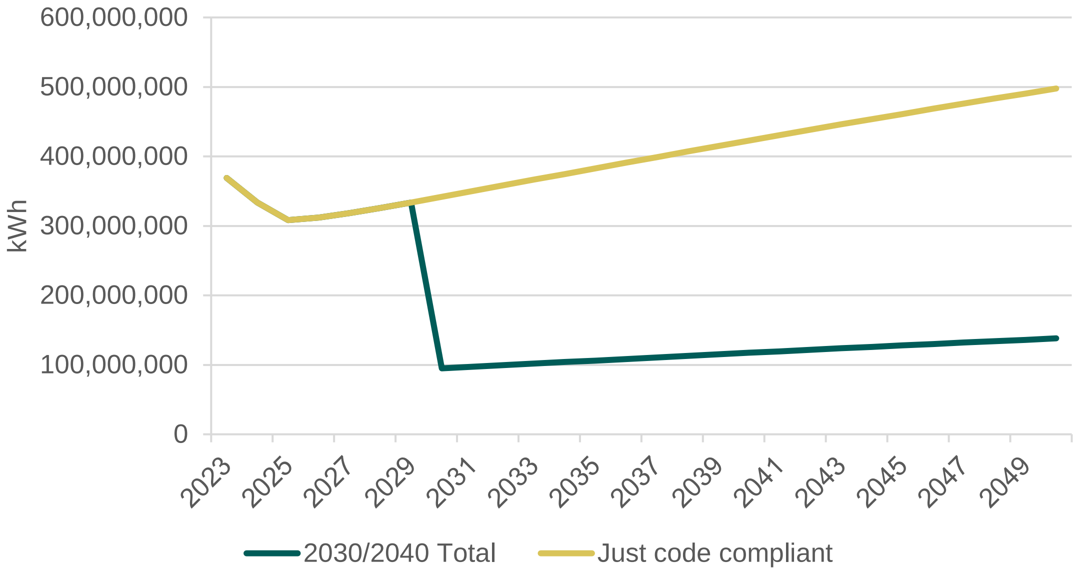


6.1.5 2030/2040 scenario

As Figure 6.2 shows, the 2030/2040 scenario is similar to the 2025/2035 scenario. However, the shift to near zero emission houses comes five years later. In 2029 electricity demand from the 40,000 houses new build houses built to the just code compliant standard is 334 million kWh. In 2030 the annual electricity demand from the 41,000 new low emission houses is 95 million kWh.

As housing stock grows by 50,000 new build houses in 2040, the just code compliant scenario will require 423 million kWh, compared to just 117 million kWh when houses are built to the near zero standard. As in the 2025/2035 scenario, by 2050 the total annual electricity demand from near zero emission houses is 138 million kWh.

Figure 6.2 2030/2040 scenario electricity demand from new build houses 2023-2050



6.1.6 Scenario comparison

As table 6.3 shows there is a significant decrease in the electricity demanded when low emission and near zero emission houses are built. In 2025 there is a 223 million kWh difference in annual electricity demand between the just code compliant scenario and the 2025/2035 scenario. In 2030, when low emission houses are first built in the 2030/2040 scenario, demand is 247 million kWh less than the just code compliant scenario, and by 2050 the difference is 360 million kWh.

Figure 6.3 Annual new build electricity demand (kWh)

Year	Just code compliant	2025/2035 scenario	2030/2040 scenario
2023	369,128,760	369,128,760	369,128,760
2024	333,813,480	333,813,480	333,813,480
2025	308,487,379	85,548,491	308,487,379
2030	341,944,403	94,826,660	94,826,660
2035	382,968,986	106,203,434	106,203,434
2040	422,934,112	117,286,403	117,286,403
2050	497,861,364	138,064,931	138,064,931

6.1.7 Total housing electricity demand and emissions reduction potential

In 2019 New Zealand's gross greenhouse gas emissions were 84.9 million tonnes of CO_2-e.[29] Nearly 41 percent of New Zealand's greenhouse gas emissions were from the energy sector. Of this 4.2 percent came from electricity generation (3.6 million tonnes). In addition, 0.9 percent of 2019 emissions were from household gas or wood burning use.[30] This is the equivalent of an additional

[29] Statistics New Zealand (2022). *New Zealand's greenhouse gas emissions.*
[30] EECA (undated) *New Zealand's emissions and energy profile by sector.*

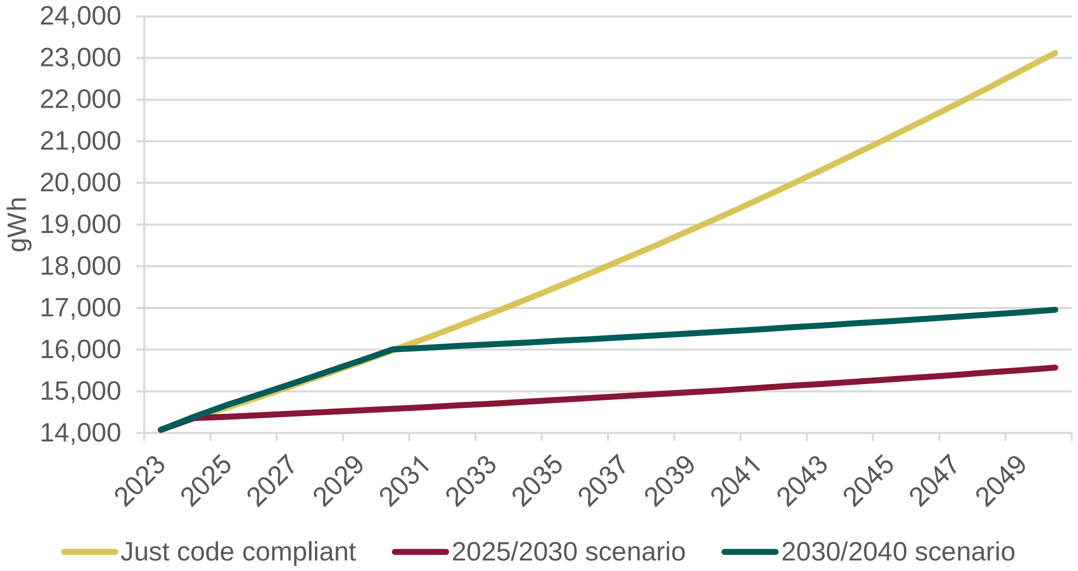
18,056 Gigawatt hours (gWh). In 2019 the electricity generation emissions were the result of 43,800 gWh of electricity generation from a range of power generating sources, of which just under 83 percent were renewable.

Using the HEES average for current stock an estimated 13,700 gWh will be used by New Zealand households in 2023.[31] As Figure 6.4 shows, in all scenarios the electricity demand from New Zealand's housing stock increases as the housing stock increases. However, once New Zealand transitions to low emission houses, either in 2025 or 2030, total electricity demand from houses levels off. This is because 20 percent of the new builds replace existing stock. Where this occurs the electricity demand from the new houses is up to three times less than the houses they replaced.

In the just code compliant scenario total demand in 2050 will be over 23,000 gWh, which is a 64 percent increase from 2023. In the 2025/2035 scenario total demand from the housing stock will be just under 16,000 gWh by 2050, an 11 percent increase from 2023, and in the 2030/2040 scenario demand of almost 17,000 gWh will be an increase of 20 percent from 2023.

In either scenario when new houses are built to the low emission or near zero emission standard it will ensure that electricity demand from houses will limit the additional pressure placed on the electricity network.

Figure 6.4 Annual electricity demand from new housing stock 2023-2050 (gWh)



6.2 Offices

As Table 6.5 shows the annual energy end use from the standard building is 165 kWh/m²/yr, which produces 18 kg CO_2-e/yr emissions, and for the near zero building annual energy use is 55 kWh/m²/yr, which results in 6kg CO_2-e/yr. This results in the standard office consuming 1.6 million kWh per year, and the near zero emission office consuming 518,000 kWh per year.

The operational energy budget for each of the buildings excludes the impact of potential tenant fit out, and the following associated energy uses including electric vehicle charging, tenant

[31] Supra n 26.

server/communications and associated cooling, carparks, specialist tenancy services, tenant lighting and power impact over and above the building base allowance, and any significant end of trip shower/hot water usage.

The annual on-site solar power generation offset assumes 30 percent of annual generation is distributed to the national grid.

Figure 6.5 Annual energy demand (kWh) and emissions ($kgCO_2$-e) by office specification

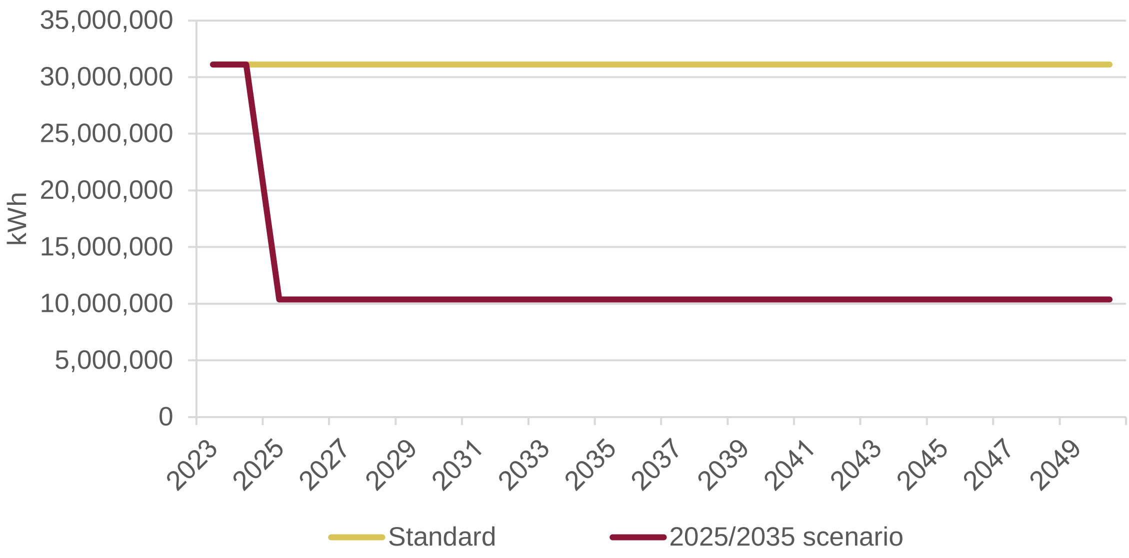
	Standard office		Near zero emission	
	kW-h	CO2-e/m2/yr	kW-h	CO2-e/m2/yr
Heating, ventilation, air conditioning and hydralics			30	3.3
Lighting (Base building and tenant use)			14	1.5
Equipment (Base buildign and tenant use)			18	2
Domestic hot water heating			3	0.3
Lifts			2	0.2
On-site renewable generation offset			- 12	- 1.3
Total per m2	165	18	55	6
Annual total per building	1,554,960	170,574	518,320	56,827

Sections 6.2.1 to 6.2.3 assess the two scenarios, and section 6.2.4 compares the impact this energy demand has on annual emissions.

6.2.1 2025/2035 scenario

Building near zero offices has a significant impact on the demand for electricity compared to the standard office. As Figure 6.6 shows, in 2025 when the near zero offices are built, the total electricity demand falls from just over 31 million kWh in 2024, to 10 million kWh in 2025 and continues at this level until 2050.

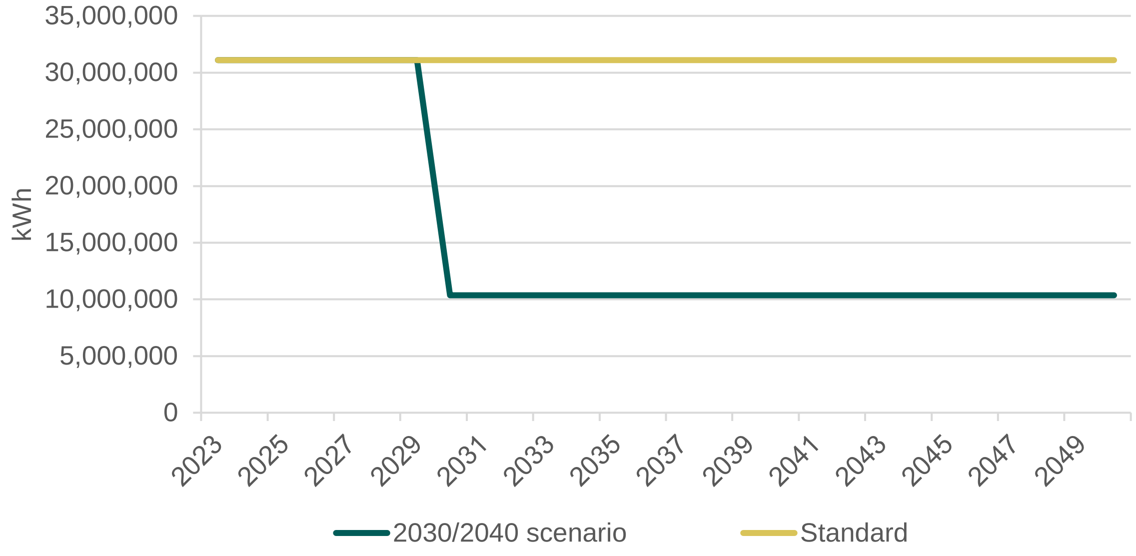
Figure 6.6 2025/2035 scenario office annual electricity demand 2023-2050



6.2.2 2030/2040 scenario

Building near zero offices from 2030 has the same impact as the 2025/2035 scenario except it occurs five years later. As Figure 6.6 shows, from 2023 to 2029 annual electricity demand from new build standard offices is over 31 million kWh per year but it falls to just over 10 million kWh when near zero offices are built.

Figure 6.7 2030/2040 scenario office annual electricity demand 2023-2050\

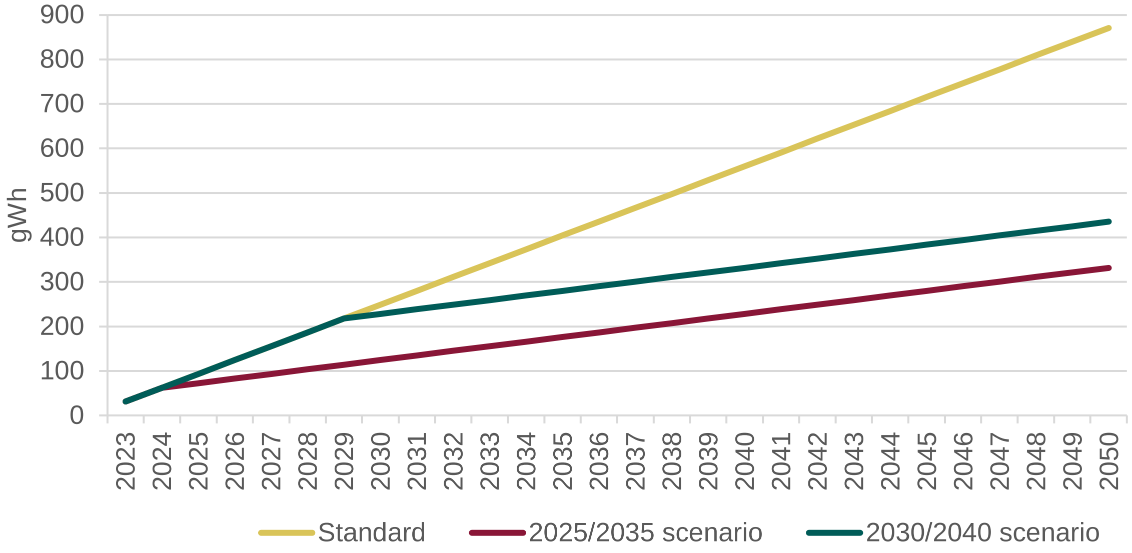


6.2.3 Scenario comparison

As expected, the sooner the near zero emission offices are constructed the greater the reduction in electricity demand. In the 2025/2035 scenario when near zero emission offices are built in 2025, total electricity demand falls by 21 million kWh when compared to the standard offices built in 2024. In the 2030/40 scenario the same effect occurs in 2030, when near zero emission offices are built.

As Figure 6.8 shows, overall, the electricity demand from new build offices in the 2023-2050 period is lowest in the 2025/2035 scenario. In 2050 the new offices built between 2023 and 2050 will demand 332 million kWh per year. This is 539 million kWh (539 gWh) less than the standard scenario, and 104 million kWh (103 gWh) less than the 2030/2040 scenario.

Figure 6.8 Annual electricity demand from new offices 2023-2050

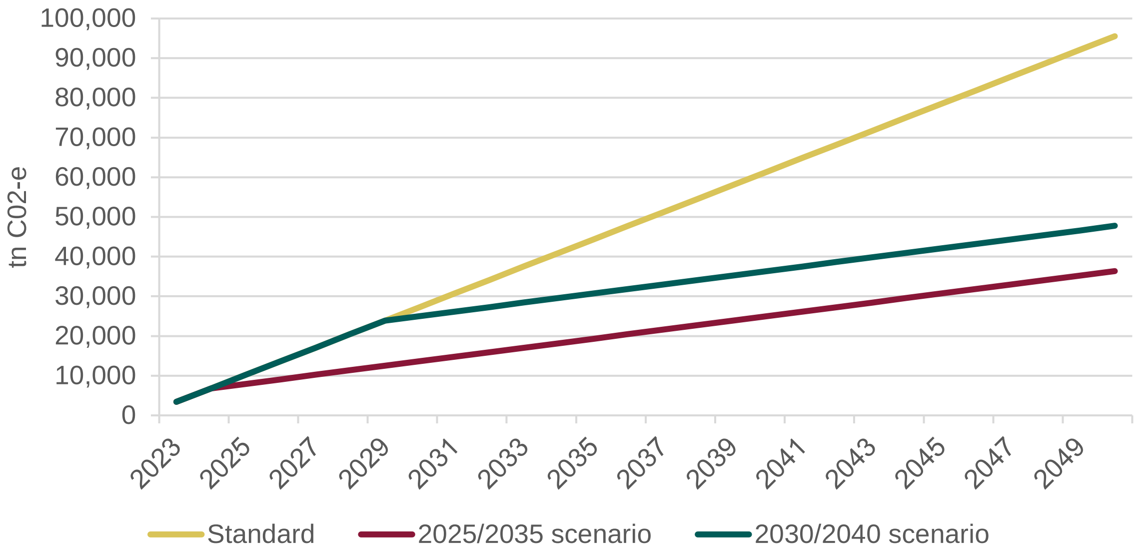


6.2.4 Operational emissions

Annual operational emissions are the same in all three scenarios in 2023 and 2024. Annual operational emissions from 20 standard offices is 3.4 million kg CO_2-e. When near zero emission offices are built annual operational emissions from the 20 new buildings will be 1.1 million kg-CO_2-e per year.

The earlier near zero buildings are constructed the lower the total operational emissions over the period. Operational emissions are lowest in the 2025/2035 scenario when 36 million kg (36,000 tn) CO_2-e come from the new offices in 2050. This is 38 percent of the 96 million kg (96,000 tn) CO_2-e that would occur if standard offices were built every year between 2023 and 2050, and 48 million kg less than the 2030/2040 scenario.

Figure 6.9 Annual new build offices emissions 2023-2050



7 Embodied emissions impact

This section considers the impact of near zero houses and offices on embodied emissions. Embodied emissions are caused by CO_2, and other greenhouse gases from non-renewable energy sources, or otherwise, being released into the atmosphere as a consequence of activities associated with a particular material or product.[32] Embodied carbon is assessed on a life-cycle basis, therefore emissions that arise at all points in the supply chain, and over the lifetime of that material or product, are considered.

Typically, the most significant embodied carbon emissions happen before the building is used, in the production of construction materials and products. However, embodied carbon emissions also occur during the building's operation due to maintenance activities, and also at the end of the life of the building due to demolition activities, and the disposal or recycling of materials and products.

This section considers the emissions across the lifetime of the building. A life cycle assessment is typically used to calculate embodied carbon emissions of a building. The life-cycle scope is specified according to European standards EN 15804 and EN 15978.[33] This is summarised in Table 7.1 which sets out the building life cycle into five stages.

Table 7.1 Building life cycle stages

Product stage	Raw material supply	A1
	Transport	A2
	Manufacturing	A3
Construction process stage	Transport	A4
	Installation	A5
Use stage	Use	B1
	Maintenance	B2
	Repair	B3
	Replacement	B4
	Refurbishment	B5
	Operational energy use	B6
	Operational water use	B7
End of life stage	Deconstruction/Demolition	C1
	Transport	C2
	Waste processing	C3
	Disposal	C4
Recovery stage	Future reuse, recycling or energy recovery	D

Source: Ministry of Business Innovation and Employment[34]

[32] Ministry of Business Innovation and Employment (2020). *Whole-of-life embodied carbon emissions reduction framework.*

[33] One Click LCA (2021). *Life cycle assessment for buildings. Why it matters and how to use it.*

[34] Supra n 31.

7.1 Houses

This section assesses the embodied emissions impact of building the three house specifications across the three scenarios. The life cycle embodied carbon associated with the construction of the three house specifications was estimated using the Homestar Embodied Carbon Calculator.

7.1.1 Just code compliant house

The lifecycle embodied carbon associated with the construction of the just code compliant house is 153 kg CO_2-e/m^2 for emissions A1-A5 and 374 kg for emissions A1-D. As table 7.2 shows, when applied to the 182^2 house footprint the total emissions from this house are 27,800 kg (28 tonnes) CO_2-e/m^2 for emissions A1-A5 and 68,000 kg (68 tonnes) CO_2-e/m^2 for A1-D emissions. From this we can deduce that B-D emissions total 40,000 kg (40 tonnes) per house.

Table 7.2 Just code compliant house embodied emissions

	Kg C02-e/m2	Kg CO2-e
House emissions A1-A5 (kg C02-e/m2)	153	27,846
House emissions B-D (kg C02-e/m2)	221	40,222
House emissions A1-D (kg C02-e/m2)	374	68,068

7.1.2 Low emission house

The lifecycle embodied carbon associated with the construction of the low emission house is 124 kg CO2-e/m^2 for emissions A1-A5 in the North Island and 128 CO_2-e/m^2 in the South Island. When B-D emissions are added total A1-D emissions are 342 kg CO_2-e/m^2 in the North Island and 351 kg CO_2-e/m^2 in the South Island. As table 7.3 shows, when applied to the 182^2 house footprint the total emissions from this house are 22,600 kg CO_2-e for emissions A1-A5 and 62,200 kg CO_2-e for A1-D emissions in the North Island. In the South Island total embodied emissions are 63,900 kg, with 23,300 kg from A1-A5 emissions. From this we can deduce that B-D emissions total 39,700 kg per house in the North Island and 40,600 kg in the South Island.

Table 7.3 Low emission house embodied emissions

	Upper North Island	Lower North Island	South Island
House emissions A1-A5 (kg C02-e/m2)	124	124	128
House emissions B-D (kg C02-e/m2)	218	218	223
House emissions A1-D (kg C02-e/m2)	342	342	351
Total emissions A1-A5 (kg C02-e)	22,568	22,568	23,296
Total emissions B-D (kg C02-e)	39,676	39,676	40,586
Total emissions A1-D (kg C02-e)	62,244	62,244	63,882

7.1.3 Near zero emission house

The near zero emission house has almost half the A1-A5 emissions of the just code compliant house in the Lower North Island and the Upper North Island, and in the South Island emissions from the near zero emission house are 42 percent less than the just code compliant house. As table 7.4 shows, the A1-A5 emissions in the Lower North Island and the Upper North Island are 89 kg CO_2-e/m^2, while in the South Island embodied emissions are 94kg CO_2-e/m^2. When B-D emissions are included embodied emissions more than double.

Table 7.4 Near zero emission house embodied emissions

	Upper North Island	Lower North Island	South Island
House emissions A1-A5 (kg C02-e/m2)	89	89	94
House emissions B-D (kg C02-e/m2)	99	99	109
House emissions A1-D (kg C02-e/m2)	188	188	203
Total emissions A1-A5 (kg C02-e)	16,198	16,198	17,108
Total emissions B-D (kg C02-e)	18,018	18,018	19,838
Total emissions A1-D (kg C02-e)	34,216	34,216	36,946

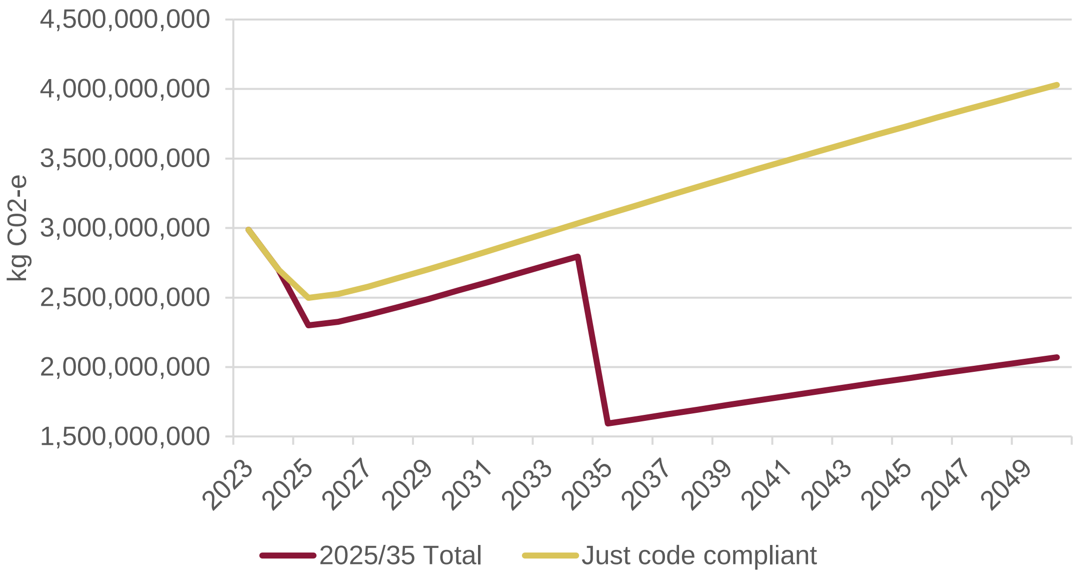
The near zero emission houses in all three regions fail to achieve the 60kg CO_2-e/m^2 carbon budget that would have scored the highest possible score (6/6) in the Homestar EN2 credit[35]. The near zero emission houses currently achieve only four points. However, in the North Island the houses are close to the next tier (5/6) of 85kg CO_2-e/m^2.

7.1.4 2025/2035 scenario

As Figure 7.1 below shows, in the 2025/2035 scenario embodied emissions from new build houses are significantly less than building just code compliant houses every year from 2025 to 2050. In 2024 the 40,000 just code compliant houses will produce 2.7 million tonnes of emissions over their lifetime. In 2025 when low emission houses are built the lifetime emissions from the construction of 37,000 houses will be 2.3 million tonnes. By 2034 when the last low emission houses will be built 45,000 houses will be built with lifetime emissions of 2.8 million tonnes. This is 239,000 tonnes of emissions less than the just code compliant scenario.

In 2035 all houses will be built to the near zero emission standard. At this point lifetime emissions from 46,000 new build houses will be 1.6 million tonnes. By 2050 emissions from houses in this scenario will be 2.1 million tonnes compared to over four million tonnes in the just code compliant scenario.

Figure 7.1 2025/2035 scenario annual embodied emissions (A1-D)



[35] New Zealand Green Building Council (2021). *Zero carbon house indicative specification.*

7.1.5 2030/2040 scenario

As Figure 7.2 below shows, in the 2030/2040 scenario in 2029 the 40,000 just code compliant houses will produce 2.7 million tonnes of emissions over their lifetime. In 2030 when low emission houses are built the lifetime emissions from the construction of 41,000 houses will be 2.5 million tonnes. By 2039, when the last low emission houses will be built, 49,000 houses will be built with lifetime emissions of 3.1 million tonnes. This is 265,000 tonnes of emissions less than the just code compliant scenario.

In 2040 all houses will be built to the near zero emission standard. At this point lifetime emissions from 50,000 new build houses built in the year will 1.8 million tonnes. From 2040 to 2050 emissions from houses in this scenario will be the same as the 2025/2035 scenario.

Figure 7.2 2030/2040 scenario annual embodied emissions (A1-D)

7.1.6 Scenario comparison

As Table 7.5 shows, because the 2025/2035 scenario sees the most near zero emission houses built it is the scenario that has the lowest total embodied emissions across the period from 2023 to 2050. Total embodied emissions over the period are forecast to be 60 million tonnes. This is almost eight million tonnes less than the 2030/2040 scenario and 30 million tonnes less than the just code compliant scenario.

Table 7.5 Embodied emission scenario comparison 2023-2050 (kg CO_2-e)

Year	Just code compliant	2025/2035 scenario	2030/2040 scenario
2023	2,988,185,200	2,988,185,200	2,988,185,200
2024	2,702,299,600	2,702,299,600	2,702,299,600
2025	2,497,278,784	2,300,434,456	2,497,278,784
2030	2,768,121,356	2,549,928,261	2,549,928,261
2035	3,100,225,128	1,593,217,298	2,855,854,441
2040	3,423,752,332	1,759,479,140	1,759,479,140
2050	4,030,306,280	2,071,189,484	2,071,189,484
Total 2023-2050	**90,334,336,092**	**60,368,297,830**	**67,967,368,080**

7.2 Offices

This section assesses the embodied emissions impact of building the two office specifications for each scenario. As BECA noted in the supporting document prepared for this work "Large-scale reductions in embodied carbon of open plan (retail and office space) multi-storey buildings in New Zealand may not be easily achievable. Seismicity of building location, and proposed building height, can preclude some of the most effective embodied carbon reduction strategies".[36]

This assessment considered impact of A1 to A5 emissions associated with construction of the offices. The emissions associated with replacement, refurbishment, maintenance, and end of life have not been considered as they are subject to future decisions regarding products, systems, deconstruction activities, and waste streams etc. In the case of the standard office used for this assessment, more than 90 percent of the embodied carbon emissions were associated with A1-A3 emissions (see section 6). Therefore, the focus on reducing overall building embodied carbon was on A1-A3, rather than A4-A5. Modules A1-A3 (raw material supply and fabrication) are much greater contributors than modules A4-A5 (transport and construction). Steel is the primary carbon intensive material 'hot-spot' followed by reinforced concrete. Thus, steel and concrete substitutions are the target for embodied carbon reduction, rather than changes to transport or construction. Although these areas can be optimised further, the impact is small relative to A1-A3 optimisation.

Also, in the case of architectural elements, such as carpets and ceilings, the exclusion of life cycle stages B2-B4 means the carbon impact of replacement every 20 years is not considered.

Emissions by building specification

The embodied emissions (A1-A5) from the construction of the standard office are 540 kg CO_2-e/m^2. As Table 7.6 shows when this is multiplied by the size of the building (9,424m^2) the total embodied emissions from the standard office is 5.09 million kg CO_2-e.

The near zero emission building reduces the emissions per square metre by 45 percent to 295 kg CO_2-e. As a result, the total embodied emissions (A1-A5) from the near zero emission office are 2.78 million kg CO_2-e.

[36] Supra n 24.

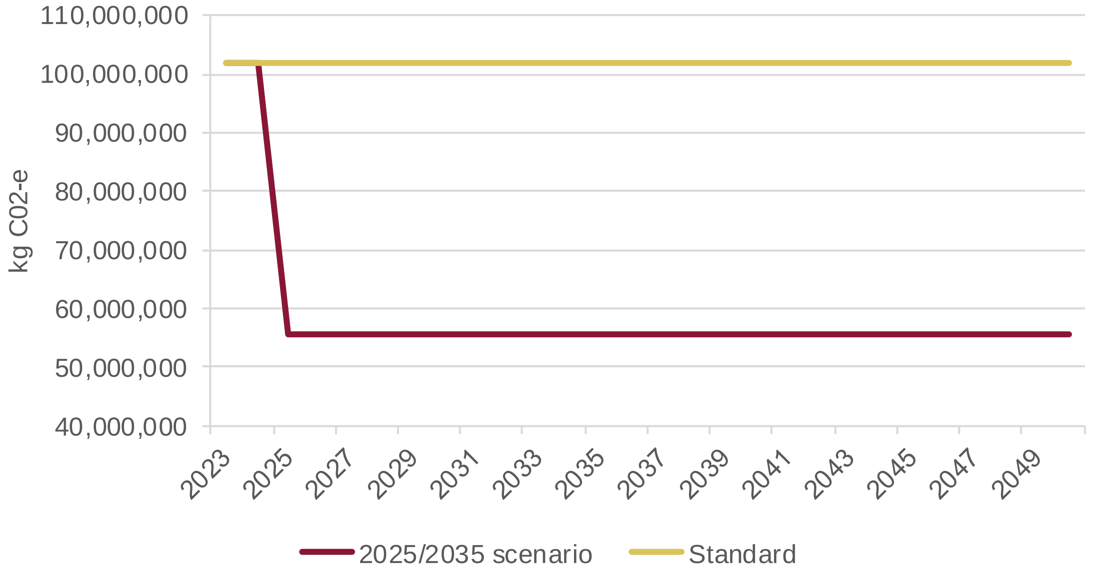
Table 7.6 Office embodied emissions

	Standard office	Near zero emission
Gross Floor area (m2)	9,424	9,424
Embodied carbon (A1-A5) (kg CO2-e/m2)	540	295
Embodied carbon (A1-A5) (kg CO2-e)	5,088,960	2,780,080

7.2.1 2025/2030 scenario

In all three scenarios, embodied emissions from the construction of 20 standard offices will produce 102,000 tonnes CO_2-e each year. In this scenario this will occur in 2023 and 2024. Then, as Figure 7.3 shows, in 2025 embodied emissions from the 20 new near zero emission offices will be 56,000 tonnes kg CO_2-e. This level of emissions then continues each year until 2050.

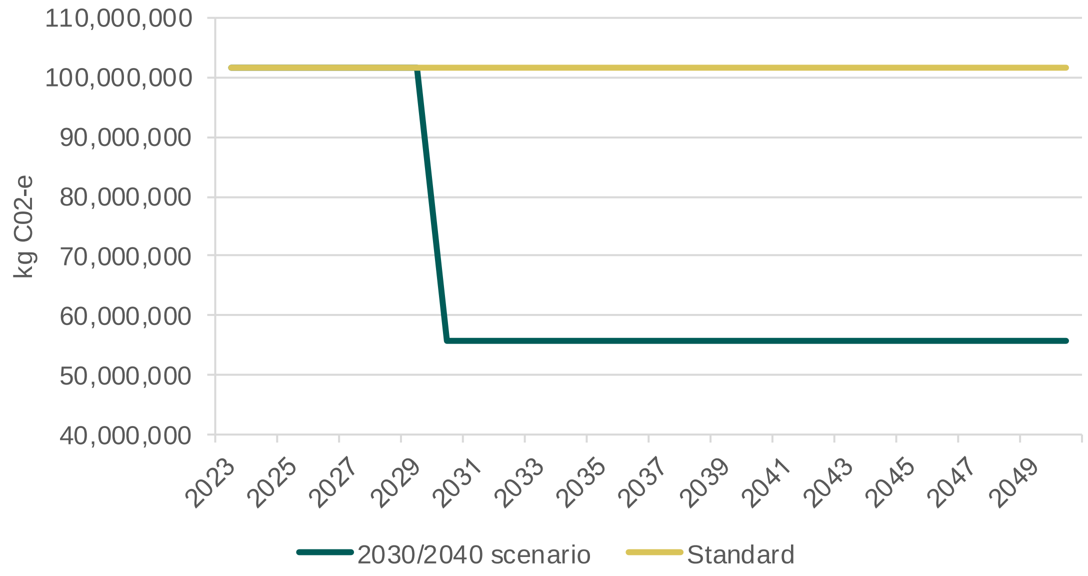
Figure 7.3 2025/2035 scenario annual new build offices embodied emissions



7.2.2 2030/2040 scenario

The construction of 20 standard offices each year from 2023 to 2029 will produce 102 million kg CO_2-e (102,000 tonnes) each year. As Figure 7.4 shows, from 2030 to 2050 when near zero offices are built, annual embodied emissions will be 56,000 tonnes CO_2-e. This is a decrease of 46,000 tonnes CO_2-e per year.

Figure 7.4 2030/2040 scenario annual new build offices embodied emissions



7.2.3 Scenario comparison

As Figures 7.3 and 7.4 above show, there is a significant gap between the emissions from the standard office scenario and the 2025/2035 and 2025/2040 scenarios. If all offices built between 2023 and 2050 are standard offices total embodied emissions would be 2.8 million tonnes CO_2-e.

As Table 7.7 shows, in the 2025/2035 scenario 1.6 million tonnes CO_2-e would be emitted from construction of the offices between 2023 and 2050. This is a 42 percent saving from the standard scenario. The 2030/2040 scenario would see almost 1.9 million tonnes CO_2-e emitted from office construction. This is a 34 percent decrease from the standard scenario, but 14 percent greater than the 2025/2035 scenario.

Table 7.7 Offices embodied emission scenario comparison 2023-2050 (kg CO_2-e)

Year	Standard	2025/2035 scenario	2030/2040 scenario
2023	101,779,200	101,779,200	101,779,200
2024	101,779,200	101,779,200	101,779,200
2025	101,779,200	55,601,600	101,779,200
2030	101,779,200	55,601,600	55,601,600
2035	101,779,200	55,601,600	55,601,600
2040	101,779,200	55,601,600	55,601,600
2050	101,779,200	55,601,600	55,601,600
Total 2023-2050	**2,849,817,600**	**1,649,200,000**	**1,880,088,000**

8 Health and wellbeing impact

The impacts on health and wellbeing are difficult to measure accurately in a theoretical context such as this. There are several factors that impact on health outcomes that are unique to individuals, including the location of their houses and workplaces. Given these complexities we have not tried to quantify the estimated health benefits of New Zealand houses and offices becoming near zero emission buildings.

Near zero emission houses and offices will keep indoor temperatures at 20 degrees. Research from initiatives that promote insulation, airtightness, and heating in houses, shows that these measures improve health, well-being, and productivity. To show what could be achieved, we highlight national and international examples of green buildings and retrofit programmes that improved housing quality.

International research, and domestic studies that address previous retrofit schemes such as Warm up New Zealand: Heat Smart (WUNZ:HS), and Warmer kiwi homes (WKH), provide an indication of what impacts better quality housing is likely to have in New Zealand

The benefits of moving to a near zero emission built environment are likely to be highly dependent on contextual factors relating to building type, building specification, building characteristics, and the surrounding environment, which are out of scope. A new house or office is superior to retrofitting, therefore we expect the benefits of building near zero emission houses and offices would have similar, if not superior, results.

8.1 Residential

Excess winter mortality and morbidity are often greatest in countries with relatively mild climates, including New Zealand. It has been speculated that this is because of poorer thermal housing standards compared with well insulated houses in colder climates.[37] A 2007 BRANZ study showed that up to two thirds of existing houses are estimated to lack a level of insulation that would bring it close to the 1996 standard for insulation in new houses.[38] This was supported by the 2015 House Condition Survey, where just under half of houses had less than 80 percent coverage of 120 mm insulation in the roof space, and just under one in five had less than 80 percent coverage of subfloor areas.[39]

In addition to the low levels of insulation in older houses, New Zealanders traditionally only heat main living areas, and approximately one tenth of houses have no heating source, or rely on portable gas heaters for warmth.[40] The 2015 Housing Condition Survey identified that overall five percent of households did not usually heat living areas at all in winter, and almost half did not usually heat any occupied bedrooms in winter.[41]

The World Health Organization recommends a minimum indoor temperature of 18°C, and ideally 21°C if babies or elderly people live in the house. [42] In New Zealand the average daily indoor

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[37] Fyfe C., Telfar-Barnard L., Howden-Chapman P., Douwes J. (2020). *Association between house insulation and hospital admission rates: retrospective cohort study using linked data from a national intervention programme.*

[38] Johnson A., Howden-Chapman P., Eaqub S. (2018). *A Stocktake of New Zealand's housing.*

[39] White V., Jones M. (2007). *Warm, dry healthy? Insights from the 2015 house condition survey on insulation, ventilation, heating and mould in New Zealand houses.*

[40] Supra n 37.

[41] Supra n 37.

[42] World Health Organisation. (2018). *Housing and Health Guidelines.*

temperature, in around a third of houses in winter, was under 18 degrees.[43] Fuel poverty in New Zealand has also been identified as a concern, and in 2011 it was estimated to contribute to New Zealand's high rate of excess winter mortality, contributing to 1,600 deaths and eight percent of winter hospitalisations.[44]

In the 2018 New Zealand census, 21.2 percent of houses were described as "too cold" by occupants, and 21.5 percent were described as "damp".[45] The World Health Organisation studies have found that houses kept at temperatures of between 18°C and 20°C could avoid indoor dampness.

Inadequately heated houses can have health consequences for occupants, particularly during winter periods. Colder houses place greater stress on older people, babies, and the sick, and are more likely to be damp and provide a more favourable growing environment for mould.

Cold indoor temperatures, dampness and mould have been linked to increased risk of respiratory symptoms. There is strong evidence for asthma exacerbation and respiratory infections, and limited evidence for asthma development in houses that are too cold, damp, or mouldy. A 2007 economic analysis calculated a 21 percent attributable fraction of asthma cases resulted from dampness and mould.[46]

By improving housing quality, especially warmth, these consequences can be minimised, and health improvements can be generated. The potential for health improvements depends on the baseline housing conditions and how well targeted intervention is. Previous research has shown clear evidence that housing interventions can improve house quality, and that these interventions to improve house quality can yield important savings in medical care, and improvements in quality of life.[47]

Using research on the impact of historic interventions intended to improve the warmth of New Zealand houses, we highlight the impacts improving the quality of New Zealand's housing stock could have on health.

8.1.1 Housing insulation and health study

To find solutions to the poor quality of New Zealand housing He Kāinga Oranga carried out a series of community trials in the early 2000s. A randomly selected group of 1,350 stand-alone house were insulated at no cost to the participants. Insulating these houses led to a significantly warmer, drier indoor environment which resulted in improved self-rated health, and a reduction in wheezing, days off school and work, self-reported visits to general practitioners, as well as a trend for fewer hospital admissions for respiratory conditions.[48]

A second community trial installed improved heating to insulated houses. Again, there were improvements to the health and wellbeing of occupants. Researchers observed a decrease in reports of poor child health, lower respiratory symptoms, and fewer days off school.[49]

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[43] Statistics New Zealand (2020). *Around a third of houses too cold in winter and too warm in summer.*

[44] Howden-Chapman P., Viggers V., Chapman R., O'Sullivan K., Telfer Barnard L., Lloyd B. (2011). Tackling cold housing and fuel poverty in New Zealand. A review of policies, research and health impacts.

[45] Supra n 20

[46] Ingham T., Keall M., Jones B., et al. *Damp mouldy housing and early childhood hospital admissions for acute respiratory infection: a case control study.*

[47] Grimes A., Denne T., Howden-Chapman P., Arnold R., Telfar-Barnard L., Preval N., Young C. (2011). *Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Programme.*

[48] Supra n 43.

[49] Ibid

8.1.2 Warm up New Zealand: Heat Smart

Warm Up New Zealand: Heat Smart (WUNZ:HS) was the Government's house insulation and heating programme. Starting in July 2009 the programme aimed to retrofit 188,500 houses with insulation and clean heaters by June 2013. WUNZ:HS subsidised improved energy efficiency for residential houses built before 2000, including:

- Retrofitted ceiling insulation and/or underfloor insulation or moisture barrier
- A range of measures including draught proofing, hot water cylinder wraps and pipe lagging
- Funding for clean heating devices.

WUNZ:HS was intended to improve household energy efficiency, leading to energy savings and improved comfort. It was also expected to provide health benefits, particularly for those at risk of respiratory illness, young people, and the elderly.

Between June 2009 and May 2010 46,655 dwellings were treated under the programme, and in 2010 researchers from Motu, He Kāinga Oranga, Victoria University, the University of Otago, and Covec completed an assessment of the impacts of WUNZ:HS on health services utilisation and costs, pharmaceutical costs, and mortality. WUNZ:HS contributed to an annual drop in mortality of 0.85 deaths per 1000 households containing 3.6 individuals. The benefit was estimated to be $439.95 per treated household. [50]

When savings on pharmaceutical costs, the benefits from fewer days off school or and reduced doctors' visits were added to the savings of reduced hospital care, the researchers estimated an on-going annual benefit of $563 for retrofitted insulation. The benefit for community service card holders (lower income households) was $818 and for those without a community services card the benefit was $227 per annum.

Motu's Warmer kiwi homes Evaluation 2020: Phase one report acknowledges that the Cost Benefit Analysis (CBA) of WUNZ:HS remains the most comprehensive and up to date CBA relevant to the EECA's Warmer kiwi homes initiative.[51]

8.1.3 Healthy houses initiative

The Healthy Houses Initiatives (HHIs) were established between December 2013 and March 2015 and covered 11 district health boards (DHBs) with a high incidence of rheumatic fever. Initially, the HHIs targeted low-income families with children at risk of rheumatic fever who were living in crowded households. In 2016, the breadth of the programme was expanded to focus more broadly on providing warm, dry, and healthy housing for pregnant women, low-income families with children aged five and under who had been hospitalised with a specified housing-related condition, and families with children aged up to five for whom at least two of the social investment risk-factors applied.[52]

The HHIs identify eligible families, working with them to carry out a comprehensive housing assessment and complete an individualised action plan to create a warmer, drier, healthier house. The HHIs then help families to get the interventions they need to create a better living environment,

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[50] Telfar Barnard L., Preval N., Howden-Chapman P., Arnold R., Young C., Grimes A., Denne T. (2011). *The Impact of retrofitted insulation and new heaters on health services utilisation and costs, pharmaceutical costs and mortality*.

[51] Grimes A., Preval N. (2020). Warmer kiwi homes *evaluation 2020: Phase 1.*

[52] The four risk factors are a finding of abuse or neglect, mostly supported by benefits since birth, parent with a prison or community sentence, mother with no formal qualification

especially for their children. Interventions given to these families include help with accessing insulation, curtains, beds, bedding, minor repairs, floor coverings, ventilation, heating sources, full and correct entitlement assessments through Work and Income, support with power bills, and finding alternative accommodation as needed.

As of December 2018, the Healthy Houses Initiative (HHI) programme received 15,330 eligible referrals and delivered over 40,000 interventions to low-income households. Motu and He Kāinga Ora conducted an interim sample analysis and estimated that the HHI programme resulted in 1,533 fewer hospitalisations, 9,443 fewer GP visits and 8,784 fewer filled prescriptions in the first year after the programme's intervention.[53]

On average, hospitalisations in the year after the intervention were less costly and shorter in duration than those prior. After adjusting for age and selection bias, the average hospitalisation post-intervention was 0.69 nights shorter and $541 less costly.[54]

The researchers then used the average cost of a hospitalisation at the time to estimate that the savings from hospitalisations avoided was approximately $6.3 million, and the reduction in severity of the hospitalisation was estimated to avert costs of $3.3 million in the earliest year post-intervention. Additionally, using the cost per visit from Treasury's CBAx Tool of $80, the expected costs averted from GP visits was $755,440 for the 9,443 GP visits prevented by the programme. Pharmaceutical dispensing averted was estimated at $74,225 in the earliest year post-intervention.[55]

8.1.4 Warmer kiwi homes

Warmer kiwi homes (WKH) is a government scheme run by the Energy Efficiency Conservation Authority (EECA). It has the primary objective of making New Zealand houses warmer, drier, and healthier, with a secondary objective of improving the energy efficiency of houses. It seeks to do this by helping low-income owner-occupiers overcome financial barriers to energy efficiency by providing insulation and clean, effective, and efficient heating to the main living area at low or no cost to the houseowner. The scheme is available to houseowners in cases where the house is in a more deprived area (NZDep = 8, 9 or 10) or in which the houseowner holds a Community Services Card (CSC). The houses must be owner occupied and built before 2008. Two core aspects of the programme are:

- Providing retrofitted insulation to older houses with insufficient existing insulation
- Providing clean heating devices to living areas in houses that do not have such heating already in place.

In 2022 Motu, in collaboration with the EECA, produced an interim report, the first report to be released as part of the Warmer Kiwis Study, which focused on understanding the outcomes of heat pump installations in participating houses. The study examined the impacts that WKH heat pump provision has on household outcomes including comfort and wellbeing, indoor environmental outcomes, and electricity use. The evaluation covered 127 households in Auckland/Waikato, the Lower North Island and Christchurch who applied for a heat pump through WKH in 2021.

The research concluded that there was an overall improvement in self-reported health amongst primary respondents in households that had received a heat pump, with the proportion of

[53] Pierse N., White M., Riggs L. (2019). *Healthy Houses Initiative Outcomes Evaluation Service: Initial analysis of health outcomes.*
[54] Ibid.
[55] Ibid.

responses stating that they were in excellent or very good health rising from 46 percent before heat pump installation to 62 percent after installation. The overwhelming majority of study participants who had received a heat pump (82 percent) said that their house was either much more comfortable or more comfortable as a result.[56]

Several responses noted an improvement in health since the heat pump had been installed, while others reflected on the reduction in stress that an effective source of heating had given them. Increased pride in the house was also identified, especially feeling more comfortable hosting family and friends.

Anecdotal feedback noted improvements in both physical and mental health, particularly around a reduction in stress from households knowing that they had an affordable means of keeping the house warm.

8.2 Offices

International studies have shown a direct link between cognitive function and the indoor environment of green buildings. The effect of indoor environmental quality in offices on employee health, wellbeing and productivity are important topics in health and public health research.

A study conducted by Syracuse University and The State University of New York Upstate Medical University re-created the conditions of green and green+ certified buildings and conventional office space and tested the performance of workers in the space. Researchers observed participants' cognitive function was significantly affected in all nine areas tested, including focused-activity levels, information usage, and strategy. Crisis-response scores were 97 percent higher at the green office setting compared with that of conventional office space, and 131 percent higher at the green+ office setting.[57]

Researchers then tested these findings in the real world where they compared staff in buildings with green certification against those without. Controlling for factors such as salary, type of work, building owner/tenant, and geographic location, the research found that workers in buildings that were green certified scored higher on the tests.[58]

The results of the study were consistent with a 2011 study where scientists at Lawrence Berkeley National Laboratory, and the Environmental Protection Agency, examined costs and benefits of improving indoor air quality in United States offices. The findings suggested that better air quality led to increased work performance, reduced sick building syndrome symptoms, reduced absence, and improved thermal comfort.[59]

To put the potential benefits of a superior working environment into context Harvard architect Holly Samuelson stated that "in an office, it might cost US$3 per square foot for utilities, while the rent or mortgage might cost another US$30 per square foot, but the salary and benefits of the employees could cost well over US$300 per square foot. So, a big challenge is overcoming the first cost in order to invest in better buildings. If we can design buildings that affect performance … that could make a big change in the company's bottom line".[60]

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[56] Fyfe C., Grimes A., Minehan S., Taptiklis P. (2022). *Warmer Kiwis Study: Interim Report. An impact evaluation of the Warmer kiwi homes programme.*

[57] Walsh C. (2018). *Your building might be making you sick. Joe Allen can help.*

[58] Allen J. (2017). *Research: Stale Office Air Is Making You Less Productive.*

[59] Fisk W., Black D., Brunner G. (2011). *Benefits and costs of improved IEQ in U.S. offices.*

[60] Supra n 57.

These results are consistent with earlier international case study experiences that indicate green buildings may positively affect public health. A study assessing two case studies of the effects of green buildings on employee health and productivity identified that improved indoor environmental quality contributed to reductions in perceived absenteeism and work hours affected by asthma, respiratory allergies, depression, and stress, and also to self-reported improvements in productivity.

Studies have shown that employees with such adverse health conditions are absent more often, lose work hours and are less productive than employees without these conditions. However, the quality of the built environment can limit these impacts. The case studies showed that the perceived improvements in asthma and respiratory allergies could provide an additional 1.75 additional work hours per year for employees with these conditions. Employees with a medical history of depression or stress might gain an additional two hours per year. The study found that the perceived productivity improvements were almost a week per employee per year.[61]

[61] Singh A., Syal M., Grady S., Korkmaz S. (2010). *Effects of green buildings on employee health and productivity.*

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Appendix A House specifications

To inform the estimates of the economic, emissions and electricity demand the New Zealand Green Building Council commissioned Rawlinsons to develop specifications for near zero emission houses in Auckland, Wellington, and Christchurch and a standard house that met the minimum requirements of the New Zealand building code H1 4th edition 2007. This house is referred to as the just code compliant house. The Auckland house was used to model the impacts of new builds and renovations for the upper North Island, Wellington was used for the lower North Island, while the Christchurch specification was used for the South Island.

Upper North Island (Auckland)

Item	Description	Quantity	Unit	Rate	Total
	Gross Floor Area: 182m2	182	m2		
1	Site Preparation	182	m2	10.99	2,000
2	Substructure	182	m2	440.00	80,080
3	Frame	182	m2	211.10	38,420
4	Roof	182	m2	229.95	41,850
5	External Walls	182	m2	429.67	78,200
6	Windows and External Doors	182	m2	183.30	33,360
7	Partitions	182	m2	64.18	11,680
8	Interior Doors	182	m2	53.30	9,700
9	Floor Finishes	182	m2	150.00	27,300
10	Wall Finishes	182	m2	140.82	25,630
11	Ceiling Finishes	182	m2	72.14	13,130
12	Fittings and Fixtures	182	m2	208.79	38,000
13	Sanitary Plumbing	182	m2	186.26	33,900
14	Mechanical Services	182	m2	130.49	23,750
15	Fire Services	182	m2	1.65	300
16	Electrical Services	182	m2	120.00	21,840
17	Drainage	182	m2	54.95	10,000
18	External Works	182	m2	0.00	0
	Element Sub-Total		**$/m2**	**2,687.58**	**489,140**
19	Preliminaries	12.0	%		58,697
20	Margins	10.0	%		54,784
21	Contingencies	10.0	%		60,262
	Construction Total		**$/m2**	**3,642.21**	**662,883**
22	Rounding				117
	Estimate Total		**$/m2**	**3,642.86**	**663,000**

Source: New Zealand Green Building Council, Rawlinsons

Lower North Island (Wellington)

Item	Description	Quantity	Unit	Rate	Total
	Gross Floor Area: 182m2	182	m2		
1	Site Preparation	182	m2	10.99	2,000
2	Substructure	182	m2	440.00	80,080
3	Frame	182	m2	298.43	54,315
4	Roof	182	m2	221.21	40,260
5	External Walls	182	m2	429.67	78,200
6	Windows and External Doors	182	m2	183.30	33,360
7	Partitions	182	m2	64.18	11,680
8	Interior Doors	182	m2	53.30	9,700
9	Floor Finishes	182	m2	150.00	27,300
10	Wall Finishes	182	m2	140.82	25,630
11	Ceiling Finishes	182	m2	72.14	13,130
12	Fittings and Fixtures	182	m2	208.79	38,000
13	Sanitary Plumbing	182	m2	186.26	33,900
14	Mechanical Services	182	m2	130.49	23,750
15	Fire Services	182	m2	1.65	300
16	Electrical Services	182	m2	120.00	21,840
17	Drainage	182	m2	54.95	10,000
18	External Works	182	m2	0.00	0
	Element Sub-Total		**$/m2**	**2,766.18**	**503,445**
19	Preliminaries	12.0	%		60,413
20	Margins	10.0	%		56,386
21	Contingencies	10.0	%		62,024
	Construction Total		**$/m2**	**3,748.73**	**682,269**
22	Rounding				-269
	Estimate Total		**$/m2**	**3,747.25**	**682,000**

Source: New Zealand Green Building Council, Rawlinsons

South Island (Christchurch)

Item	Description	Quantity	Unit	Rate	Total
	Gross Floor Area: 182m2	182	m2		
1	Site Preparation	182	m2	10.99	2,000
2	Substructure	182	m2	460.00	83,720
3	Frame	182	m2	298.43	54,315
4	Roof	182	m2	221.21	40,260
5	External Walls	182	m2	448.35	81,600
6	Windows and External Doors	182	m2	212.31	38,640
7	Partitions	182	m2	64.18	11,680
8	Interior Doors	182	m2	53.30	9,700
9	Floor Finishes	182	m2	150.00	27,300
10	Wall Finishes	182	m2	125.22	22,790
11	Ceiling Finishes	182	m2	72.14	13,130
12	Fittings and Fixtures	182	m2	208.79	38,000
13	Sanitary Plumbing	182	m2	186.26	33,900
14	Mechanical Services	182	m2	130.49	23,750
15	Fire Services	182	m2	1.65	300
16	Electrical Services	182	m2	120.00	21,840
17	Drainage	182	m2	54.95	10,000
18	External Works	182	m2	0.00	0
	Element Sub-Total		**$/m2**	**2,818.27**	**512,925**
19	Preliminaries	12.0	%		61,551
20	Margins	10.0	%		57,448
21	Contingencies	10.0	%		63,192
	Construction Total		**$/m2**	**3,819.32**	**695,116**
22	Rounding				-116
	Estimate Total		**$/m2**	**3,818.68**	**695,000**

Source: New Zealand Green Building Council, Rawlinsons

Just code compliant house

Item	Description	Quantity	Unit	Rate	Total
	Gross Floor Area: 182m2	182	m2		
1	Site Preparation	182	m2	10.99	2,000
2	Substructure	182	m2	210.00	38,220
3	Frame	182	m2	239.01	43,500
4	Roof	182	m2	174.07	31,680
5	External Walls	182	m2	359.62	65,450
6	Windows and External Doors	182	m2	143.41	26,100
7	Partitions	182	m2	64.18	11,680
8	Interior Doors	182	m2	53.30	9,700
9	Floor Finishes	182	m2	150.00	27,300
10	Wall Finishes	182	m2	140.82	25,630
11	Ceiling Finishes	182	m2	72.14	13,130
12	Fittings and Fixtures	182	m2	208.79	38,000
13	Sanitary Plumbing	182	m2	169.78	30,900
14	Mechanical Services	182	m2	38.46	7,000
15	Fire Services	182	m2	1.65	300
16	Electrical Services	182	m2	120.00	21,840
17	Drainage	182	m2	54.95	10,000
18	External Works	182	m2	0.00	0
	Element Sub-Total		**$/m2**	**2,211.15**	**402,430**
19	Preliminaries	12.0	%		48,292
20	Margins	10.0	%		45,072
21	Contingencies	10.0	%		49,579
	Construction Total		**$/m2**	**2,996.55**	**545,373**
22	Rounding				-373
	Estimate Total		**$/m2**	**2,994.51**	**545,000**

Source: New Zealand Green Building Council, Rawlinsons

Appendix B Office specifications

Near zero emission office

Project:	Net Zero Carbon Office	**Details:**	Concept Estimate
Building:	Optimised Carbon Office		

Item	Description	Quantity	Unit	Rate	Total
	Gross Floor Area: 9424m2	9,424	m2		
1	Site Preparation	9,424	m2	3.08	29,040
2	Substructure	9,424	m2	432.29	4,073,920
3	Frame	9,424	m2	839.46	7,911,069
4	Upper Floors	9,424	m2	248.42	2,341,120
5	Roof	9,424	m2	65.68	619,000
6	External Walls	9,424	m2	20.11	189,500
7	Windows and External Doors	9,424	m2	897.28	8,456,000
8	Stairs and Balustrades	9,424	m2	15.19	143,160
9	Partitions	9,424	m2	2.93	27,600
10	Interior Doors	9,424	m2	5.36	50,500
11	Floor Finishes	9,424	m2	82.67	779,120
12	Wall Finishes	9,424	m2	16.43	154,810
13	Ceiling Finishes	9,424	m2	120.00	1,130,880
14	Fittings and Fixtures	9,424	m2	84.04	792,000
15	Sanitary Plumbing	9,424	m2	24.62	232,000
16	Mechanical Services	9,424	m2	630.00	5,937,120
17	Fire Services	9,424	m2	174.89	1,648,160
18	Electrical Services	9,424	m2	224.01	2,111,088
19	Vertical and Horizontal Services	9,424	m2	13.79	130,000
20	Specialist Services	9,424	m2	5.31	50,000
21	Drainage	9,424	m2	2.12	20,000
22	External Works	9,424	m2	17.44	164,400
23	Sundries	9,424	m2	20.27	191,000
	Element Sub-Total		**$/m2**	**3,945.40**	**37,181,487**
24	Preliminaries	12.4	%		4,620,141
25	Margins	8.0	%		3,344,130
26	Contingencies	20.0	%		9,029,152
	Construction Total		**$/m2**	**5,748.61**	**54,174,910**
27	Professional Fees	16.8	%		9,127,986
28	Rounding				104
	Estimate Total		**$/m2**	**6,717.21**	**63,303,000**

Standard office

Project:	Net Zero Carbon Office	**Details:**	Concept Estimate
Building:	Standard Office		

Item	Description	Quantity	Unit	Rate	Total
	Gross Floor Area: 9424m2	9,424	m2		
1	Site Preparation	9,424	m2	3.08	29,040
2	Substructure	9,424	m2	409.79	3,861,880
3	Frame	9,424	m2	629.85	5,935,712
4	Upper Floors	9,424	m2	155.26	1,463,200
5	Roof	9,424	m2	58.18	548,320
6	External Walls	9,424	m2	20.11	189,500
7	Windows and External Doors	9,424	m2	898.34	8,466,000
8	Stairs and Balustrades	9,424	m2	3.18	30,000
9	Partitions	9,424	m2	7.43	70,000
10	Interior Doors	9,424	m2	5.36	50,500
11	Floor Finishes	9,424	m2	82.67	779,120
12	Wall Finishes	9,424	m2	16.43	154,810
13	Ceiling Finishes	9,424	m2	120.00	1,130,880
14	Fittings and Fixtures	9,424	m2	155.35	1,464,000
15	Sanitary Plumbing	9,424	m2	19.31	182,000
16	Mechanical Services	9,424	m2	413.00	3,892,112
17	Fire Services	9,424	m2	90.00	848,160
18	Electrical Services	9,424	m2	161.67	1,523,600
19	Vertical and Horizontal Services	9,424	m2	12.73	120,000
20	Specialist Services	9,424	m2	5.31	50,000
21	Drainage	9,424	m2	2.12	20,000
22	External Works	9,424	m2	17.44	164,400
23	Sundries	9,424	m2	20.27	191,000
	Element Sub-Total		**$/m2**	**3,306.90**	**31,164,234**
24	Preliminaries	12.5	%		3,886,037
25	Margins	8.0	%		2,804,022
26	Contingencies	20.0	%		7,570,859
	Construction Total		**$/m2**	**4,820.16**	**45,425,151**
27	Professional Fees	16.9	%		7,688,024
28	Rounding				-175
	Estimate Total		**$/m2**	**5,635.93**	**53,113,000**
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Appendix C 2025/2035 scenarios annual economic impact

Direct impact - Houses

Year	Annual New builds	2025/2035 Direct expenditure ($m)	2025/2035 Direct GDP ($m)	2025/2035 Direct FTEs
2023	43,900	23,926	6,771	63,640
2024	39,700	21,637	6,123	57,552
2025	36,688	23,391	6,676	62,308
2026	37,091	23,648	6,749	62,992
2027	37,893	24,160	6,895	64,354
2028	38,776	24,723	7,055	65,854
2029	39,707	25,316	7,225	67,435
2030	40,667	25,928	7,400	69,066
2031	41,639	26,548	7,576	70,716
2032	42,618	27,172	7,755	72,379
2033	43,598	27,797	7,933	74,043
2034	44,574	28,419	8,110	75,701
2035	45,546	30,735	8,676	80,588
2036	46,512	31,387	8,860	82,297
2037	47,470	32,033	9,042	83,992
2038	48,420	32,674	9,223	85,673
2039	49,364	33,311	9,403	87,343
2040	50,299	33,942	9,581	88,997
2041	51,226	34,568	9,758	90,638
2042	52,145	35,188	9,933	92,264
2043	53,056	35,803	10,106	93,876
2044	53,959	36,412	10,278	95,473
2045	54,854	37,016	10,449	97,057
2046	55,741	37,615	10,618	98,626
2047	56,620	38,208	10,785	100,182
2048	57,491	38,796	10,951	101,723
2049	58,355	39,379	11,116	103,251
2050	59,210	39,956	11,279	104,764

Total impact - Houses

Year	Annual New builds	2025/2035 Total expenditure ($m)	2025/2035 Total GDP ($m)	2025/2035 Total FTEs
2023	43,900	62,666	23,617	192,802
2024	39,700	56,670	21,358	174,357
2025	36,688	60,926	23,002	187,528
2026	37,091	61,595	23,254	189,588
2027	37,893	62,927	23,757	193,688
2028	38,776	64,393	24,311	198,201
2029	39,707	65,939	24,895	202,960
2030	40,667	67,533	25,496	207,867
2031	41,639	69,147	26,106	212,835
2032	42,618	70,773	26,720	217,839
2033	43,598	72,401	27,334	222,848
2034	44,574	74,021	27,946	227,837
2035	45,546	80,341	30,226	246,354
2036	46,512	82,045	30,867	251,579
2037	47,470	83,735	31,503	256,761
2038	48,420	85,411	32,133	261,899
2039	49,364	87,076	32,760	267,005
2040	50,299	88,725	33,380	272,063
2041	51,226	90,361	33,995	277,077
2042	52,145	91,982	34,605	282,047
2043	53,056	93,589	35,210	286,975
2044	53,959	95,182	35,809	291,859
2045	54,854	96,760	36,403	296,700
2046	55,741	98,325	36,992	301,498
2047	56,620	99,875	37,575	306,252
2048	57,491	101,412	38,153	310,964
2049	58,355	102,936	38,726	315,637
2050	59,210	104,444	39,294	320,261

Direct impact – Offices

Year	New builds	Expenditure ($m)	GDP ($m)	FTEs
2023	20	1,062	314	2,762
2024	20	1,062	314	2,762
2025	20	1,266	375	3,325
2026	20	1,266	375	3,325
2027	20	1,266	375	3,325
2028	20	1,266	375	3,325
2029	20	1,266	375	3,325
2030	20	1,266	375	3,325
2031	20	1,266	375	3,325
2032	20	1,266	375	3,325
2033	20	1,266	375	3,325
2034	20	1,266	375	3,325
2035	20	1,266	375	3,325
2036	20	1,266	375	3,325
2037	20	1,266	375	3,325
2038	20	1,266	375	3,325
2039	20	1,266	375	3,325
2040	20	1,266	375	3,325
2041	20	1,266	375	3,325
2042	20	1,266	375	3,325
2043	20	1,266	375	3,325
2044	20	1,266	375	3,325
2045	20	1,266	375	3,325
2046	20	1,266	375	3,325
2047	20	1,266	375	3,325
2048	20	1,266	375	3,325
2049	20	1,266	375	3,325
2050	20	1,266	375	3,325

Total impact – Offices

Year	New builds	Expenditure ($m)	GDP ($m)	FTEs
2023	20	2,701	1,053	8,408
2024	20	2,701	1,053	8,408
2025	20	3,220	1,255	10,079
2026	20	3,220	1,255	10,079
2027	20	3,220	1,255	10,079
2028	20	3,220	1,255	10,079
2029	20	3,220	1,255	10,079
2030	20	3,220	1,255	10,079
2031	20	3,220	1,255	10,079
2032	20	3,220	1,255	10,079
2033	20	3,220	1,255	10,079
2034	20	3,220	1,255	10,079
2035	20	3,220	1,255	10,079
2036	20	3,220	1,255	10,079
2037	20	3,220	1,255	10,079
2038	20	3,220	1,255	10,079
2039	20	3,220	1,255	10,079
2040	20	3,220	1,255	10,079
2041	20	3,220	1,255	10,079
2042	20	3,220	1,255	10,079
2043	20	3,220	1,255	10,079
2044	20	3,220	1,255	10,079
2045	20	3,220	1,255	10,079
2046	20	3,220	1,255	10,079
2047	20	3,220	1,255	10,079
2048	20	3,220	1,255	10,079
2049	20	3,220	1,255	10,079
2050	20	3,220	1,255	10,079

Appendix D 2030/2040 scenario annual economic impacts

Direct impact - Houses

Year	Annual New builds	2030/2040 Direct expenditure ($m)	2020/2040 Direct GDP ($m)	2030/2040 Direct FTEs
2023	43,900	23,926	6,771	63,640
2024	39,700	21,637	6,123	57,552
2025	36,688	19,995	5,659	53,185
2026	37,091	20,215	5,721	53,770
2027	37,893	20,652	5,844	54,932
2028	38,776	21,133	5,981	56,212
2029	39,707	21,640	6,124	57,562
2030	40,667	25,928	7,400	69,066
2031	41,639	26,548	7,576	70,716
2032	42,618	27,172	7,755	72,379
2033	43,598	27,797	7,933	74,043
2034	44,574	28,419	8,110	75,701
2035	45,546	29,039	8,287	77,352
2036	46,512	29,655	8,463	78,992
2037	47,470	30,266	8,637	80,619
2038	48,420	30,871	8,810	82,233
2039	49,364	31,473	8,982	83,836
2040	50,299	33,942	9,581	88,997
2041	51,226	34,568	9,758	90,638
2042	52,145	35,188	9,933	92,264
2043	53,056	35,803	10,106	93,876
2044	53,959	36,412	10,278	95,473
2045	54,854	37,016	10,449	97,057
2046	55,741	37,615	10,618	98,626
2047	56,620	38,208	10,785	100,182
2048	57,491	38,796	10,951	101,723
2049	58,355	39,379	11,116	103,251
2050	59,210	39,956	11,279	104,764

Total impact - Houses

Year	Annual New builds	2030/2040 Total expenditure ($m)	2030/2040 Total GDP ($m)	2030/2040 Total FTEs
2023	43,900	62,666	23,617	192,802
2024	39,700	56,670	21,358	174,357
2025	36,688	52,371	19,738	161,128
2026	37,091	52,946	19,954	162,898
2027	37,893	54,091	20,386	166,421
2028	38,776	55,351	20,861	170,299
2029	39,707	56,680	21,362	174,387
2030	40,667	67,533	25,496	207,867
2031	41,639	69,147	26,106	212,835
2032	42,618	70,773	26,720	217,839
2033	43,598	72,401	27,334	222,848
2034	44,574	74,021	27,946	227,837
2035	45,546	75,636	28,555	232,805
2036	46,512	77,240	29,161	237,743
2037	47,470	78,831	29,762	242,640
2038	48,420	80,408	30,357	247,496
2039	49,364	81,976	30,949	252,321
2040	50,299	88,725	33,380	272,063
2041	51,226	90,361	33,995	277,077
2042	52,145	91,982	34,605	282,047
2043	53,056	93,589	35,210	286,975
2044	53,959	95,182	35,809	291,859
2045	54,854	96,760	36,403	296,700
2046	55,741	98,325	36,992	301,498
2047	56,620	99,875	37,575	306,252
2048	57,491	101,412	38,153	310,964
2049	58,355	102,936	38,726	315,637
2050	59,210	104,444	39,294	320,261

Direct impact – Offices

Year	New builds	Expenditure ($m)	GDP ($m)	FTEs
2023	20	1,062	314	2,762
2024	20	1,062	314	2,762
2025	20	1,062	314	2,762
2026	20	1,062	314	2,762
2027	20	1,062	314	2,762
2028	20	1,062	314	2,762
2029	20	1,062	314	2,762
2030	20	1,266	375	3,325
2031	20	1,266	375	3,325
2032	20	1,266	375	3,325
2033	20	1,266	375	3,325
2034	20	1,266	375	3,325
2035	20	1,266	375	3,325
2036	20	1,266	375	3,325
2037	20	1,266	375	3,325
2038	20	1,266	375	3,325
2039	20	1,266	375	3,325
2040	20	1,266	375	3,325
2041	20	1,266	375	3,325
2042	20	1,266	375	3,325
2043	20	1,266	375	3,325
2044	20	1,266	375	3,325
2045	20	1,266	375	3,325
2046	20	1,266	375	3,325
2047	20	1,266	375	3,325
2048	20	1,266	375	3,325
2049	20	1,266	375	3,325
2050	20	1,266	375	3,325

Total impact – Offices

Year	New builds	Expenditure ($m)	GDP ($m)	FTEs
2023	20	2,701	1,053	8,408
2024	20	2,701	1,053	8,408
2025	20	2,701	1,053	8,408
2026	20	2,701	1,053	8,408
2027	20	2,701	1,053	8,408
2028	20	2,701	1,053	8,408
2029	20	2,701	1,053	8,408
2030	20	3,220	1,255	10,079
2031	20	3,220	1,255	10,079
2032	20	3,220	1,255	10,079
2033	20	3,220	1,255	10,079
2034	20	3,220	1,255	10,079
2035	20	3,220	1,255	10,079
2036	20	3,220	1,255	10,079
2037	20	3,220	1,255	10,079
2038	20	3,220	1,255	10,079
2039	20	3,220	1,255	10,079
2040	20	3,220	1,255	10,079
2041	20	3,220	1,255	10,079
2042	20	3,220	1,255	10,079
2043	20	3,220	1,255	10,079
2044	20	3,220	1,255	10,079
2045	20	3,220	1,255	10,079
2046	20	3,220	1,255	10,079
2047	20	3,220	1,255	10,079
2048	20	3,220	1,255	10,079
2049	20	3,220	1,255	10,079
2050	20	3,220	1,255	10,079

Appendix E Economic impacts by building specification and location

The tables in this appendix show the economic impacts (expenditure, gross domestic product and employment) from the single construction of each of the three house specifications in each of the regions.

Near zero emission

Upper North Island

	Direct	Indirect	Induced	Total
Expenditure ($m)	0.66	0.86	0.21	1.73
GDP ($m)	0.19	0.35	0.12	0.65
Employment (FTEs)	1.75	2.82	0.75	5.32

Lower North Island

	Direct	Indirect	Induced	Total
Expenditure ($m)	0.68	0.88	0.22	1.79
GDP ($m)	0.19	0.36	0.12	0.67
Employment (FTEs)	1.78	2.92	0.77	5.47

South Island

	Direct	Indirect	Induced	Total
Expenditure ($m)	0.70	0.90	0.22	1.82
GDP ($m)	0.20	0.37	0.12	0.68
Employment (FTEs)	1.81	2.98	0.78	5.56

Low emission

Upper North Island

	Direct	Indirect	Induced	Total
Expenditure ($m)	0.63	0.80	0.20	1.63
GDP ($m)	0.18	0.33	0.11	0.62
Employment (FTEs)	1.68	2.64	0.71	5.03

Lower North Island

	Direct	Indirect	Induced	Total
Expenditure ($m)	0.65	0.83	0.21	1.69
GDP ($m)	0.18	0.34	0.11	0.64
Employment (FTEs)	1.71	2.74	0.73	5.18

South Island

	Direct	Indirect	Induced	Total
Expenditure ($m)	0.66	0.84	0.21	1.71
GDP ($m)	0.19	0.34	0.11	0.64
Employment (FTEs)	1.73	2.78	0.74	5.25

Just code compliant

National

	Direct	Indirect	Induced	Total
Expenditure ($m)	0.55	0.71	0.18	1.43
GDP ($m)	0.15	0.29	0.10	0.54
Employment (FTEs)	1.45	2.32	0.62	4.39

Standard office

	Direct	Indirect	Induced	Total
Expenditure ($m)	53.1	63.6	18.3	135.0
GDP ($m)	15.7	27.1	9.9	52.7
Employment (FTEs)	138	218	64.1	420

Near Zero office

	Direct	Indirect	Induced	Total
Expenditure ($m)	63.3	75.9	21.8	161.0
GDP ($m)	18.7	32.2	11.8	62.8
Employment (FTEs)	166	261	76.5	504

Appendix F New build houses by house specification and region

Year	Stock	2025/2035 new builds			2030/2040 new builds			New builds by region			
		Just code compliant	Low operational	Near zero	Just code compliant	Low operational	Near zero	Upper North Island	Lower North Island	South Island	Total
2023	2,063,323	43,900			43,900			25,023	6,585	12,292	43,900
2024	2,095,083	39,700			39,700			22,629	5,955	11,116	39,700
2025	2,124,432	-	36,688		36,688			20,912	5,503	10,273	36,688
2026	2,154,106	-	37,091		37,091			21,142	5,564	10,385	37,091
2027	2,184,420	-	37,893		37,893			21,599	5,684	10,610	37,893
2028	2,215,441	-	38,776		38,776			22,102	5,816	10,857	38,776
2029	2,247,207	-	39,707		39,707			22,633	5,956	11,118	39,707
2030	2,279,741	-	40,667		-	40,667		23,180	6,100	11,387	40,667
2031	2,313,052	-	41,639		-	41,639		23,734	6,246	11,659	41,639
2032	2,347,146	-	42,618		-	42,618		24,292	6,393	11,933	42,618
2033	2,382,024	-	43,598		-	43,598		24,851	6,540	12,207	43,598
2034	2,417,684	-	44,574		-	44,574		25,407	6,686	12,481	44,574
2035	2,454,121	-	-	45,546	-	45,546		25,961	6,832	12,753	45,546
2036	2,491,328	-	-	46,512	-	46,512		26,512	6,977	13,023	46,512
2037	2,529,303	-	-	47,470	-	47,470		27,058	7,121	13,292	47,470
2038	2,568,039	-	-	48,420	-	48,420		27,599	7,263	13,558	48,420
2039	2,607,529	-	-	49,364	-	49,364		28,137	7,405	13,822	49,364
2040	2,647,766	-	-	50,299	-	-	50,299	28,670	7,545	14,084	50,299
2041	2,688,747	-	-	51,226	-	-	51,226	29,199	7,684	14,343	51,226
2042	2,730,463	-	-	52,145	-	-	52,145	29,723	7,822	14,601	52,145
2043	2,772,908	-	-	53,056	-	-	53,056	30,242	7,958	14,856	53,056
2044	2,816,074	-	-	53,959	-	-	53,959	30,757	8,094	15,109	53,959
2045	2,859,958	-	-	54,854	-	-	54,854	31,267	8,228	15,359	54,854
2046	2,904,550	-	-	55,741	-	-	55,741	31,772	8,361	15,607	55,741
2047	2,949,846	-	-	56,620	-	-	56,620	32,273	8,493	15,854	56,620
2048	2,995,839	-	-	57,491	-	-	57,491	32,770	8,624	16,097	57,491
2049	3,042,520	-	-	58,355	-	-	58,355	33,262	8,753	16,339	58,355
2050	3,089,889	-	-	59,210	-	-	59,210	33,750	8,882	16,579	59,210