External Study Report

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Building Beyond Minimum Requirements: a literature review

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NZIER was established in 1958.

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Key points

What we found

- Many studies focused on energy savings as the sole benefit.
- The estimation of the financial cost saving was consistently completed to a high standard.
- However, few studies assessed the environmental benefits from the energy savings despite the methodology being well-established in the environmental economics literature.
- Health benefits were rarely considered, except in the more recent studies.
- Water-saving benefits were explored by a few studies for specific interventions.
- Construction waste and the embodied carbon in construction materials were explored by a few studies and the quality of those studies was good. More research would be helpful to deepen and enrich the evidence-base in these areas.
- The private net-benefits of building beyond the minimum were greater than the societal net-benefits.
- The market benefits from energy savings were frequently enough to offset the additional costs of building beyond the minimum and this could explain the limited consideration of non-market benefits.
- When non-market benefits were included in the assessment, the total benefits exceeded the total costs of building beyond the minimum in most cases. Double glazing in warmer climate zones was an exception.
- The reason for building a home to an 'above code' standard is not always environmental. Preferences and objectives such as aesthetics and comfort can motivate above code design choices too. These objectives can influence the costs and benefits, but also the scope of the assessment.
- Distinguishing between the comfort, health and environmental elements of building beyond the minimum influences the assessment of the additional cost, but that distinction may not be straightforward as some design elements have multifaceted benefits.
- The additional cost of building a Homestar-6 has been estimated at 2–3% based on larger volume building schemes. Such costs are outweighed by the benefits, but not by a lot over the evaluation period.
- The additional cost of building to a Homestar-7 or -8 rating could increase the cost of construction by 5–19%, compared to the minimum requirements of the Building Code.
- Choice of discount rate can affect the assessment over the life of the house. Treasury guidance suggest a discount rate of 4% for housing, which is consistent with international studies.

There is room for improvement in the assessments

- The assessments of costs and benefits of building beyond the minimum in New Zealand deserves more research to enrich and broaden the evidence base specific to the local building approach and standards.
- The focus of many local studies was energy savings in terms of long-term occupant cost savings.
- Other aspects such as the environmental impacts of construction materials, construction waste, health impacts and environmental impacts generally were rarely considered. So, the social benefits are being not fully captured by assessments and as a result, may not be duly considered in decisions.

Applicability of overseas studies to New Zealand?

- The local New Zealand context is important when assessing the benefits and costs.
- Some international studies find that what is true for one region within a country may not be generalisable to the whole country, due to consistent climate differences. Implying that researchers should be cautious about generalising the at the national level and taking international findings at face value.
- The international literature should be seen as a good source for assessment approaches, but International construction methods, materials, and building standards are not necessarily applicable to New Zealand.
- International research can inform the development of richer and more consistent cost-benefit analysis for construction in New Zealand.

Further research is needed to improve the assessment

- More consistent and in-depth assessment could be encouraged through the development of a set of guidelines for the assessment of the costs and benefits of building beyond the minimum.
- These guidelines should take a societal perspective and include the suggested methods, explanations and key references for estimating the non-market impacts.
- Investigating the willingness-to-pay premium for buildings that are built to a higher standard in New Zealand would add value to the discussion and decision-making associated with the choice to build beyond the minimum.
- There is a gap in understanding the economic flow-on effects of building beyond the minimum, if it became more common. Further research could jointly consider the economic and environment effect of a range scenarios.

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1. Objective and scope

1.1. Purpose

BRANZ commissioned NZIER to complete a literature review of the economic assessment of the costs, benefits and methods for the construction of houses that are designed and built to standards that exceed the minimum requirements as defined by the Building Code.

1.2. Scope

The scope included international and local assessments, academic and grey literature and industry material such as facts sheets. The applicability of international studies was limited due to the variations in building standards in New Zealand and overseas. Therefore, the review of the international literature focused on the following aspects:

- The types of costs and benefits that were quantified and monetised including:
  - Market costs and benefits (those priced in markets)
  - Non-market costs and benefits e.g. environmental, health and social impacts (commonly not priced by markets, although carbon prices are an exception to the rule).
- The overall results and if the studies found that benefits exceeded the costs.
- The payback periods.
- Estimates of the financial return on investment.
- Whether non-market benefits were quantified.
- Whether there were obvious reasons that some costs or benefits were not relevant to New Zealand, e.g. the common use of heating oil overseas is not relevant.

Retrofitting to higher standards

Studies on the costs and benefits of retrofitting beyond the minimum standard of the Building Code were initially considered out of scope as the original scope was limited to new builds. However, we did find several published studies that undertook an economic assessment of retrofitting that focused on the economic and social case for such investment. These studies, typical assessed the return on investment in the context of social housing and social policy (fuel poverty, affordability and thermal comfort associated with health outcomes).

Due to the relevance of the issues being reviewed to New Zealand’s housing challenges and the comparability of the economic assessment frameworks used, the scope was expanded to include studies about retrofitted residential improvements, particularly where the design standard involved increasing the performance of the house from a code compliant standard (at construction) to a passive house standard.

The march of time and standards in New Zealand

For New Zealand-based studies, we focused on studies that had been published over the last decade or so. We found some studies that had conducted their assessment of the costs and benefits compared to the standard of the day, which had been superseded by amendments to the Building Code. The Building Code is revised frequently, which shifts the reference point for the minimum requirements.

Where possible we have provided the reference year for the ‘prices’ of the costs and benefits. Where it was not provided in the literature, the year of publication was the natural second-best option.

We note the additional costs and benefits cited in this report are subject to the effects of supply and demand. In periods of high demand and supply constraints the price of building per square metre of construction can increase materially. This may affect the relationship between standard designs and building beyond the minimum, especially where the labour to materials ratios are different between designs.

Some studies were out of scope

Studies about commercial building or office space such as Sun et al. (2016) were out of scope.

2. Thematic categorisation

An initial scan of each article was done before we comprehensively reviewed the sourced literature. Each article was summarised and categorised according to common themes and elements.

Purpose

The purpose of the initial scan was to:

- Gain an overview of the literature in terms for the coverage, typical results and common jargon or key phrases.
- Categorise the literature found in the initial literature search according to common themes to develop the structure.
- Gain early insights.
- Identify gaps or additional areas in the literature to explore.
- Prioritise the literature for the comprehensive review.
- Identify articles that were not relevant or were beyond the scope or the literature review.

The initial scan provides a multi-purpose foundation at the beginning of the project that supported a more efficient and structured literature review than just simply diving straight into the literature.

Approach

The references compiled in the initial literature scan were captured in a Zotero document library[1] and sorted from newest to oldest.

An initial review of each reference was systematically done by reading the abstract, introduction and conclusion of each reference. Then following elements were summarised and documented:

- Authors
- Title
- Year of publication
- A short summary of what the articles covers and its relevance to the review
- The types of benefits and costs considered
- Payback period
- Which country or countries the research relates.

The payback period was included as a key element of the theme categorisation because it was frequently mentioned in the abstracts and conclusions. We found it to be a useful metric for summarising the results and comparing similar appraisals. Including a country category provided a context for the focus of the research.

1 Zotero is a free, easy-to-use tool to help you collect, organize, cite, and share research. See https://www.zotero.org/

Summary of the findings from the thematic categorisation

The key findings were:

The number, relevance and location of the articles

- We initially sourced 28 articles.
- We found 5 that discussed but did not quantify the benefits and costs.
- 4 articles were deemed out of scope.
- The studies were mostly international – very few domestic.
- Predominately from the UK, Australia and USA.

The major themes

- Big focus on energy savings as the key benefits.
- Payback periods ranged from 10 to >40 years – and were very sensitive to energy cost forecasts and discount rates.
- A payback period greater than 40 years was considered impractical.
- In one case the retrofitting of social housing houses in the UK had an undiscounted payback period of 4 years.
- Several studies considered the costs and benefits of retrofitting existing houses to a passive home standard.
- New Zealand's focus on health benefits of home heating seems unique. Other countries tended to focus on fuel poverty and environmental effects related to the source of heating, including the type of electricity generation.
- Some studies considered non-market benefits such as health outcomes, thermal comfort, wellbeing – as well as energy savings.
- The benefits typically exceeded the costs when non-market benefits were considered. Non-market benefits drew on health economics and environmental economics.
- A few studies considered the non-market value of lower emissions due to energy savings. This approach to estimating the benefits is relevant to New Zealand.
- Some recognised that there were other unquantified benefits, e.g. health.

Relevance to New Zealand

- Some overseas studies looked at heating oil costs, which is of less relevance to New Zealand.
- Our review to date suggests the local New Zealand context is important in an assessment of the benefits and costs, particularly when the emissions from energy generation is an important aspect of the research.

Relevance to exceeding the minimum

- Our view is that retrofitting can be included in the scope of the review because the analysis and findings are relevant to the 'conversation' even if they diverge from the focus on new builds.

Other findings that emerged from the categorisation

- As part of the review we are developing a glossary of terms for clarity. For example, low energy, passive homes, net zero energy.
- New Zealand has been slow to consider energy savings.

3. Defining key terms

Fuel poverty

A household is in fuel poverty if it would need to spend more than 10% of the total household income on all household fuels to achieve a satisfactory indoor environment (Lloyd, 2006, p. 142).

Passive houses

Passive houses are designed to maintain a comfortable indoor temperature during any season without conventional heat distribution systems. The name 'passive house' came from the passive use of incidental heating sources. The passive heating sources can be internal (electric appliances) and external (solar radiation). Passive houses are a refinement of low energy houses (Schnieders 2003).

Net-zero energy

Buildings that use a combination of renewable energy and energy efficiency to meet the building's energy needs (Kadam and Kadam 2001).

Payback period

The period required for the financial or economic benefits to offset the costs.

Internal rate of return (IRR)

The capital interest rate or discount rate that would cause the net present value of the costs and benefits to be zero. Projects are generally considered profitable (or net beneficial) if the IRR is greater than cost for capital (or the discount rate).

4. Literature review

The literature reviewed covered a wide field which included construction materials, design specifications for post-construction, environmental impacts, retrofitting existing housing, the response to policy changes and the effects of technical assumptions in the derivation of outcomes.

In one place and easy

The main purpose of the review was to collate and document the various costs and benefits of building beyond the minimum standard embedded in the Building Code. The motivation was to explore the benefits and costs and summarise them in one place, in order to make the costs and benefits more accessible, to encourage greater consideration of exceeding the minimum. Or at least, to consider construction options that go beyond the minimum, which is the very common status quo in New Zealand.

The scope was widened to include retrofitting

The original intention of the literature review was to focus on new construction. However, from the early stages of our review, it became clear that there was not a lot of literature on new construction, but there was a body of literature on retrofitting approaches. A discussion was taken to include the literature on costs and benefits of retrofitting because it was broadly relevant to the programmes and government policy objectives in housing and environmental policy.

5. Building above code

5.1. Objectives matter

The reasons for building a home at an ‘above code’ are not always environmental. Preferences and objectives such as aesthetics and comfort can motivate above code design choices too.

Wilson (2018) compared the tender price of an above code design to a minimum compliance design. The study was set in British Columbia, Canada. The cost challenge (or cost disadvantage) and energy savings of building above code were compared to that of minimum compliance design.

The initial results indicated the above code design resulted in:

- a 22.5% cost disadvantage
- an energy advantage of 22.5 kWh/m2/yr
- a payback period of over 79 years.

However, they also found that some aspects of above code design in the initial investigation were largely of aesthetic value, such as metal roofing. Other above code design elements were for comfort, such as floor-cavity insulation. After adjusting for above code design elements that were for aesthetic or comfort purposes, they estimated the above code design choices for environmental reasons. The updated results are as follows:

- a cost-disadvantage of 2.1%
- an energy advantage of 15kWh/m2/yr
- payback period of over 16 years

The significant difference in the costs and payback period indicate that it is critical to have a clear understanding of the objectives and motivations that influence the decision-making process that underpins the construction and design of above code houses. The results of this study suggest the real costs of building beyond the minimum can be less than the costs associated with the look and feel of the house. Therefore, when the assessing the costs and benefits of exceeding the code it would be useful to distinguish between elements that exceed the code for comfort reasons and the elements that exceed the code for environmental reasons. There may also be overlaps between comfort elements, health elements and environmental elements. For example, improved insulation could benefit thermal comfort, health outcomes and environmental outcomes.

5.2. Objectives and preferences can also affect market prices

In the context of considering the costs and benefits of building beyond the minimum for the additional sale value or the market’s willingness-to-pay for buildings constructed to a higher standard was rarely considered.

Eichholtz, Kok, and Quigley (2010) found that there was evidence of a willingness-to-pay a premium for the intangible or non-market benefits of a green office building compared to other office buildings.

In Switzerland, Banfi et al. (2008) estimated that the willingness-to-pay for above code insultation was a 3% premium on the rental price of a rental property. They also found that tenants were willing to pay an 8–13% premium for ventilation system improvements. This suggests that there is a market for buildings that go beyond the minimum in Switzerland. To the best of our knowledge, comparable studies on the willingness-to-pay a premium for buildings that are built to a higher standard have not been published in New Zealand. Such studies would add value to the discussion and decision-making associated with the choice to build beyond the minimum in New Zealand.

5.3. New Zealand based studies

Few New Zealand-based studies were found during the literature search. The ones that we did identify warranted greater attention as they have the greatest potential to offer New Zealand specific insights. Even the information gaps in the New Zealand-based studies are worth noting because these gaps represent opportunities for fresh New Zealand-based findings.

New Zealand appears to be lagging other western nations in investigating the sustainability of housing design. Housing design is regarded as more of a public health issue, than an environmental issue. The dominance of renewable electricity generation is cited by Kerr, Gouldson, and Barrett (2017) as the major reason that sustainability of housing design in New Zealand has been slow to attract attention compared with other countries.

The Cost of Homestar: A Case Study on How to Achieve a 6–10-Homestar Rating for Stand-Alone and Terraced Housing in Hobsonville Point (Ade 2018)

Ade (2018) assessed the costs, benefits and payback periods of constructing dwellings to different Homestar ratings. This report is an excellent study comparing the ratings, but like many of the studies we reviewed, it does not quantify or monetise the non-market benefits.

Table 1 shows the payback period, median additional cost and annual savings for Homestar designs 6–10, compared to a Homestar-4 design standard, which is equivalent to a home constructed to the minimum standard of the Building Code. Homestar 10 is considered to be a passive house design standard (Quinn 2019).

Table 1 Costs, savings and payback period

Compared to a Homestar-4 house

Homestar rating	Median additional cost	Annual savings	Payback period (years)
6	$2,834	$266	6
7	$4,057	$548	7
8	$35,396	$809	51
9	$53,630	$2,806	20
10	$53,630	$2,806	20

Source: Ade (2018)

These estimates indicate that the Homestar 6,7,9 and 10 designed houses would be considered cost-effective. The 51-year payback period for Homestar-8 rating is above the 40- year payback, which is considered to be the reasonable benchmark compared to the life expectancy of the owner.

The costs and benefits of Homestar-6 houses (Sense Partners 2018)

The Sense Partners (2018) study is one of a few recent studies that investigate the costs and benefits of building beyond the minimum in New Zealand. Their study uses a social benefit cost analysis framework to consider and compare market and non-market values. They also considered who benefits from the outcomes. They distinguish between the impact that falls to the owner (private impacts) and those that fall on society (social impacts). Their study was focused on Homestar-6 rating houses in the context of large-scale building schemes such as Kiwibuild.

Table 2 shows the costs, benefits and Net Present Value (NPV) for house designs in Auckland, Wellington and Christchurch to allow for climatic variation. In this study the additional cost of building a Homestar-6 has been estimated at 2–3% based on larger volume building schemes.

Table 2 The costs and benefits of Homestar-6 houses

Element	Beneficiary	Auckland	Wellington	Christchurch
Upfront costs				
Construction	Private	$5,692.00	$7,060.00	$6,920.00
Certification and assessment	Private	$850.00	$850.00	$850.00
Diverted waste	Private/social	$523.00	$523.00	$523.00
Annual savings				
Energy	Private	$379.00	$490.00	$494.00
Carbon	Social	$4.00	$5.00	$5.00
Water	Private/social	$105.00	$101.00	$70.00
Wastewater	Private/social	$523.00	$523.00	$523.00
Runoff etc	Private/social	$66.00	$63.00	$22.00
NPV over 30 years, 8% discount rate				
Private		$2,281.00	$1,579.00	$1,588.00
Social		$934.00	$2,226.00	$1,295.00
Total		**$3,216.00**	**$3,745.00**	**$2,883.00**

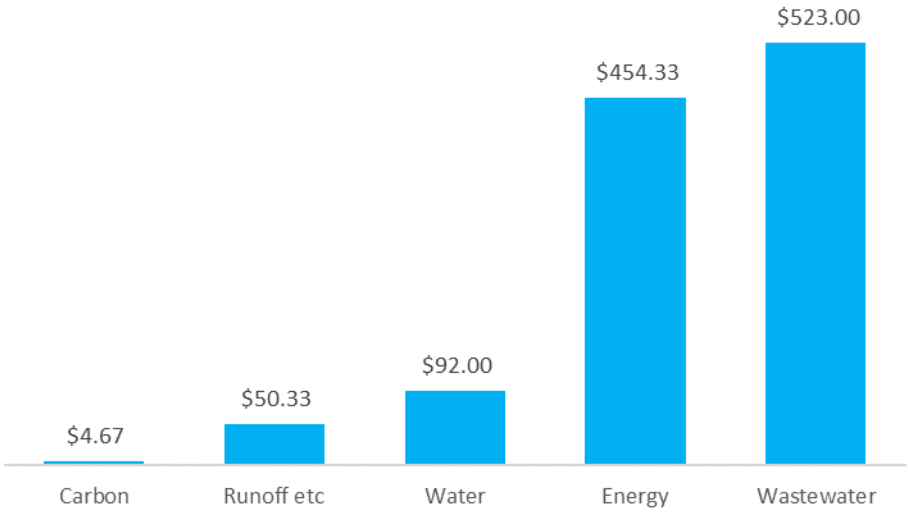
Source: Sense Partners (2018)

The net benefits were not large considering the 30-year evaluation period. They estimated the total private and social benefits were $3,216 in Auckland, $3,745 in Wellington and $2,833 in Christchurch, for an average sized home. The point of interest is that the benefits offset the cost of building to a standard that exceeds the minimum, not the size of the net benefits. The presence of net benefits indicates that the societal case of exceeding the minimum through a Homestar-6 was socially and economically justified, under the assumptions made in the analysis by Sense Partners (2018). However, the private net-benefits are greater than the social net-benefits.

Figure 1 shows the average annual savings per house estimated by Sense Partners, for New Zealand, based on the application of a Homestar-6 design specification. Of note is that wastewater reductions would exceed the energy savings. The finding supports our view that it is important to consider the benefits of improvements beyond energy savings in the New Zealand context.

Figure 1 Average annual savings for a Homestar-6 house

2018 values



Source: NZIER based on Sense Partners (2018)

The value of carbon reductions

The value of carbon reductions was found to be around 1% of energy savings. This result is significant given the level of renewable energy production in New Zealand. Sense Partners applied different carbon prices over the 30-year analysis. They used the following values:

- $20 per tonne.
- The value rising gradually to $22 by 2025.
- After 2025 they assume the value of carbon increase to $250 per tonne by 2048.

The 10-fold increase in the unit value of carbon savings suggests that the sensitivity analysis and clear communication of assumptions around unit pricing will be important in the analysis of the case for exceeding the minimum.

A review by NZIER (2020) of the value of carbon found that the estimates of the value of carbon vary significantly. Table 3 summarises some examples of the social cost of carbon. Values vary by source, country and year.

Table 3 A selection of carbon value estimates

Per tonne of CO_2-e

Author	Country	Year	Value (original currency)	NZD (2019$)
Hohmeyer et al. (1992)*	US	1992	$220	$542
Bein (1997)*	US	1997	$1,000 (up to $4,264)	$2,233 (up to $9,522)
European Commission (1999)	EU	1999	€20 (up to €46)	$50 (up to $115)
Tol (2005)*	EU	2000	€11 (-€4 - €53)	$27 (-$10-$130)
DLR (2006)*	EU	2000	€70 (€15 - €280)	$177 ($38-$707)
Jacob et al. (2005)*	NZ	2003	$270	$375
European Commission (2005)	EU	2005	€19 (€18-€24)	$45 ($43-$57)
Smith and Braathen (2015)	US	2010	$43	$74
Nocera et al. (2015)	US	2010	$45 ($38 - $52)	$78 ($66-$90)
Ricardo-AEA (2014)	EU	2010	€90 (€48 - €168)	$203 ($108-$379)
Austroads (2012)	Australia	2012	$52	$55
Tol (2012)	EU	2012	€76	$163
ITF/OECD	OECD	2015	$US2-$US14	$3-$22

* See Maibach et al. (2008).

Source: Authors as stated and NZIER adjustments to 2019 prices in NZD

The approach to valuing carbon was one reason for the variation in the value of carbon. Internationally, there are four different ways in which agencies have incorporated a value of carbon into their decision-making. We have summarised these approaches in Table 4.

Table 4 There is a catalogue of valuation techniques available to value GHGs

Approach	Description	Methodology
Social cost of carbon	The global cost attributable to one additional tonne of GHG emission.	Derived from models that combine economic and physical aspects of climate change.
Abatement cost, also known as the shadow price of carbon	Measures the costs to an economy of reducing emissions by one tonne.	The results of modelling the cost and effectiveness of various options to reduce emissions, usually at the national level.
Carbon prices	Carbon prices are not a value of carbon, but an administratively imposed charge on activities that lead to emissions.	Set within the design of the scheme applied. Taxes are usually set by a government, while the cost of units in an emissions trading type scheme are based on the stringency of the emissions target and the coverage of the scheme.
Public willingness-to-pay measures	The amount a group of people say they would be prepared to pay to see emissions reduced by one tonne.	Inferred through stated preference surveys.

Source: ITF/OECD 2015

The value of waste reductions

The cost of waste applied was $209 per tonne. There are additional benefits of reducing leachate and other externalities. These were estimated to be $1-$19/tonne based on Covec (2012).

The value of water savings

The potential savings for an average household were around 100 litres per day (or the equivalent of $300 per year) based on Page (2016).

The Value of Sustainability – Costs and Benefits of Sustainability and Resilience Features in Houses (Page 2016)

Page (2016) provides the most extensive and up-to-data analysis of the costs and benefits of building beyond the minimum, because the study considers the impacts in New Zealand across multi-regions.

The high-level findings are summarised below. The report contains more detail. Tables 11–14 are especially useful.

The report monetises the costs and benefits of above code levels for insulation, water uses, rainwater collection, solar water heating and heat pump water systems. A cost-effectiveness approach was applied. The non-market benefits were not quantified nor monetised, so the assessment represents a market-driven perspective.

The summary findings of the report are as follows:

- The minimum standards for insulation were close to being financially optimal for most households, based on the climate zones New Zealanders commonly live in.

- In Welling and the lower South Island slightly more ceiling and under-floor insulation was cost-effective. Results were sensitive to winter heating temperatures.
- The benefit-cost ratios of above minimum insulation for most areas were less than 1, indicating that the enhancements were not cost-effective over 25 years.
- The cost-effectiveness of increased insulation was proportional to the desired temperature.
- Rainwater tanks generated savings that had payback periods between 9 and 15 years and were therefore considered cost-effective.
- Solar water heaters had payback periods were at least 10 years.
- Heat pump hot water systems' payback periods were usually 16 years or more.

Page considered a payback period of up to 15 years to be a good return on investment (equivalent to 5% return p.a.). A payback period of 40 years or more was effectively not cost-effective, in practical terms.

The Beacon Pathway High Standard of Sustainability Study (Stroombergen et al. 2007)

Beacon Pathway Ltd commissioned Stroombergen et al. (2007) to complete a qualitative study of their High Standard of Sustainability (HSS) for housing. Data limitations meant that only the benefits for energy and water savings were assessed.

Lighting energy savings

Lighting consumes 9% of the energy used in a typical New Zealand house. The assessment of energy savings from alternative lighting options found that for Compact Fluorescent Lighting (CFL), the payback period was less than a year due to the 80% reduction in lighting energy consumption per CFL unit compared to an incandescent bulb. So, despite the cost of a CFL unit being three times the cost of an incandescent bulb, the case for using CFL was strong.

Water heating

The study compares three water heating options to the traditional electric water heating tank: solar heating, a heat pump and instant gas heating. Table 5 compares the costs, energy savings and internal rate of return (IRR) for each option relative to traditional electric water heating tanks.

Table 5 Comparing water heating alternatives

Relative to traditional electric water heating tanks.

Heating option	Cost	Energy savings	IRR
Solar water heating	+$5,100	83.5%	5.9%
Heat pump hot water	+$3,900	65.6%	6.3%
Instant gas heating	+$400	15.2%	79.8%

Source: Stroombergen et al. (2007)

Water consumption

Table 6 below shows the water use and costs for low-flow shower heads, dual flush toilets and water efficient washing machines.

Table 6 Water consumption

Fitting	Savings	Description	Cost
Low flow shower heads	8.4%	Low saving due to due high proportion of low-pressure systems and assumed take-back of flow rates less than 9 litres/minute	$50 material and $118 labour, for 34.8% of dwellings.
Dual flush toilets	54.5%	5 litres versus 11 litres	No extra cost.
Efficient washing machines	60%	60 litres per wash compared to 150 litres	$60 above standard machine.

Source: Stroombergen et al. (2007)

A CBA of Secondary Glazing as a Retrofit Alternative for New Zealand Homes (Smith 2009)

Smith (2009) presents an assessment of the cost-effectiveness of options for retrofitting secondary glazing in traditional single pane glazing in aluminium frames in four climate zones in New Zealand. The thesis considered following options:

- thin film adhesive
- magnetic acrylic sheet
- secondary retrofitting double glazing into exist frames
- Low-E secondary retrofitting double glazing into exist frames.

Each option was simulated and compared to a traditional single pane glazing in an aluminium frame. The estimation of the benefits was based on the energy savings calculated for each option. Smith notes that there are likely to be health benefits from the glazing options, but the benefits were not quantified and included in the assessment. This means that if the health benefits were included the payback would be shorted than Smith estimated.

The Low-E option had the shortest payback period and was cost-effective in three out of the four climate zones. The option was not cost-effective in warmer climates, such as the Auckland region. In climate zones like Wellington the payback period for Low-E option was estimated to be 20–22 years, without quantifying the health benefits. In climate zones such as Christchurch or Dunedin, the payback period was estimated to be 14–20 years.

Thin film plastic adhesive was not cost-effective in any climate zone and was difficult to install and needed to be replaced once a year. Smith notes it might be attractive to people looking to reduce condensation in cold climate zones.

5.4. Low-energy social housing delivers savings for low-income tenants and benefits the environment

Moore et al. (2017) considered some of the life-time benefits and costs of especially constructed low energy houses for low-income housing in Australian social housing. The costs and benefits were compared to the standard departmental social house. The technical performance benefits included:

- Tenants in low-energy houses consumed 45–53% less electricity and 3–15% less gas compared to the standard design.
- The 1.5kW solar system provided between 46–56% of total electricity consumed.
- Low-energy households consumed 22–28% less water.
- Overall the reduction in energy consumption was estimated to reduce the associated emissions in CO_2-e by 40–50%.
- The average annual household financial saving was A$1,050 per year.
- The tenants experienced greater thermal comfort and reported improved health outcomes.

The additional cost of construction was A$75,700 compared to a standard social house. The payback period was estimated to exceed the 40-year benchmark. Moore et al. concluded that cost was a challenge for wider implementation, but economies of scale could help lower those costs. The economic benefits of a small environmental footprint or improved health outcomes were not monetised. The economic benefits and costs were not fully explored in a way that was consistent with the social cost-benefit analysis set out by the Treasury guidelines (New Zealand Treasury 2015), a limitation if the research was to be completed for the purpose of policy in New Zealand.

In an earlier study (Moore, Strengers, and Maller 2016) concluded that a traditional cost-benefit analysis did not capture all the benefits and a mixed-method approach was necessary. This finding suggests a better understanding of social cost benefit analysis and the approach to monetise non-market benefits is needed.

Overall this literature suggests the non-market economics and the approaches to valuing benefits such as improved health outcomes and low environmental impacts, are not fully utilised in construction and housing research. This represent a significant lost opportunity.

5.5. Passive houses: costs, benefits and methods

The references reviewed on passive houses covered both new builds and retrofitting existing conventional houses to passive house standards. The primary focus of the passive house literature was on energy savings, or avoided energy consumption, and the cost of a passive house (PH) compared to a conventional house (CH). Some literature went beyond energy savings and estimated the environmental benefits of energy savings due to reduced emissions from decrease demand of energy generation.

Future energy prices are the main source of uncertainty in the literature on passive housing, which is consistent with the overall literature on housing energy savings regardless of the housing standard.

The passive house cost disadvantage

The literature frequently recognised that building a PH standard imposes additional construction costs on the home builder compared to a CH standard. This cost is labelled the cost disadvantage in some literature such as Galvin (2014). The cost disadvantage of PHs has been estimated to range from 0 to 17% in European countries, with a mean of 8% (Schnieders and Hermelink, 2006). The cost disadvantage appears to vary by country in Europe. For example, Audenaert, De Cleyn, and Vankerckhove (2008) report a cost disadvantage of 16% in Belgium.

Audenaert et al. (2008) identified seven categories for extra costs for PHs compared to low energy or standard houses. The categories include the following:

- heating
- venting
- insulation
- air tightness
- groundwork
- floor surface differentiation
- other additional costs.

PHs have a thicker wall design than low-energy houses. The main source of other extra costs was related to small differences in building method. Insulation and ventilation made up 64% and 27% respectively, of the total extra costs.

Ade (2018) estimated the additional cost of a passive house (Homestar-10 rating) to be NZ$53,630.

The benefits of passive houses

Energy savings are the primary aim and benefits of PH design. Truong et al. (2017) found that a house constructed to a PH standard used 64% less energy than a comparable conventional house, while maintaining thermal comfort with minimum heating when outdoor temperatures varied from -2 degrees Celsius and 37 degrees Celsius.

In the Belgium cases studied by Audenaert et al. (2008), the low energy house begins to have a net positive impact on the household budget, due to energy savings, within 2 years. Whereas the PH takes an additional 15 years or more to make a net positive impact on a household’s budget. The results for PH were quite sensitive to energy price forecasts.

Net-zero Houses

Net-zero houses are technically feasible, but the pay-back period appears to be quite long. In a case study of a net-zero house in the relative warm climate of Florida USA, Kadam and Kadam (2001) estimated the payback period to be more than 60 years. Kadam and Kadam concluded that prototype was not economically viable due to the long payback period. A first home buyer who was over 20-years-old might not realise the benefits in their lifetime with such a payback period. Table 7 shows the costs, benefits and payback periods associated with each element of net-zero houses. The benefits are estimated in energy consumption savings and monetised in terms of energy cost savings. Some of the components have payback periods that exceed 100 years. For example, the roof tiles, the photo-voltaic system and the exterior wall insulation. Such payback periods would influence the uptake of these component options.

Table 7 The costs and benefits of a net-zero house

US dollars

Component	Costs	Energy saving	Savings	Payback
	$	kwh/yr	$/yr	Years
Advanced Windows	$4,266	1610	112.7	38
White Tile Roof	$10,829	1342	93.94	115
Wider Overhang $	$1,882	537	37.59	50
High Performance AC	$1,263	2376	166.32	8
Interior Duct System	$950	1150	80.5	12
Exterior Wall Insulation	$11,500	307	21.49	535
Solar Water Heater	$2,989	2097	146.79	20
High Efficiency Lighting	$525	1479	103.53	5
Refrigerator	$298	388	27.16	11
Utility Integrated PV System	$40,000	5600	392	102
Total	**$74,502**	**16886**	**1182.02**	**63**

Source: Kadam and Kadam (2001)

5.6. Methods of estimating the payback period of passive houses

The payback period for a PH depends on a range of factors including:

- cost disadvantage
- energy prices
- cost of capital (fixed or variable mortgage rates)
- construction costs in general.

Galvin (2014) provided a formula for calculating the number of years until the additional initial capital cost of a PH breaks even. The formula allows the user to adjust the input assumptions and understand how they affect the payback period.

$$T_N = \frac{ln[1 + B_C + C_B/(100 \times D_E - P_E) \times (A - 1)]}{ln(A)}$$

Where

$$A = \frac{1 + F}{1 + R}$$

T_N is the number of years to pay back the additional costs of PH construction through energy savings

B_C is the cost of building a CH

C_B is the additional cost of a PH compared to a CH in percentage terms

D_E is the difference CH heating demand compared to a PH

P_E is the price of energy

A is the annuity factor for the comparing energy price inflation to the cost of capital

F is the expected energy price inflation rate

R is the cost of capital or discount rate.

5.7. What about concrete and waste?

Reduced energy consumption is a major theme of the literature reviewed and for good reason. The energy consumption profile associated with a design standard has a big impact on the life-cycle impacts linked to the house. But the construction materials and waste products associated with the projects are also contributing factors to the social, environmental and economic impacts of a house.

The literature review revealed a limited set of findings on the costs and benefits of construction materials such as concrete and waste products. In New Zealand, construction and demolition waste is over a quarter of total waste generated, with concrete 7% of that total (Chishom 2012). Waste minimisation polices in other countries have been successful in reducing the waste from construction and demolition where there are low cost alternatives including recycling and/or clean-fill (Chisholm 2012).

There are a wide range of social, economic and environmental costs associated with construction waste including the following:

- Environmental costs from waste disposal include:
  - limited reuse of landfill sites due to potential health hazards
  - energy required in transportation
  - pollution to land, air and water from heavy metals and toxic chemicals
  - greenhouse gas emissions
  - unsustainable depletion of resources.
- Economic costs from waste disposal include:

- cost of operating and maintaining landfill sites
    - cost of transporting waste to landfills
    - loss of financial benefit from using recycled or salvaged materials.
- Social costs from waste disposal include:
    - noise, dust and traffic pollution to the community
    - effects of hazardous or nuisance waste to workers on a building site and to the community (BRANZ 2020).

Using waste and input into concrete production is an option to improve the construction industries' impact on the environment. A cost-benefit analysis of using concrete with waste ceramic tiles and fly ash as partial replacements to coarse aggregates and cement, found that the optimal mix could increase the strength by 27.7% and reduce the cost by 12.5%, compared to standard concrete (Gallardo and Elevado 2017).

Thinkstep's (2019) report for the Green Building Council estimated the embodied greenhouse gases (GHGs) in concrete represented 50% of the carbon footprint of residential and non-residential building in New Zealand. They subsequently estimated that switching to low carbon concrete that uses fly ash could reduce the emissions associated with residential construction by:

- 21–24% per m^3 in the short term using a 50/50 combination of local and imported volcanic ash as a substitute
- 6–7% per m^3 of concrete in the long term
- an overall potential: 28–32% per m3 of concrete.

5.8. Retrofitting: costs, benefits and assessment

Several countries have policies to retrofit with better insulation, improved glazing and more efficient heating systems. Kerr, Gouldson, & Barrett (2017) investigated the policy rationale for retrofit policies in New Zealand, Ireland, Germany and the UK. They found that New Zealand's retrofit policy was an outlier because New Zealand's policy was focused primarily on health outcomes, whereas the other countries were focused on energy and environmental outcomes. They note the one explanation for this was the dominance of renewable energy generation in New Zealand. Interviewees from New Zealand did not see the link between housing and carbon emissions from energy consumption as important.

Coyle (2015) shows that a 'deep retrofit' of PH standards to existing conventional houses in Ireland can have a payback period of 28 years based on energy savings alone. If the discount rate is zero, then the simple payback is 18 years.

5.9. Raising the bar

Jacobsen and Kotchen (2011) assessed the response to a change in the building code in Florida in 2002. The used a difference-in-difference approach to test for a statistically significant change in energy consumption and associated emissions following the introduction of stricter energy-efficiency standards in the local building code.

The evaluation found the change in the building code was effective in reducing energy consumption and emissions (CO_2 and SO_2). The payback period was estimated to range from 3.5 to 6.4 years.

Jacobsen and Kotchen commented that the scale of the results may not be able to be generalised due to regional variations in building codes and consumption. But they concluded that the method could be used elsewhere, if sufficient data was available.

5.10. The effect of discount rates

Discount rates are known to have a material effect on long-term benefits. This a particularly important issue when considering intergenerational environmental issues such as climate change (Stern, 2007 and Weitzman, 2007). Discount rates also affect the appraisal of long-lived infrastructure such as roads. The sustainability of houses is both an intergenerational environmental issue and a long-lived infrastructure.

Morrissey et al. (2013) focused on the impact of the choice of discount rate for the assessment of the costs and benefits of investment in residential construction over the life-cycle of houses in Australia. They show that a low discount rate (3.5%) is aligned with sustainability principals in the context of housing policy. They find that a lower discount rate would prioritise projects with environmental benefits, such as low energy consumption.

At the time of writing this the Treasury recommend discount rate for housing (referred to as accommodation buildings) is 4.0%, which is two-thirds of the recommended discount rate for infrastructure (Treasury 2018). Such a low discount rate would allow the long-term benefits to have a greater effect than they might using a discount rate based on a commercial rate of return.

6. Overall findings

Our overall conclusion from examining the literature was that the costs and benefits of building beyond the minimum have only been sporadically explored in New Zealand, and overseas.

The economic analysis could be more complete

Much of the work is focused on the costs and benefits of a change in energy consumption over the life of the house. The interest in energy savings was commonly motivated by two outcomes.

The first is climate change and environmental impacts, which is unsurprising given the discussion of emissions' policy over years. However, we were surprised that many of the studies that quantified the reduction in emissions did not go to the next step and estimate the social benefits of the reduction in emissions, even though the methods for estimating the value of a quantum of emissions is well established and easily accessible. Such studies did not provide a complete economic analysis of the total costs and benefits from building beyond the minimum. In our assessment the failure to applied established economic approaches to valuing the benefits of improved environmental outcomes is due to:

- Inadequate knowledge of economics in building and housing research.
- The failure of economics as a profession to engage with building and housing researchers to ensure knowledge sharing.
- The need for more multi-disciplinary research teams.

The second outcome that has motivated an interest in energy savings is an interest in fuel poverty and more generally the affordability of the ongoing costs of housing and heating. Fuel poverty appears more frequently in the international literature than it does in the New Zealand-based literature. In New Zealand, the literature is more frequently focused on health outcomes associated with heating than heating costs.

More complete economic analysis would strengthen the case for exceeding the minimum

We also found that the health benefits associated with building beyond the minimum were sometimes quantified, but not always valued, so as with the unmonetised emission reductions, the health benefits were fully not considered – including in the public health literature. An opportunity for a more complete application of economics to be included clearly exists in building and housing research.

There's more to exceeding the minimum than energy savings, especially in New Zealand

Energy consumption is an important issue and relevant to the affordability of housing for occupants, but in the context of New Zealand's use of renewable energy, the use of energy is of less interest than the embodied emissions in construction materials (including the embodied emissions associated from construction waste).

It's hard to make generalisations from the literature

Table 8 provides a stylised summary of the costs and benefits from the New Zealand-based literature on building beyond the minimum. Overall, we struggled to be confident about the comparability of studies. The method of estimating the costs and benefits were generally consistent with cost-benefit analysis, but the underlying specifications of the design and fittings were difficult to compare.

Further research is needed to improve the assessment of the costs and benefits related to residential construction

This literature review found some gaps in the research and some areas for where the assessment of costs and benefits could be more complete and more consistent. The next steps for making improvements in assessment of the cost and benefits of building beyond the minimum are outlined below.

A set of guidelines could be developed to support the assessment of the costs and benefits of building beyond the minimum. The guidance could be similar to Treasury's guidelines for social cost benefit analysis, or more prescriptive like NZTA's Economic Evaluation Manual.

These guidelines should take a societal perspective and include the suggested methods, explanations and key references for the estimate of non-market impacts.

There also appears to be a gap in investigating the willingness-to-pay a premium for buildings that are built to a higher standard in New Zealand. Such studies would add value to the discussion and decision-making associated with the choice to build beyond the minimum in New Zealand. There is also a gap in understanding the economic flow-on effects if building beyond the minimum became more common.

The assessment of the costs and benefits should be multi-disciplinary, involving economists to ensure the development of high quality and comprehensive evaluation.

Table 8 Summary of the additional costs and benefits

Compared to a house constructed to minimum standard. Green = frequently, orange = sometimes, Red = rarely

Element	Costs	Benefits	Frequency of discussion	Frequency of quantification	Frequency of monetisation	Non-market impact considered	Payback period
House design							
Homestar 6, 80% energy reduction (house area 180m^2)	\$3,000-\$6,000	\$360-\$500 p.a.					6 years
Homestar 7 80% reduction + heat pumps for space and water heating	\$4,000+	\$1,600-\$1,900 p.a.					7 years
Homestar-9/10 (passive)	+\$53,630	\$2,806 p.a.					20 years
Net zero	Considered technically feasible but the payback period is unpractical						60 years
Design elements							
Energy savings							4-15 years
Construction waste	\$209 per tonne	\$209 per tonne					1 year
Waste leachate	NA	\$1-\$19 per tonne of waste					NA
Water use saving	\$50-\$300 per house	\$300 p.a.					1-6 years
Efficient lighting	+300%	80% reduction					>1 year
Retrofitted double-glazing							14-22 years
Hot water heat pump	\$2,100-\$3,300	\$580-\$1,240					2-6
Non-market benefits							
Carbon savings		\$20-\$250+ per tonne				NA	
Health benefits						NA	
Noise reduction						NA	

Source: NZIER

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