NEW ZEALAND INSTITUTE OF ECONOMIC RESEARCH

Healthy Homes Standards

Cost Benefit Analysis of proposed standards on rental home insulation, heating, ventilation, draught stopping, moisture ingress and drainage

NZIER report to Ministry of Business, Innovation and Employment

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Key points

We present a cost benefit analysis of options for five proposed Healthy Housing Standards for insulation, heating, draught stopping, ventilation, moisture ingress and drainage. These standards address deficiencies identified in substantial proportions of the current rental stock of 574,000 dwellings.

New Zealand's rental housing tends to be older, smaller and less well equipped with insulation and heating appliance than owner-occupied homes. A wide range of benefits from warmer, drier homes has been identified in international and New Zealand studies, although this provides little precise guidance of the rate at which they change with housing condition.

The analysis identifies and quantifies benefits for tenants' reductions in energy costs, tenants' reductions in health costs, reductions in greenhouse gas emissions and producer surplus for new appliances or energy used under the standards.

Costs identified and quantified are landlord's capital and operating costs in complying, and tenants' costs associated with increased energy use (and associated emissions costs). The analysis also considers government administration costs in overseeing implementation of the standards but does not attribute these to individual standards and options.

Costs are more concrete than benefits…

Costs are relatively easy to quantify, but there is limited information on which to assess the effect of interior moisture in properties or the benefits of ventilation and controlling moisture ingress. In the absence of useable estimates of larger quantitative benefits of moisture control, these standards do not show a positive net benefit but if there are unquantified benefits greater than the calculated negative net benefit, these standards would yield a positive net present value.

Other potential benefits that have not been quantified or included in the analysis include cleaning costs for moisture damage, property maintenance costs, subjective well-being and improvements in educational attainment, all of which have been associated with improvements in housing condition. There is a lack of clear evidence on how much they vary with changes in housing condition, so they cannot be quantified or valued in this analysis and their significance is unknown.

The benefit cost ratios in this analysis are incomplete to the extent they exclude significant items, but they are still informative of how large those items would need to be to provide an economic justification for proceeding with an option.

Coverage of homes is critical to the results

One of the drivers of the analysis is the number of houses that might need to be retrofitted to meet the proposed standards. Some standards would affect a large number of houses and result in substantial aggregate costs. Costs will accumulate for those individual houses that need to be retrofitted for multiple standards.

Table 1 summarises the houses affected and net benefits in total for the affected houses, and on average per house affected and the average across all rentals. The ventilation options of bathroom and kitchen fans can be added together, but the insulation options are mutually exclusive, as are the moisture ingress options.

Quantified analysis has mixed results

Our analysis suggests proposed insulation options yield net benefits, but the benefit cost ratio is slightly lower for Option 3 that updates all insulation below the current 2008 benchmark than for Option 2 that updates only that below the 2001 benchmark. The benefits are sufficiently high that both Option 2 and Option 3 of the insulation standard are likely to be net beneficial across the range of rental homes expected to need new insulation and, if these exceed 62,736 houses, cover expected government costs.

The heating standards are also likely to yield net benefits if applied to living rooms only but become slightly less net beneficial if extended to cover bedrooms. The heating standards results are also stronger for the 18°C temperature level than the 20°C level. Because the living rooms of houses cover larger areas they require higher capacity fixed heaters to effectively heat them and landlords need to be involved in their installation. For heating bedroom areas portable electric heaters, which tenants can buy and operate for themselves, are often sufficient although less energy efficient. Heating benefits rise with the active participation by tenants and the proportion who use heating to pursue healthy temperatures, so this standard could also cover all government costs in overseeing the standards.

Draught stopping is another standard that is likely to yield net benefits although the evidence for specific temperature gain is rather thin. It is a low cost, passive measure that needs no involvement by the tenants (e.g. in operating fans and heaters), but will require periodic checks and repair (by the landlord).

All ventilation options produce net costs in the quantified analysis as there is no reliable basis for translating moisture into quantifiable sources of avoidable costs in the home. Such costs include those due to health impairment, increased heating costs, to additional cleaning or repair of damaged fittings and contents, and more intangible effects on subjective well-being.

Mechanical fans for bathrooms and kitchens are costlier to install and need both the active involvement of tenants to use them, and their willingness to incur energy costs in using them. Kitchen fans result in a larger net cost than bathroom fans, reflecting greater expected energy use in their operation.

Improving subfloor ventilation in houses with subfloors may require some houses to fit a large number of new vents, but installing a moisture barrier as an effective alternative would be a more feasible choice in many cases to comply with the moisture ingress standard Option 2. This option yields a net cost as there is no reliably generalisable way to estimate how moisture reduction is transmitted to reductions in costs to health and damage to property.

Variations and distributional matters…

Variations in discount rate and specific input assumptions do not significantly change the pattern of results in the absence of firmer information on how the measures would change the amount of moisture in and under houses and its action in creating quantifiable costs for occupants and building owners. Although this analysis does not quantify all effects, it does indicate how standards applied to sizeable proportions of the rental housing stock can accumulate to large costs across the rental sector.

Most of the quantifiable benefits for energy savings and health improvements accrue to the tenants. Depending on the state of the housing markets they operate in, landlords may be able to pass on their compliance costs in rents, particularly in large cities and centres experiencing growth in demand, which is greater than the supply of rental properties. Landlords facing the cumulative cost of complying with several standards may face costs up to around $10,000 for an average sized New Zealand house but individual standards are less costly.

Introducing standards would increase demand for suppliers of materials needed to comply, and for building and electrical workers. In some areas introducing standards may increase demand for skills in the short term at a time when house building is increasing and push up prices. This may create employment and enable skills to be developed, but would be short-lived and last only as long as the hump of retrofits take to be completed.

Implications for policy

Although the quantification is incomplete, the following conclusions can be drawn based on available information and the quantified analysis.

The proposed insulation standard is likely to yield net benefits. Option 2, which updates insulation only in houses meeting less than 2001 requirements and applies to fewer houses, is slightly more net beneficial than Option 3 on a cost per house basis. But Option 3 affects more houses and therefore results in greater total net benefits than Option 2.

The proposed heating options are also likely to produce net benefits when applied to heating living rooms, but extending them to bedrooms reduces the net benefits.

The proposed draught stopping standard is likely to yield net benefits although the evidence is thin. It is a low-cost measure and also passive, requiring no involvement by the tenant.

The proposed ventilation options produce net costs in the analysis, because there is no reliable basis for translating moisture into quantifiable sources of costs in the home or the benefits of these measures. Of the options considered, fitting window security stays is low cost and does not involve tenants in spending money on power, and might facilitate improved ventilation. All ventilation measures require tenant involvement.

The proposed moisture ingress options also produce net costs in the analysis because of no reliable basis for translating sub-floor moisture into quantifiable costs in the home.

There are inter-linkages between proposed standards, particularly between insulation, heating and draught stopping which are complementary and also between moisture ingress and ventilation.

Table 1 Summary of results

Present values discounted over 15 years at 4%

Measure	Number of houses affected	Aggregate net benefits PV$'000	Net benefit per house affected PV$	Net benefit per total rentals PV$	Cost per house affected PV$	Reliability of data: Low/Medium/High
Insulation Option[1]2: Upgrade insulation less than 2001 requirement to meet 2008 requirement – minimum houses affected	10,000	7,240	724	13	1,340	Medium-High
Insulation Option 2: Upgrade insulation less than 2001 requirement to meet 2008 requirement – maximum houses affected	70,000	50,677	724	88	1,340	Medium-High
Insulation Option 3 Upgrade insulation less than 2008 requirement to meet 2008 requirement – minimum houses affected	80,000	54,064	677	94	1,340	Medium-High
Insulation Option 3: Upgrade insulation less than 2008 requirement to meet 2008 requirement – maximum houses affected	190,000	130,029	684	227	1,340	Medium-High
Heating Option[2] 2: capacity to achieve 18 ºC in Living rooms only	179,071	168,507	941	294	2,800	Medium-High
Heating Option 2: capacity to achieve 18 ºC in Living rooms and Bedrooms	250,444	156,849	876	273	2,889	Medium-High
Heating Option 3: capacity to achieving 20 ºC in Living rooms only	285,219	169,513	594	295	2,087[3]	Medium-High
Heating Option 3: capacity to achieve 20 ºC in Living rooms and Bedrooms	411,170	163,333	573	285	2,195	Medium-High
Draught stopping[4]: stop gaps or holes of 3mm or greater	172,200	94,787	548	164	232	Medium
Ventilation – Install mechanical extraction fans in bathrooms	252,560	-54,550	-216	-95	216	Low-Medium
Ventilation – Install mechanical extraction fans in kitchen	212,380	-68,313	-322	-119	322	Low-Medium
Moisture ingress[5] Option 2 – Install subfloor vents to meet specified standard	47,986	-35,057	-731	-66	731	Low-Medium
Moisture ingress Option 2 – Install moisture barrier to meet specified standard	143,959	-76,762	-533	-52	533	Low-Medium
Moisture ingress Option 2 – combined installation of moisture barrier and vents to meet specified standard	191,946	-111,820	-583	-195	583	Low-Medium

Source: NZIER

1 For insulation standard options, see report pages 15-17.
2 For heating standard options, see report pages 18-24.
3 NB: Heating Option 3 has lower cost per house affected than Option 2 because affected houses are those that raise their temperature (including using existing heating), not the number having new heaters installed.
4 For draught stopping standard, see report pages 34-36.
5 For moisture ingress standard options, see report pages 29-34.

Contents

Appendices

Tables

1. Introduction

We have prepared a report on the results of our cost benefit analysis (CBA) of proposed healthy home standards for rental properties in New Zealand. The analysis aims to examine the type and extent of standards that are likely to produce the greatest net benefits over time.

1.1. Problem definition

Rental residential properties in New Zealand tend to be older and smaller than owner occupied houses, and likely to be currently fitted with less effective levels of insulation or less efficient heating appliances (see Appendix A). Not only are they more difficult to heat, they may also be more draughty, damper and prone to growth of moulds whose spores are allergens that can aggravate people's existing respiratory conditions. The condition of houses can contribute to a range of society-wide costs, such as medical costs, productivity losses from days off work or school, and individual costs such as damage to the house fabric and contents which could be reduced with cost effective retrofitting of improvements to the houses.

There is a well-documented market failure in energy efficiency provision in rental properties caused by split incentives between landlord and tenants: for example, tenants have little incentive to invest in improvements that need to be fixed to the building (such as insulation, fixed heating and draught stopping), and landlords also have little incentive to invest in these changes that are of most apparent benefit to tenants. The result is rental properties with limited insulation, costly to run heating appliances and excessive dampness, which lack the ability to heat to healthy temperatures. There can be a level of information failure in the rental market as well as market failure, as landlords have little ability to distinguish their properties' heating characteristics from other market offerings, and prospective tenants may find it difficult to discern the heating characteristics of properties, and may not recognise deficiencies until having moved in and settled on a rental agreement.

Similar issues can arise with dampness and moisture ingress into houses, which may be more effectively tackled by modifications in the house structure than by portable appliances.

This result can be sub-optimal from a national perspective if there are significant externalities not accounted for in the decisions made by landlords and tenants, such as impacts on public health services or on the wider environment from insufficiently warm and dry houses. Setting basic requirements for insulation, heating, ventilation and moisture removal could address those market failures, if they can be implemented at reasonable cost. This report examines whether introducing standards would create national benefits in excess of their costs of implementation.

1.2. Requirements to be examined

Insulation

Proposed requirements with respect to insulation from 1 July 2019 include the following:

- Option 1: continue the status quo, in which any house with less ceiling and underfloor insulation than the 1978 benchmark is required to update to the 2008 benchmark
- Option 2: would require all rental properties with ceiling and underfloor insulation below the 2001 benchmark to upgrade to the 2008 benchmark, but require no change for those at or above the 2001 benchmark
- Option 3: would require all rental properties with ceiling and underfloor insulation below the 2008 benchmark to retrofit up to the 2008 benchmark.

Heating

The heating standard is to consider the options of:

- Continuing with the status quo in which landlords are required to provide some form of heating in the living room, but which does not specify the type of heating (which may be an open fire or unflued gas heater) or the temperature to which it can heat the room
- Option 2: Providing heating capacity capable of reaching internal temperatures of at least 18^{o}C, consistent with the World Health Organization (WHO) general guidance on healthy indoor temperatures
- Option 3: Providing heating capacity capable of reaching internal temperatures of at least 20^{o}C, consistent with the WHO guidance on healthy indoor temperatures for at risk groups, including the very young and the elderly
- Variants of these options include:
  - achieving the proposed level(s) of heating in living rooms only or in living rooms and bedrooms, or extending it to the entire house
  - excluding certain heating devices from compliance with the heating standard, in particular those which emit toxic fumes and moisture into the house or which exhibit poor energy efficiency and economy for tenants.

Ventilation

A ventilation standard is to consider the options of:

- Continuing with the status quo in which landlords are only required to ensure every habitable room has an opening external window:
  - a sub-option considering the costs and benefits of requiring security stays to be fitted to a window in each habitable room to encourage their use
- Option 2: Requiring landlords to fit mechanical extraction fans vented to the outside in bathrooms and kitchens.

Moisture Ingress

A proposed standard on moisture ingress would examine:

- Continuing with the status quo in which landlords are required to maintain the premises in a reasonable state of repair including providing efficient drainage and stormwater removal from the property

- Option 2: Additional to the status quo, landlords are required to ensure adequate ventilation into the under-floor space, and/or installation of ground moisture barrier under the house
- Option 3: Require landlords to provide all the requirements of Option 2 above and, in addition, to provide ground moisture barrier if they have not already done so.

Draught stopping

A proposed standard on draught stopping would consider options of:

- Continuing with the status quo in which landlords are required to maintain their properties in a good state of repair
- Option 2: require landlords to stop any unnecessary gaps or holes in windows, doors, walls, ceilings, floors and access hatches that cause a noticeable draught and colder home.

How standards work

Applying standards requires landlords to change the state of housing infrastructure to make it better able to achieve healthy indoor temperatures and moisture conditions which creates an opportunity for tenants to achieve these temperatures (at lower costs than they could without the standards). Some of the proposed standards are “passive” in that they provide benefits once met without any further human action; e.g. insulation will reduce the heating needed to reach and maintain a given temperature, and is expected to continue working for the life of the insulation with minimal maintenance. Others are “active” in that they depend on behavioural changes by occupants to realise their benefits (e.g. heaters, ventilation). It is difficult to regulate for behavioural change, so there is greater doubt over the degree to which benefits of active interventions will be realised.

One way of assessing the effect of standards on healthy housing is to consider the ease with which households can achieve the WHO recommended temperatures of 18°C for general occupants and 20°C for vulnerable groups such as the very young and the elderly. The capability of rental properties to reach such temperatures depends on a number of characteristics of the building, including its size, level of insulation, heating, air infiltration through gaps in the building fabric, solar gain during the day, internal moisture levels and external climatic zone.

While plug in electric heaters are cheap to buy, they can be expensive to run and are inadequate to heat rooms larger than about 20 square metres. Using multiple electric heaters in one room is not feasible due to the load they put on the electrical circuits, as two may exceed the capacity (amperage rating) of the relevant fuse and pose an overloading danger. Their cords are also a trip hazard. Fixed heating appliances like heat pumps can deliver higher energy output, have a longer lifetime, and are more economical to run.

Approach to modelling

At the core of this cost benefit analysis is a model of residential housing energy demand use for space heating. This draws on EECA’s Net Benefit Model and its AccuRate tool for assessing heating capacity in homes of varying characteristics. This model covers 16 regions merged into the 3 climate zones specified in the proposed Healthy Homes Standards. The model includes variables for heating appliances and fuel types, level of insulation in a house, heating regime (evenings only, all day, 24-hour) and area of house heated (living rooms only or living rooms and bedrooms). It covers all residential properties but for this analysis focuses on rental properties only, reflecting the characteristics of such properties inferred from the Census and the House Condition Survey and similar sources.

The model is used to first establish the current residential heating energy use, based on energy shares of the total residential energy use from MBIE's energy statistics. That forms the baseline against which to compare the changes brought about by the introduction of the various standards. The principal variables that can be addressed through the model are changes to the insulation standard and changes to the mix of heating appliances.

Source of benefits from insulation and heating standards

When insulation is installed, occupants can respond in three ways:

- They may maintain their current heating level, the effect of which is to raise indoor temperatures and provide a range of benefits from a healthier indoor environment (discussed in Section 1.3 below)
- They may maintain their current temperatures by reducing heating use, realising energy savings and reductions in environmental impacts from lower energy use or generation
- Combine both approaches with some energy reduction but applying enough heat to raise temperature levels as well.

Insulation provides a passive benefit, as once installed the existing temperature in a house can be achieved with lower input of heating energy. But insulation is often accompanied by behaviour change as occupants "take back" some of the energy saving by achieving higher temperatures – and in so doing enabling some additional benefits in reduced adverse effects on occupant health, comfort and subjective well-being.

As it is difficult to predict such behavioural change we model instead the effect of reaching the WHO recommended temperatures of 18°C and 20°C. This isn't to predict that these temperatures will be reached, but rather to show that ***if*** these temperatures were reached, what would be the balance of costs and benefits? If the benefits exceed the costs the standard is worthwhile. Such analysis can also show how many tenants would need to reach the target temperatures to achieve the break-even point where benefits just equal costs across the country at large.

Modelling other standards

Our energy model can provide present value costs and benefits of the insulation and heating standards. Other standards (draught stopping, ventilation and moisture ingress) are more problematic to incorporate into the model, so are estimated outside it in a discounted cash flow framework to provide costs and benefit estimates for each one. The present values of all the standards are then combined in an overview analysis.

The energy model uses Statistics New Zealand's projections to predict population and housing growth across 16 regions which are then combined into three climate zones, to account for different regional specific fuels, different energy demands in reaching target temperatures and to calibrate the model to national energy use. The modelling of other standards does not account for regional variations.

The analysis covers a 15-year period and uses a discount rate of 4% (in line with Warm Up New Zealand Heat Smart (WUNZ)) and a variant of 6% (Treasury's current standard for public sector analysis). Where retrofits are required, they are assumed to be evenly spread over five years (2019-2024) to avoid causing demand spikes in the supply industries. The Healthy Housing Standards discussion document does not specify this timing, but some assumption is needed for modelling. If standards are implemented over a shorter period, costs and benefits will be higher in the initial years, but this would also have a greater impact on supply industries in meeting new demands created by the standards.

1.2.1. The counter-factual

The counter-factual situation without standards applied is generally a continuation of the status quo, with under-insulated, under-heated and under-ventilated houses which are cold and often damp.

This analysis estimates what change would be brought about by applying each of the standards. One change is the costs incurred in bringing rental properties into compliance with the standards. Another is the change in benefits that can be brought about by the standards.

In such analysis it is not necessary to calculate costs and benefits of the counter-factual, only of the changes that implementation of the standards is likely to bring. The standards are assessed by comparing the additional costs incurred in complying with the standard, against the additional benefits obtained in terms of energy savings, health costs avoided, emission reductions and other potential benefits.

1.3. Benefits of intervention

There is a long history of cost benefit analyses of proposals to improve the residential housing stock. These seek to compare the costs of proposed improvements (such as upgrades to the building codes, or specific regulations on building design and uses) against estimated benefits over the 'counter-factual' that would happen in the absence of the proposed changes. Such benefits include:

- Reductions in the cost of heating (or cooling) dwellings to healthy temperature (as evident in energy efficiency improvements), including:
  - savings in the energy costs of reaching specific temperatures with existing heating
  - savings in indoor air quality benefits from removing non-compliant heaters (open fires and unflued gas) from the existing appliance mix
- Improvements in health outcomes for occupants of dwellings, arising from:
  - reduced incidence of hospitalisation and medical treatments:
    - following the lead of WUNZ study (see appendix)
  - reduced days off work (and school) and associated loss of productivity (or educational achievement):

        - following the lead of WUNZ study (see appendix)
        - work loss valued that can be valued at the opportunity cost of time (borne by businesses/employers in a regular wage setting, but by employees in a casual work setting), but here using an updated value from the WUNZ study; school achievement assessed qualitatively[6]
    - reduction in mental health problems:
        - no sound basis for quantification[7]
    - reduced incidence of premature death due to health conditions:
        - modifying the lead of WUNZ study (see appendix)
    - improvements in subjective well-being and comfort:
        - no sound basis for quantification[8]
- Reductions in costs of moisture on indoor air quality, including increased cleaning of clothing for occupants and of soft fabric furnishings and fittings for property owners:
    - dampness is an acknowledged issue for New Zealand householders as evidenced by the sale of dehumidifiers and products like Damp-rid, but there is no firm basis on which to estimate this cost or changes brought about by healthy home measures
- Improvements in environmental effects external to the occupants (e.g. greenhouse gas emissions or discharges into air that reduce local air quality):
    - changes in greenhouse gas emissions from marginal changes in energy use (assuming thermal generation at the margin):
        - following the lead of WUNZ study (see appendix to this memo).
- Increased profitability for industry supplying new equipment, known as the "producer surplus",[9] which represents the margin or profit on additional sales of equipment and appliances and is quantified from the operating surplus of respective industries in the national input output tables.

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6 The Ministry of Education's NZ Schools Attendance Survey 2017 shows that NCEA level 1 attainment has a strong relationship with attendance in Year 11, and that the probability of achieving NCEA declines as individual non-attendance increases because of sickness or other matters. It does not however attribute this to causes of sickness that could be linked to housing condition. While it has been suggested absences could be valued at a dollar cost per pupil day of attendance, that would be an average not a marginal value and meaningless in this context, as most school costs are fixed and do not vary with attendances or absences and underutilisation of the provided capacity.

7 There is literature linking reduction in mental anxiety and diagnosed mental health conditions with energy efficiency measures, as reviewed in Howden-Chapman P & Chapman R (2009), Note on Mental Health Benefits of Home Insulation Retrofits: Evidence for Cost-Benefit Study (Briefing paper for EECA). They suggest an average benefit per dwelling insulated of $200, but this is based on an incidence of mental illness in the New Zealand population of 28% having a diagnosable mental disorder in the past 6 months, which is high relative to general statistics of 16% of adults being diagnosed with a mental disorder in their lifetimes and 6% of adults experiencing psychological distress in the previous month (Mental Health Foundation: Quick Stats and Facts 2014). This value provides a weak basis for inclusion in this analysis.

8 In principle it is possible to infer values for comfort and subjective well-being from revealed preferences in observed behaviour or from stated preferences from survey-based studies. One such study of Pasifika tenants in New Zealand found willingness to pay highest for HRV systems that have poor performance in heating, which suggests a distorted linkage to comfort and may reflect the influence of advertising on consumer preferences (Gibson J, Scarpa R & Rohorua H (2017) Estimating the willingness to pay for warmer and drier homes, *New Zealand Economic Papers*, 51:1, 15-27). The values obtained are more for the products than the comfort obtained and are unsuitable for inclusion in this analysis.

9 We include producer surplus to be consistent with previous analyses in this area, including the Warm Up New Zealand evaluation and Sapere's (2014) Cost benefit analysis for a minimum standard for rental housing. While some argue that in the long run there is no producer surplus, in the medium term timeframe for this analysis there is scope for new demand to improve capacity utilisation and raise supplier profits above normal.

There may be other benefits, such as standards reducing uncertainty about what is required for compliance, but these are not quantifiable in this analysis.

1.4. Costs of intervention

Costs of implementing standards fall largely on landlords in the first instance, although some of that they can expect to recover from tenants through rents and reduced maintenance over the long term. There will also be some costs for government agencies in publicising and enforcing the standards.

In an economic cost benefit analysis, the focus is on the real cost of resources used up in implementing the standard, not the financial cost of funding the measures. Resources used are valued at their opportunity cost in some other purpose.

For each standard, the costs are:

- Capital costs of appliances, fittings and installation (for landlords)
- Running and operating costs of new fittings (for tenants)
- Implementation, monitoring and enforcement (for government agencies)
- Costs for industry in gearing up for increased supply (for industry – but subsumed within the profitability benefit, which is increased revenue less costs).

1.5. Exclusions

We have excluded certain items from the analysis which are not informative on resource use efficiency, which is the focus of an economic cost benefit analysis.

Changes in rents are not included in a cost benefit analysis, as they are strictly a transfer payment between tenants and landlords: the tenant pays more to the landlord, who in doing so recovers some of the cost of their investment in the property. Predicting rent changes across the rental market is beyond the scope of the analysis, although commentary is provided on who is likely to pay for what.

Although new fittings and warmer housing in principle can improve property values, these are not included in the cost benefit analysis to avoid double counting.[10] This is because a purchaser considering two otherwise identical houses apart from their insulation and heating condition may not pay more for the warmer house than it would cost to upgrade the colder house to the same condition. The property value benefit of the improved insulation/heating is the capitalisation of the benefits it provides, which are mostly captured by the tenants as reduced energy cost or improved health and comfort. Hence there is a split incentive between the investor (landlord) and beneficiary (tenant). If there is any change in rent this is a transfer payment – tenant pays, landlord receives – of no consequence to the net gain in value to New Zealand.

[10] As explained on page 13 from Treasury's Guide to Social Cost Benefit Analysis (2015), "capital gains should generally be ignored as they either reflect a change in the market's discount rate or they represent the NPV of future increased earnings [or benefits], which will be recognised in the cost benefit analysis".

2. Settings and assumptions

2.1. Modelling the rental housing stock

Statistics New Zealand estimates there were 574,000 households in residential rental properties in New Zealand at the end of 2017. Housing some of these are an estimated 62,917 social housing units operated by HNZC (11%), 7,706 units provided by local councils (1.2%), and 12,651 units provided by Community Housing Organisations (2.2%).[11] Assuming there is one household per rental dwelling, this would mean that 86% of rental housing units are let by other providers, mostly private entities ranging from property companies to owners who own one or multiple properties for investment purposes.

There is no comprehensive inventory of rental residential properties and their characteristics in New Zealand. Hence we use a model based on EECA's Net Benefit Model and its AccuRate heating estimator and informed by BRANZ's House Condition Survey and Census data that distinguishes between rental and owner-occupied housing and heating characteristics. This model estimates total residential heating load from MBIE's energy statistics and distributes it across 16 regions according to an energy shares' model that reflects regional characteristics such as temperature zone and local energy characteristics (e.g. reticulated natural gas only in the North Island).

The model estimates the effects of changing insulation and heating characteristics on heating loads across a selection of housing types to represent national housing characteristics across the stock. It can estimate changes in energy use in meeting targeted temperatures, changes in greenhouse gas emissions and changes in residential health impacts in response to changes in indoor temperature.

A lack of robust data on Community Housing Organisation properties mean the specific characteristics of this segment of the rental market cannot be included in this analysis. Similarly, we do not distinguish the specific characteristics of properties run by HNZC or any other owner.

The model is not designed to predict impacts on particular property owners. HNZC, local councils, Community Housing Organisations and private landlords will need to make their own assessments of their property needs in meeting the new standards, and how to finance and schedule this in light of their own circumstances.

2.2. Guidance from the literature

This section outlines findings from international and New Zealand literature on the relationship between home temperature and moisture conditions and occupant health, as a basis for setting assumptions in modelling proposed standards. The WHO recognises that when indoor living area temperatures fall below 16^{o}C in winter months there is increased risk of exacerbating cardiac, circulatory and respiratory ailments.

11 Alan Johnson, Philippa Howden-Chapman and Shamubeel Eaqub (February 2018) Stocktake of New Zealand's Housing, independent report for Ministry of Business Innovation and Employment https://www.beehive.govt.nz/sites/default/files/2018-02/A%20Stocktake%20Of%20New%20Zealand's%20Housing.pdf

International literature

Cooler houses have higher relative humidity that increases the likelihood of dampness, condensation and moulds whose spores can aggravate allergies and respiratory conditions. The WHO recommends indoor winter-time temperatures of 18°C for general use and 20°C for vulnerable groups such as the elderly and the very young.[12]

The WHO's recommendations rest on international literature that a recent review undertaken by Public Health England found provided limited robust evidence on which to base the recommended target temperatures.[13] In another review of international literature only four of the forty-five studies examined collected sufficient information to conduct evaluations of economic costs and benefits, often lacking specific temperature changes and comparison with control groups.[14]

New Zealand housing, heating, insulation and health

In New Zealand, BRANZ's Housing Condition Surveys and its Household Energy End-use Project (HEEP) suggest that winter living room temperatures are generally below 18°C and bedroom temperatures are below 16°C. A government-sponsored residential insulation upgrade programme found upgraded houses had 0.6°C increase in the average winter temperature,[15] but indoor temperatures remained well below WHO guidelines. Upgrading insulation without addressing the adequacy of heating has limited effect on temperature, a finding that is reflected in international literature.[16]

When schemes have installed new heaters they are operated for longer and increase average winter-time living room and bedroom temperatures by 2.3°C and 1.3°C, respectively compared to houses with old heaters.[17] Replacing old heaters with clean heating devices raised average winter temperatures by 1.1°C in living rooms and 0.57°C in bedrooms, resulting in reduced symptoms of asthma in the children and 1.8 fewer days off school compared to other families without new heating.[18]

The Warm Up New Zealand (WUNZ) evaluation found installation of new insulation reduced hospitalisations for occupants, but the incremental gain from heating appliances was small after accounting for the gain provided by insulation. This evaluation provides a large observational study of changing the insulation and heating

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12 WHO, (1987), Health Impact of Low Indoor Temperatures: Report on a WHO meeting Copenhagen 11-14 November 1985. Copenhagen: WHO.

13 Public Health England (2014) Minimum home temperature thresholds for winter: a systematic literature review; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/468196/Min_temp_threshold_for_homes_in_winter.pdf

14 Fenwick E, MacDonald C and Thomson H (2013) Economic analysis of impact of housing improvement studies – a systematic review; J Epidemiol Community Health. 2013 Oct; 67(10): 835–845.

15 Lloyd CR, Callau MF, Bishop T & Smith IJ (2008) "The efficacy of an energy efficient upgrade program in New Zealand"; *Energy and Buildings* 40, 1228-1239.

16 Gustafsson S (2000) "Optimisation of insulation measures on existing buildings, *Energy and Buildings* 33 1459-1471.

17 Boulic,M, Fjallstrom P, Phipps R, Cunningham M, Cleland D, Howden-Chapman P, Chapman R & Viggers H (2007) "Cold homes in New Zealand – Low Heater Capacity or Low Heater Use? http://www.branz.co.nz/cms_show_download.php?id=fe9084ea793a665fc66be4d14907b2ccde10d4a3

18 Howden-Chapman P et al (2008) Effects of improved home heating on asthma in community dwelling children: randomised controlled trial; BMJ 2008;337:a1411

equipment of a cross section of houses, but does not assess the change in overall heating capacity of the houses, or in average or winter-time indoor temperatures.[19]

A subsequent assessment of WUNZ data found no statistically significant change in hospital events for the total rental population, but statistically fewer hospitalisations among children aged under 5 years. Across all housing (not just rentals) there was a significant benefit from reduced mortality for those aged 64 and over with a prior circulatory hospitalisation.[20]

The major health benefit from the WUNZ evaluation comes from reduced winter-time mortality, based on a value of $150,000 per life year gained by averting premature death. This value is derived by a method which differs from that recommended in recent OECD reviews of international practice,[21] which would suggest mortality benefits about 1/3 of those in the WUNZ analysis (see Annex B explanation and sources). However, for consistency we use the WUNZ study value updated by CPI to an average of $1,120 per household retrofitted with improved insulation and heating.

New Zealand mortality records over the period 1980-2001 show an excess of 1,600 deaths in winter time,[22] and increased risk of dying in winter for most New Zealanders, but more so among low-income people and those living in rented accommodation and those living in cities.[23]

Moisture and Ventilation

Even more so than with heating and insulation, the literature on residential ventilation, draught stopping and controlling moisture ingress is limited by small sample sizes and studies that do not provide information on relationships between house condition and beneficial outcomes suited to economic analysis. There is measurement of physical characteristics, such as how moisture accumulates under houses and the common sources of draughts in houses, but relatively less about the extent of problems across the housing stock and how to translate a source of moisture into a quantified economic value against which to measure the effectiveness of interventions.

There are limited studies of the effects of intervention, such as one that found five single bedroom flats in Wellington to be on average 1-1.36°C warmer after draught stopping.[24] Larger samples of a wider range of house types and wider range of external settings would be needed to place reliance on such results for evaluating future policies and standards.

Warmer, drier houses have the potential to reduce a range of adverse health effects as well as affecting energy efficiency and associated emissions from energy sources.

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19 Grimes A, Denne T, Howden-Chapman P, Arnold R, Telfar-Barnard L, Preval N & Young C (2012) *Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Programme;* Report for Ministry of Economic Development.

20 Telfar Barnard L & Preval N (2018) *Healthy Homes Guarantee Standard Cost Benefit Input: Warm Up New Zealand evaluation rental sector sub-analysis: differences in health events and costs by existing insulation status*; Housing and Health Research Programme, University of Otago Medical School, Wellington May 2018.

21 Navrud, S., Braathen, N. A., Biausque, V. (2011) Valuing mortality risk reductions from environmental, transport and health policies: Policy Implications. Paris: OECD.

22 Davie GS, Baker MG, Hales S and Carlin JB (2007) Trends and determinants of excess winter mortality in New Zealand: 1980-2000; *BMC Public Health* 2007, 7:263.

23 Hales S, Blakely T, Foster RH, Baker MB, Howden-Chapman P (2010) Seasonal patterns of mortality in relation to social factors, *JECH Online First*, 10.1135/jech.2010.111864

24 Lara Rangiwhetu, Nevil Pierse & Philippa Howden-Chapman, Effects of minor household interventions to block draughts on social housing temperatures: a before and after study | Kōtuitui: New Zealand Journal of Social Sciences Online, Volume 12, 2017 - Issue 2**Published online:** 14 Sep 2017 Pages 235-245.

Although literature provides little guidance on how these change with variation in temperature, we develop a model based on the EECA AccuRate database that estimates temperature changes across houses with varying characteristics of insulation and heating.

2.3. Quantifying energy impacts

The AccuRate database provides the energy required to heat a given dwelling type to a certain temperature. Among the different dwelling types considered are those with varying levels of insulation. The database shows how for a given temperature, the more insulation the dwelling has the less energy is required to heat it.

Some of the potential temperature gain from installing insulation will be "taken back" as reductions in energy consumption. The WUNZ study found there was a small reduction in energy consumption which equates to around 2% of annual heating demand. From our model we estimate that retrofitting houses with no or poor insulation would result in an increase in temperature of around 1.7°C if we assume only 2% energy take back, or 1.5°C increase with 10% energy take-back. In other words, if houses use 2% less energy than they currently do, improved insulation raises their temperature by 1.7°C; but if they use 10% less energy the temperature rises by only 1.5°C.

The household energy and heating model can therefore examine effects of changes in heating and insulation on energy costs for tenants, environmental costs in terms of greenhouse gas emissions from marginal changes in fuel use, and temperature changes from which to infer likely impacts on occupant health.

2.4. Quantifying health benefits

To quantify the benefits we use estimates of health benefits from the WUNZ to help determine the health benefits of raising the indoor temperatures of dwellings. Although the WUNZ study did not estimate the resulting increase in indoor temperatures from installing insulation, we infer what this temperature rise might have been by using the EECA AccuRate dataset.

We obtain an annual health benefit of around $125 ($124.78) per "average" household as shown in the table below.[25] If we assume these houses, on average, increased the indoor temperature by 1.5°C, then the benefit per degree is about $86 ($85.79) per year. This "per degree Celsius" estimate is a simple point estimate that must be used with caution, as a one degree increase from 20°C will have far less benefit than a one degree increase from 15°C. Sensitivity analysis tests the robustness of the CBA to changes in the assumed benefit values.

[25] Mortality benefit is removed from the health estimate as WUNZ provides no basis for it varying with temperature gain: it is treated separately in the analysis at a flat rate per house affected by temperature rise from insulation or heating.

Table 2 Deriving annual health benefits per household per degree

	All households
WUNZ study	$636.33
Less Mortality benefits	$465.36
Subtotal	$170.97
NZIER CBA assumptions[26]	$124.78
Est temperature increase	1.5°C
Estimated benefit per degree	**$85.79**

Source: NZIER

Table 3 Benefits per degree per person in different household types

Benefits	All houses	Rentals only	Over 65s	Under 5s
Benefits per degree per person				
Hospitalisation & pharmaceutical use	$7.41	$7.41	$37.07	$22.24
Other (medical visits, days off school/work, caregiver costs)	$24.17	$24.17	$8.06	$16.11
Estimated health impact per person per degree	**$31.58**	**$31.58**	**$45.12**	**$38.35**
Average persons per dwelling	2.6	2.8	1.9	2.9
Estimated benefits per household per degree	**$85.79**	**$88.42**	**$87.81**	**$113.05**

Source: NZIER, drawing on the WUNZ CBA

Children under 5 and adults of 65 and over spend a greater proportion of their time at home, and may be more vulnerable to cold, damp houses. Hospitalisation rates are higher for these vulnerable groups, so we expect an amplified health benefit (when compared to people aged 6-64) when heating these dwellings. In the absence of any research available for these specific age groups, we have applied a simple scaling factor to the WUNZ benefits to weight the health benefits for 5 years and under and 65 years and over.

The largest benefits in the WUNZ assessments were mortality benefits from the expectation of reduction in rates of excess winter mortality in houses with new insulation and clean heaters. The WUNZ assessments found a benefit for houses fitted with upgraded insulation but none from those with clean heaters, possibly due to the incremental effect of adding heaters to houses that already had insulation fitted.

26 This is principally adjusting the Community Service Card holder benefits to reflect the proportion of cardholders in New Zealand which is 18%, rather than the 57% in the WUNZ sample.

We follow the approach used in the WUNZ assessments and update the mortality value to 2018 values. We apply this to houses receiving new insulation and new heating, as it appears unlikely that heating would have zero effect

2.5. Quantifying environmental benefits

The principal environmental impact is a reduction of greenhouse gas emissions from changes in energy use. We assume that any reductions in energy use from adding insulation result in a reduction in thermal electricity generation at the margin, and are valued at \$25/tonne CO_2e.[27]

More stringent emission reductions over the longer term in pursuit of emission reduction targets would need a substantial lift in the carbon price. As carbon prices rise over time, the benefits arising from measures that reduce household energy use will also increase. The precise level of this increase depends on international developments in carbon markets and domestic policy decisions that have yet to be made. We use a short-term carbon price which is appropriate for the 15 year timeframe of this analysis and the introduction of standards.

2.6. Analysis of the standards

For each of the standards, we outline the principal assumptions used in the analysis, the number of houses affected by retrofitting requirements, and the values used. The analysis estimates a stream of costs over a 15 year period, a stream of benefits expected to accrue, and estimates the net benefits after subtracting costs. These are discounted at 4% over the 15 year period.

The principal results are the Net Present Value (NPV), which, if positive, indicates the quantified benefits exceed the quantified costs. This estimates the size of the net benefit in present value terms. An alternative presentation of result is the ratio of benefits to costs (in present value terms), which indicates the rate of return from costs incurred.

Where benefits are unable to be fully quantified, the net present value may be negative. In such cases we present a break-even analysis to show what value such unquantified benefits would need to be for them to outweigh the net costs of the measure. This is then converted to a more relatable scale – an annual value per house affected.

[27] A figure of \$25/tonne CO2 has been used as it is has long been a benchmark value used in the New Zealand Emissions Trading Scheme. Current prices are somewhat lower around \$21/tonne but have been climbing over recent years (see https://www.commtrade.co.nz/)

3. Standards

In this section we examine the individual options for standards being considered, as outlined in the MBIE's discussion document on *Healthy Homes Standards – Proposed healthy homes standards for insulation, heating ventilation, moisture ingress and drainage and draught stopping.* In each case we outline the status quo against which to compare the changes brought about by the proposed options for different standards, then specify the input assumptions used in the analysis, describe the results and provide some interpretation.

As a prelude to the analysis, we ran the model to show what it would take to reach healthy temperatures with the current stocks of heaters and insulation, in the absence of standards. Currently the majority of rental properties do not reach healthy temperatures. Table 4 shows the modelling results for reaching the healthy temperature benchmarks now, by turning up the existing stock of heaters and, where this is insufficient, adding new heaters to the stock in proportion to the current shares across energy and heater types. Around 40,300 rental properties have no heating now and remain so in this scenario.

Table 4 Reaching healthy temperatures now

Present values discounted over 15 years at 4%

	Reaching 18°C now	Reaching 20°C now
Houses with higher temperature in living rooms	294,702	520,062
Houses with higher temperature in bedrooms	151,552	267,445
Benefits PV$'000		
Unquantified benefits for school attendance, mental health and subjective well-being and comfort		
Tenants' reduced costs from ill-health	348,528	925,441
Tenants' reduction in energy costs		
Better environment (CO_2 reduction)	-24,816	-51,171
Producer surplus on new suppliers	390,204	757,210
Costs PV$,000		
Landlords' capital cost	-53,214	-92,043
Increase in energy costs	-1,742,211	-3,387,475
Net present value PV$'000	**-1,081,509**	**-1,848,038**
Total benefits PV$'000	**713,916**	**1,631,480**
Total cost PV$'000	**-1,795,425**	**-3,479,518**
Benefit cost ratio	**0.40**	**0.47**
NPV per affected house PV$	**-$3,670**	**-$3,553**

Source: NZIER

Rather this shows the substantial energy cost involved in reaching healthy temperatures on the current pattern of heating and insulation in rental properties. With the current stock of heaters and current insulation characteristics of rental houses it is not cost effective to reach healthy temperatures. This would involve some capital cost for landlords in installing new heaters, which could include less healthy and non-compliant appliances, defined here as open fires and unflued gas and LPG heaters, which emit toxic gases and water vapour into the indoor environment.[28] It also includes substantial energy costs for tenants in using them to reach the guideline temperatures. Costs would exceed quantifiable benefits even if it were feasible to enforce a requirement for occupants to reach recommended temperatures.

The modelling suggests reaching the 18°C benchmark temperature would require living room temperatures to be raised in 294,702 houses, and bedroom temperatures to be raised in 151,552 houses. To reach the 20°C temperature would require living room temperatures to be raised in 520,062 houses and bedroom temperatures to be raised in 267,445 houses.[29] Because of the current state of heating and insulation in rental houses, it would require a lot of additional energy use and associated greenhouse gas emissions to get to healthy temperatures, at considerable cost in terms of both energy use and new heating capacity. This cost could be alleviated by standards on insulation, clean heating, draught stopping, ventilation and moisture ingress prevention.

3.1. Insulation standard

Option 1 is a continuation of the status quo, in which requirements under the 2016 Residential Tenancies Act (RTA) regulations would continue to apply after 1 July 2019, whereby landlords must replace or retrofit insulation in their rental houses that do not meet those requirements for ceiling and underfloor insulation. This means that rental properties with no or less ceiling and/or underfloor insulation than the 1978 benchmarks, or insulation that is damaged or degraded, are required to be upgraded to the 2016 RTA insulation requirements (i.e. meeting or exceeding 2008 benchmarks).

Option 2 under the proposed standards is that landlords must replace or retrofit ceiling and underfloor insulation in their rental homes that was installed before 1 July 2019 if it is not in a reasonable condition and, did not meet the 2001 benchmark when originally installed. This would require all rental properties with ceiling or underfloor insulation below the 2001 benchmark to retrofit insulation to meet the 2008 benchmark.

Under Option 3 landlords must replace, retrofit or 'top-up' ceiling and underfloor insulation that is below the 2008 benchmarks (including damaged or degraded insulation fitted after 2008) to retrofit up to the 2008 benchmarks.

[28] A review of LPG cabinet heaters in 2010 by NZIER found substantial health costs associated with the use of these heaters which aggravated those with asthma and other pre-existing respiratory conditions, and also some risk of accidental asphyxiation when used in small rooms without ventilation, and fire risk when lighting. See https://nzier.org.nz/project/review-of-lpg-cabinet-heaters/

[29] The reason why the benefit cost ratio is higher, and NPV per house lower, at 20°C than 18°C is because although more houses need to raise their heating to reach 20oC, some of these are at or above 18oC already and need to apply smaller increments of energy than those with lower current temperatures.

The discussion document suggests that, drawing on the House Condition Survey 2015 and changes that have occurred since then, Option 1 (status quo) would apply to between 0 and 40,000 rental properties, depending on how “reasonable condition” of insulation is interpreted. Option 2 is estimated to affect between 10,000 and 70,000 homes, and Option 3 between 80,000 and 190,000 homes.

The average cost per house of purchasing and installing insulation top-ups, inferred from recent EECA programmes, would be $1,448 excluding GST.[30] This is less than the $2,000-$4,500 sometimes quoted for a new ceiling and underfloor insulation in a house with none previously fitted, because all houses under Option 2 and Option 3 will be topping up some previous insulation, and any house with no insulation is required to install it under the status quo. Some recent analysis of the WUNZ results indicates there is no significant difference in the health benefits for occupants between those houses receiving top-ups and those being insulated for the first time.[31]

Table 5 Number of houses needing insulation retrofits

Insulation Standard	Estimates based on HCS 2015	
	Low	*High*
Option 1 Status Quo	0	40,000
Option 2	10,000	70,000
Option 3	80,000	190,000
Annual retrofit over 5 years		
Option 1 Status Quo	0	8,000
Option 2	2,000	14,000
Option 3	16,000	38,000

Source: NZIER, drawing from BRANZ Housing Condition Survey 2015

Over the 10 years 2008-2017 an average of 18,250 new houses were built each year, rising to 26,700 in 2018. The insulation supply industry catered for that amount of new installations plus an indeterminate level of retrofits on the existing housing stock, and commercial buildings. Between July 2009 and 2018 about 307,000 insulation retrofits were subsidised by EECA, including owner occupied as well as rental housing. This is equivalent to 34,111 retrofits per year, which suggests that if retrofits were phased equally over a five-year period, the installation industry’s recent capacity would be sufficient to handle all options except for the high retrofit requirement of Option three, for which retrofitting capacity would need to be about 10% larger.[32] To the extent that the rate of new house building increases, or demand for retrofits increases in the owner occupier market, that expansion would need to be larger still.

[30] Energy Efficiency and Conservation Authority, Warm Up New Zealand Programme average cost of ceiling top up excluding GST.

[31] Telfar Barnard L & Preval N (2018) *Healthy Homes Guarantee Standard Cost Benefit Input: Warm Up New Zealand evaluation rental sector sub-analysis: differences in health events and costs by existing insulation status*; Housing and Health Research Programme, University of Otago Medical School, Wellington May 2018.

[32] On average if 18,250 new houses and 34,111 existing houses are fitted per year, to reach 38,000 retrofits would require capacity for an extra 3,889 retrofits per year. That would be 7% larger than the combined new build and retrofit capacity.

In all cases we assume occupants run their heating to its current temperature setting (not energy loading), so there will be benefits in savings in energy and greenhouse gas emissions. As the temperature settings are unchanged, health benefits all come from mortality benefits which are modelled as proportional to the number of treated houses rather than to temperature rise.

Table 6 shows all the insulation options would yield positive net benefits which principally accrue to tenants through reductions in ill-health and energy costs. There is also a benefit from reduced greenhouse gas emissions, but suppliers of energy lose some producer surplus that outweighs the gain in producer surplus for suppliers of insulation. Landlords bear the principal costs in the first instance, although may try to recover this through rents.

The results suggest that Option 3 has slightly lower return per cost incurred than Option 2. This is because it incurs more cost in covering more houses, but the incremental energy saving is slightly less in topping up some insulation currently at the 2001 benchmark insulation rather than the 1978 benchmark. However, because Option 3 covers more houses it produces greater total net benefits than Option 2.

Table 6 Insulation results

Present values discounted over 15 years at 4%

	Option 2 Minimum houses affected	Option 2 Maximum houses affected	Option 3 Minimum houses affected	Option 3 Maximum houses affected
Number of properties	10,000	70,000	80,000	190,000
Benefits PV$’000				
Unquantified benefits for school attendance, mental health and subjective well-being and comfort				
Tenants’ reduced costs from ill-health	11,196	78,372	89,568	212,725
Tenants' reduction in energy costs	9,627	67,387	70,120	161,070
Better environment (CO_2 reduction)	147	1,027	1,173	2,787
Producer surplus on new suppliers	-322	-2,251	467	8,203
Project costs PV$’000				
Landlords’ Capital costs	13,408	93,857	107,265	254,755
MBIE regulatory administration				
Net present value PV$’000	**7,240**	**50,677**	**54,064**	**130,029**
Total benefits PV$’000	**20,648**	**144,534**	**161,329**	**384,784**
Total cost PV$’000	**13,408**	**93,857**	**107,265**	**254,755**
Benefit cost ratio	**1.54**	**1.54**	**1.50**	**1.51**
NPV per house affected PV$	**724**	**724**	**676**	**684**

Source: NZIER

3.2. Heating standard

The WHO recommends minimum indoor temperatures of 18°C for the general population and 20°C or 21°C for elderly people and children.[33] Risk of cardiovascular disease and respiratory conditions increases below 18°C.[34] Data from a BRANZ study indicates that, during the winter months, mean living room temperatures in New Zealand fall outside the recommended range,[35] with living room and bedroom mean temperatures typically 15.8°C and 14.2°C, respectively during the day and 13.5°C and 12.6°C, respectively overnight.

A large portion of New Zealand rental homes have inadequate heating available for tenants to reach healthy indoor temperatures. The BRANZ 2015 House Condition Survey found 23% of rental homes have no fixed heating, 21% have unflued gas heaters and for 7%, unflued gas heaters are the only source of heat. While tenants can use portable electric heaters to warm a room, they are insufficient to heat large living spaces because of their maximum 2.4 kilowatt output and capacity constraints on household power circuits that limit the use of multiple heaters.

Option 1 (status quo) for heating is that landlords continue to be required to provide a form of heating in the living room, with no specifications for minimum achievable indoor temperature or on the type or capacity of heaters required. Under this old existing requirement, an open fire or unflued gas heater would be compliant (except where proscribed by local authority air quality requirements).

Under Option 2, landlords must provide efficient heating devices to be able to achieve an indoor temperature of at least 18°C in rooms covered by the heating standard at a reasonable cost to operate. They may need to supplement or replace any existing heating devices that do not have sufficient capacity to heat the room to 18°C, but landlords and tenants are not required to *maintain* this indoor temperature.

Option 3 requires landlords to provide efficient heating capacity to be able to achieve 20°C in any areas covered by the heating standard at a reasonable cost to operate.

Variants around Options 2 and 3 include:

- Achieving the proposed level(s) of heating in living rooms only or in living rooms and bedrooms, or extending it to all habitable areas in the entire house
- Excluding certain heating devices from compliance with the heating standard, in particular those which emit toxic fumes and moisture into the house or which exhibit poor energy efficiency and economy for tenants.

3.2.1. Assumptions on heating

Under Options 2 and 3, some landlords will incur higher compliance costs than the status quo because they will be required to provide higher capacity heating. There is a

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33 WHO, (1987), Health Impact of Low Indoor Temperatures: Report on a WHO meeting Copenhagen 11-14 November 1985. Copenhagen: WHO.

34 WHO, (1987), Health Impact of Low Indoor Temperatures: Report on a WHO meeting Copenhagen 11-14 November 1985. Copenhagen: WHO.

35 BRANZ, (2010), Energy Use in New Zealand Households: Final Report on the Household Energy End-use Project. BRANZ Study Report SR 221: the Household Energy End-Use Project http://www.branz.co.nz/cms_show_download.php?id=a9f5f2812c5d7d3d53fdaba15f2c14d591749353.

wide variety of alternatives for them to choose from. However, we make the simplifying assumption that new heaters fitted in living areas will be heat pumps, and new heating capacity provided for bedroom areas will be plug-in electric resistance heaters. This is because we further assume:

- Landlords will opt for low cost ways of complying with new requirements, and heat pumps are less costly to install than flued gas or wood burners or more elaborate central heating systems
- Heat pumps are available nationwide, unlike flued natural gas which is largely confined to parts of the North Island (other than flued LPG heaters)
- Heat pumps are clean, convenient and economical for tenants to operate
- Even with their limited output plug-in electric heaters are sufficient to heat and raise temperatures in most bedrooms to healthier levels.

For simplicity our model defines primary heating as that found in living rooms and secondary heating as that found elsewhere. We focus our modelling on bedrooms and living rooms only. This is because there is too much variability in the size and shape of bathrooms, laundries and hallways to model this effectively, and because the WHO guidelines are most pertinent to rooms in which people spend most time, which is living rooms and bedrooms.

The model assigns multiple heat pumps to some houses with large living rooms as determined by analysis of ground plans.[36] Some larger houses may need heat pumps in bedrooms but there is insufficient data on the stock of heaters to accurately model this. So we assume that in houses that need to raise their temperatures with additional secondary heating, 20% is fixed heating or new heat pumps to account for large rooms, and 80% of secondary heating uses electric resistance heaters.

Notwithstanding heat pump warranties commonly in the range of 4-6 years, we assume 15 years as the lifespan of a heat pump, in line with BRANZ SR329 Heat Pump study (2015) which recorded some models still operating after more than 20 years, and other sources suggesting 15 years as an average life span.[37]

We assume an annual maintenance cost for heat pumps of a minimum of $20 and maximum of $100 falling initially on the landlord. The BRANZ SR329 reports that over 70% of owners do maintenance themselves and many others do no maintenance at all or are put off by commercial quotes of $75-$105 per heat pump.[38] However, even if pumps are maintained by the occupants or owners there is an opportunity cost for their time and a longer term expected cost for repairs or maintenance to interior or exterior units, which means the economic cost of maintenance is not zero.

The average installed cost for a medium-sized heat pump of 5-7 kilowatts is approximately $3,000 to $3,500 including GST.[39] Excluding GST, the range becomes $2,609 to $3,043 with a mid-point value of $2,826.

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36 The heating model calculates the energy load required to meet target temperatures for given areas of living room and assigns more than one heat pump to the largest spaces. This may overstate installation costs as the proposed standard only requires a heat pump in the main living room of a house which will usually be served by one heat pump (of varying size).

37 https://www.conditionedairinc.com/blog/how-long-will-hvac-system-last

38 BRANZ SR329 suggests $75-$95, and on-line survey of suppliers' websites suggests higher range up to $105 excluding GST.

39 Energy Efficiency and Conservation Authority estimate based on survey of four Warm Up New Zealand service providers who install heat pumps.

For resistance plug-in heaters we assume a basic oil filled or convection heater (quieter than fan heaters for bedrooms) with thermostat and timer switches which are available for $30 to $50.[40] Removing the GST ($26-$43 per heater) and taking a mid-point gives a value of $35 per heater. We assume an effective life span of 5 years for such heaters and that it is cheaper to replace them than to repair them.

The number of houses affected and increasing their heating is generated by the model and varies with the higher temperature being sought (18°C or 20°C) and the proportion of tenants who choose to pursue these temperatures. Since many New Zealand houses are not heated to healthy temperatures at present, we assume in the first instance that half of tenant households would pursue healthier higher temperatures, and then consider if all houses not currently reaching healthy temperatures did so (Table 7).[41]

Table 7 Assumptions and settings for heating standard

All prices exclusive of GST; figures subject to rounding

Item	Unit cost	Properties affected	Properties affected	Properties affected	Properties affected
	$/unit	Half aim for 18°C	Half aim for 20°C	All aim for 18°C	All aim for 20°C
Heat pump (15-year life assumed)	2,826	179,071	285,219	334,998	560,398
Heat pump maintenance (annual assumed cost)	20	179,071	285,219	334,998	560,398
Portable electric heaters (5-year life assumed)	35	71,373	125,951	151,552	267,358

Source: NZIER

3.2.2. Results on heating

Option 2 Capacity to heat to 18°C

The results of our modelling of Option 2 of the heating standard are set out in Table 8. It separates out the increase in primary fixed heating capacity in living areas, secondary portable heating capacity in bedrooms, and the combined effect of the two. The model does not predict whether the two categories overlap so the combined number of properties is indeterminate. The model assumes 50% of households pursue the 18°C temperature in winter times.

In living room heating, increasing or replacing fixed heating capacity involves substantial capital costs for landlords over the 15-year period, and landlord's operational and maintenance cost of $20 per property per year also mounts up over that time. That generates a positive producer surplus for suppliers of equipment but

40 Sourced from on-line search of retail websites of Bunnings and Mitre 10.

41 Note that because of rounding and discontinuous functions in the heating model, "half" of tenancies is not exactly 50% but 53.5% at 18°C and 50.9% at 20°C in living rooms and 47.1% for both temperatures in bedrooms. These figures are illustrative as the actual behavioural response to presence of improved heating in rental housing cannot be predicted.

that is outweighed by reductions in producer surplus for energy suppliers as new heaters displace some older less energy efficient ones. Tenants enjoy a reduction in energy costs on their primary heating if replaced by more energy efficient devices and this also leads to a reduction in CO_2 emissions. Tenants enjoy a reduction in ill-health from warmer homes, and also benefit from reduced mortality risk. Quantified benefits exceed quantified costs when including these two health-related values.

Table 8 Heating standard Option 2 – capability to achieve 18°C

Present values discounted over 15 years at 4%

Present value $'000	Living rooms	Bedrooms	Combined
Number of properties	179,071	71,373	
Benefits PV$'000			
Unquantified benefits for school attendance, mental health and subjective well-being and comfort			
Tenants' reduced costs from ill-health	129,805	53,407	183,212
Mortality benefits	100,245	39,955	140,199
Tenants' reduction in energy costs	476,188	-115,932	360,255
Better environment (CO_2 reduction)	9,136	-835	8,301
Producer surplus on new suppliers	-45,424	27,561	-17,863
Costs PV$'000			
Landlords' capital cost	456,444	15,814	472,258
Landlord operational costs	44,999		44,999
MBIE regulatory administration			
Net present value PV$'000	**168,507**	**-11,659**	**156,849**
Total benefits PV$'000	**669,950**	**4,155**	**674,105**
Total cost PV$'000	**501,443**	**15,814**	**517,257**
Benefit cost ratio	**1.34**	**0.26**	**1.30**
NPV per house affected PV$	**941**	**-163**	**876**

Source: NZIER

When heating bedrooms fewer properties need to increase their secondary heating as the model assumes such plug-in electric heaters are already widely distributed. New secondary heating still generates capital costs for landlords and producer surplus for suppliers of heaters, and also for energy suppliers as these heaters increase demand for energy when used. Tenants face an increase in energy costs (a negative reduction) and there is also a negative impact on CO_2 reduction. Better heating in bedrooms has a proportionately larger impact on bedroom temperature than primary heating in living areas, so the general health benefits per house are larger from heating bedrooms. But the gain in aggregate mortality benefits is lower in bedrooms than in living areas, as these benefits are modelled in proportion to the number of houses in which more heating is applied, and there are fewer houses applying additional heat to bedrooms than to living areas.

On the assumptions in this analysis, upgrading the primary heating in living areas alone is more net beneficial than upgrading secondary heating in bedrooms, exceeding break-even with a benefit cost ratio of 1.34. Heating bedrooms alone however does not break even, having a benefit cost ratio of 0.26. In combining a standard for both living rooms and bedrooms the benefit cost ratio would be 1.30. Adding bedrooms to living rooms brings down the positive result slightly but would also involve tenants in increased heating costs and a consequent rise in energy and greenhouse gas emissions.

The benefit cost ratio of 1.30 means that costs could be 30% larger than initially assumed before the analysis ceased to break-even, other things held constant. Conversely, benefits could be 23% smaller before the analysis ceased to break-even, other things held constant. Low and high cost variants for heat pump installation ($2609 to $3,043) and portable heaters ($26 to $43 per unit) would individually not change this result, and landlord operational costs could be over three times as large as initially estimated before the net present value was reduced to zero.

Option 3 Capacity to heat to 20^{o}C

The modelling results for Option 3 in which 50% of rental households with upgraded heating pursue the 20^{o}C temperature are outlined in Table 9, with separate results for living rooms only, bedrooms and the combined effect of both. Compared to Option 2 more properties would need to upgrade their heating to achieve the higher 20^{o}C temperature and landlords would face greater costs than in Option 2 in upgrading the primary heating in living rooms. Also compared to Option 2 suppliers of new equipment enjoy a larger producer's surplus which is not offset by reductions in energy use.

Tenants save some energy cost from having more efficient heating, but also need to increase energy use to reach the higher temperature, so their overall energy saving is lower than for Option 2. But their health and mortality benefits are higher in Option 3. Tenants' benefits from reduced ill-health increase by more than their mortality benefits in moving from Option 2 to Option 3 as the health benefits are modelled as directly related to temperature increase, whereas mortality benefit only rises in proportion to the number of properties in which temperature gains occur.

There is also reduction in greenhouse gas emissions but this is also larger for Option 2 at 18^{o}C than Option 3 at 20^{o}C because of the extra energy used to reach the higher temperature, other things held constant.

Raising heating capacity in bedrooms affects fewer properties and entails lower overall cost than adding heating to living rooms. Tenants would still enjoy some health benefits, but they would also face higher energy costs and cause higher greenhouse gas emissions in heating bedroom areas with less efficient heaters. Landlords still face capital costs in providing secondary heaters while suppliers of such heaters and the energy they consume enjoy a producer surplus.

Table 9 Heating standard Option 3 capability to reach 20°C

Present values discounted over 15 years at 4%

	Living rooms	Bedrooms	Combined
Number of properties	285,219	125,951	
Benefits PV$'000			
Unquantified benefits for school attendance, mental health and subjective well-being and comfort			
Tenant's reduced costs from ill-health	330,058	156,407	486,465
Mortality benefits	159,666	70,508	230,174
Tenants' reduction in energy costs	255,892	-260,727	-4,835
Better environment (CO_2 reduction)	5,026	-3,056	1,971
Producer surplus on new suppliers	14,172	61,346	75,517
Costs PV$'000			0
Landlords' capital cost	541,861	30,658	572,520
Landlord operational costs	53,439		53,439
MBIE regulatory administration			
Net present value PV$'000	**169,513**	**-6,180**	**163,333**
Total benefits PV$'000	**764,814**	**24,478**	**789,292**
Total cost PV$'000	**595,301**	**30,658**	**625,959**
Benefit cost ratio	**1.28**	**0.80**	**1.26**
NPV per house affected PV$	**594**	**-49**	**573**

Source: NZIER

Heating the living rooms alone produces positive net benefits and a benefit cost ratio of 1.28, but raising heating capacity in bedrooms has a negative net present value with a benefit cost ratio of 0.80.[42] The combined effect of applying the standard to living rooms and bedrooms is a net present value of $163 million with a benefit cost ratio of 1.26. These results are lower than for Option 2 because of the additional costs of new heating and the energy used to reach the higher temperature.

Variants on the results

These heating results are based on 50 percent of tenant households pursuing the target temperatures. If 100 percent of tenants pursue these temperatures tenants would face increased energy costs, particularly in secondary heating in bedrooms, but the analysis yields larger net benefits due to the size of mortality benefits assumed over larger numbers of warmer houses. In brief:

42 The higher benefit cost ratio for bedrooms under the 20°C option compared to the 18°C option is because in modelling increasing temperatures in bedrooms, more houses apply additional heat in their bedroom areas, raising the estimated benefit of reduced mortality risk which is proportional to properties affected.

- If all tenants with new heating pursue 18°C, the modelling finds there would be a benefit:cost ratio of 1.54 in living rooms only in around 335,000 rental houses and a ratio of 1.60 across living rooms and bedrooms combined, higher than in Table 8
- If all tenants with new heating pursued 20°C there would be a benefit:cost ratio of 1.49 in living rooms only in 560,360 rental houses and 1.58 across living rooms and bedrooms combined, higher than in Table 9.

Tenants benefit from mortality benefit and reduced ill-health, but their savings in energy costs in living rooms would be outweighed by increased energy costs if the standard extended to bedrooms. Landlords could also face increased costs in maintaining and replacing the heating stock when it is used more intensively, and the clearest beneficiaries of this scenario would be the suppliers of appliances and energy who gain producer surplus, particularly when bedrooms are included.

In the case of all households pursuing higher temperatures, even bedroom heating alone appears net beneficial. The results improve because although the number of affected houses (and people) pursuing higher temperatures increases, and with it the number of health and mortality benefits, the capital costs of new installations do not rise proportionately, as this scenario assumes higher utilisation of new and existing heaters rather than increase of heaters.

However, this scenario is unlikely, given what the literature says about how many New Zealanders do not heat their houses to 18°C or higher, and their continuing this behaviour even when equipped with new efficient heaters in trials. The heating standard depends on behavioural response on the part of tenants and their commitment to achieving healthy temperatures by spending on additional heating energy rather than on other things.

The scenario results are illustrative of what might potentially happen, not what is likely to happen. For this reason we believe the 50% pursuit of healthy temperatures is more informative of what is likely. It still suggests net benefits will be achieved if health benefits of the scale assumed can be realised, although is more circumspect about applying a heating standard to bedrooms, the heating of which tenants have more control over because suitable heaters are cheap and portable when moving house.

The model has also been run to examine the effect of forcing non-compliant heaters (open fires and unflued gas) to be replaced by heat pumps and electric resistance heaters (rather than just replacing them with clean heaters at the end of their useful lives). Bringing forward the date at which these heaters are replaced with higher capital cost appliances increases the monetary costs, other things held constant. Removing unflued gas would also avoid health costs and moisture damage and give more positive results[43].

3.3. Moisture and Ventilation standard

The purpose of ventilation is to allow moist air to be replaced in a house by drier air from outside. Poor ventilation is associated with the growth of mildew and mould, which can trigger allergenic reactions and aggravate respiratory conditions; also with dampness in soft furnishings and clothing, which necessitates increased cleaning or

[43] NZIER (2010) Review of Portable LPG Cabinet heaters; report to Ministry of Economic Development.

replacement costs; and with increased heating costs in overcoming the latent heat absorbed in evaporating water.

Many New Zealand rental homes are currently poorly ventilated leading to dampness and mould,[44] which can lead to poor health outcomes for tenants.[45,46] This is particularly apparent with activities such as cooking, showering, washing and drying clothes indoors, which in rooms not adequately ventilated can lead to moisture accumulation in the house.

The discussion document cites BRANZ data that suggests around 37% of rental homes in New Zealand do not have mechanical ventilation (e.g. fans to extract moisture) in the kitchen and 44% do not have mechanical ventilation in the bathroom.[47] While the general associations between moisture and various costs have been often explained in the literature, there is little guidance from the literature on what difference the specific proposed standards would make to entry or expelling of moisture from the interiors of rental houses.

The simplest means of ventilation is to open windows for 10-15 minutes which is sufficient to expel water vapour from a high moisture generating event,[48] such as showering or cooking, but this may not always be possible due to occupants' security concerns. Mechanical ventilation (e.g. fans to extract moisture) is an alternative, but as stated above, significant proportions of rental properties do not have mechanical ventilation in the bathrooms or kitchens.

3.3.1. The proposed ventilation standards

Under Option 1 (status quo), landlords must ensure each habitable room has a window openable to the outside with an area no less than 5 percent of its floor area; every bathroom has a window that opens directly to the outside unless other ventilation is provided to the satisfaction of the local authority; and every other room that is not a habitable room has such windows as the local authority considers necessary for adequate ventilation. Landlords are not required to ensure that windows can be securely opened by tenants to enable ventilation to take place.

A sub-option that was proposed would supplement the status quo by requiring landlords to ensure tenants can open windows in their rental home and leave them open without undermining the security of the home or the tenants. We model this by considering the costs and benefits of requiring security stays to be fitted to a window in each habitable room to encourage ventilation.[49]

Option 2 requires landlords to install properly sized mechanical extractor fans in indoor rooms that have a shower or bath, and rooms that have indoor cook tops. A landlord

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44 White, V. Jones, M. Cowan, V. Chun, S. (2017). BRANZ 2015 House Condition Survey: Comparison of house condition by tenure. SR370. BRANZ Ltd. p25.

45 Braubach, M., & World Health Organization. (2011). Environmental burden of disease associated with inadequate housing: a method guide to the quantification of health effects of selected housing risks in the WHO European Region. p7.

46 Heseltine, E., & Rosen, J. (2009). WHO guidelines for indoor air quality: dampness and mould. WHO Regional Office Europe.

47 White, V. BRANZ information provided to MBIE (27 Feb 2018): Analysis of the 2015/16 House Condition Survey Data.

48 White, V. Jones, M. (2017) Warm, dry, healthy? Insights from the 2015 House Condition Survey on insulation, ventilation, heating and mould in New Zealand houses. Study Report SR372. BRANZ Ltd. p23.

49 Since this analysis was done, for wider policy reasons the proposed window stays sub-option has been withdrawn from the standards

would be required to fit security stays to openable windows (as for Option 1) and these requirements would be in addition to the status quo of having openable windows.

3.3.2. Assumptions on ventilation

We model this proposed standard by estimating the costs involved in retrofitting houses with security window stays and extraction fans for bathrooms and kitchen range hoods and wall fans. We identify the likely price of these appliances from on-line surveys of retailers' websites then apply hourly rates for builders and electricians to install them. The hourly charge out rates are $43/hour for builders' work and $53/hour for electricians, reflecting national means rather than localised peak prices.

The cost assumptions are outlined in Table 10.

Table 10 Cost assumptions for ventilation standards and options

All prices exclusive of GST; figures subject to rounding

Item[50]	Low $/unit	High $/unit	Properties affected	Low aggregate property cost $m	High aggregate property cost $m
Stays, cost per unit (unbranded, branded)	$10	$17	143,500 (25%)		
Applies to 6 windows, fit 3 per hr @43/hr	$143	$190	143,500 (25%)	20.5	27.2
Applies to 12 windows, fit 3 per hr @43/hr	$285	$379	143,500 (25%)	41.0	54.4
Bathroom fans					
Fan in external wall + exterior flashing for 44% of bathrooms	$43	$122	252,560 (44%)	11.0	30.8
Plus 2 hrs installing @$43 & 1 hr wiring up @53/hr	$138	$138	252,560 (44%)	34.9	34.9
Installed fan cost for 44% of rental houses	$182	$260	252,560 (44%)	45.9	65.7
Kitchen fans					
Range hood plus ducting to exterior for kitchens in 37% of rental properties	$348	$609	212,380 (37%)	73.9	129.3
Plus 3 hrs installing @$43 & 1 hr wiring up @53/hr	$181	$181	212,380 (37%)	38.4	38.4
Installed range head cost for 37% of kitchens	$529	$790	212,380 (37%)	112.3	167.7

50 Sourced from online survey of retailers Bunnings and Mitre 10 for appliances and labour charges $43.67/hr for hammer-hands and $53/hour for electricians from https://builderscrack.co.nz/

Item[50]	Low $/unit	High $/unit	Properties affected	Low aggregate property cost $m	High aggregate property cost $m
Installed bathroom-style fan for 37% of kitchens	$182	$260	212,380 (37%)	38.6	55.2

Source: NZIER

For window stays we assume six windows need to be fitted to the median three-bedroom house – one for each bedroom and for the kitchen, bathroom and living room. We make no allowance for rooms upstairs or otherwise inaccessible, nor for larger houses which may need more stays (which in rental properties are outnumbered by one or two-bedroom houses which may need less).

For mechanical ventilation, we assume that all bathrooms have an external wall on which mechanical fans can be simply fitted and vented. Kitchens are more problematic as stoves are often not on outside walls and could require significant ducting for fan exhausts to reach the outside. There are also many kitchens with stoves set against a window for ventilation, which would make a range hood an intrusive addition.

The kitchen range hoods are costlier than bathroom fans, because the appliances themselves are more expensive and because the fitting with ventilation ducting takes more time. We assume bathroom-style fans will also be compliant and appropriately sized for use in kitchens and show them as the lowest cost option in the bottom row.

The number of properties affected and likely to need retrofitted equipment is drawn from BRANZ data for bathrooms and kitchens. The number of houses needing window security stays is indeterminate, so we examine the effect on costs of varying proportions of houses affected.

3.3.3. Results of ventilation standard components

The results of fitting window stays, new bathroom fans and new kitchen fans are outlined below (Table 11). We start with an assumption of 25% of rental properties needing to be fitted with window stays.

We have not found reliable information to quantify the causal chain between these measures removing moisture from homes and reduction in the costs that moisture can cause. The principal quantifiable items are the capital costs for landlords in fitting such equipment, the energy costs for tenants in using them, and the producer surplus for suppliers of equipment and energy. Consequently, the net present value is negative.

Table 11 Costs and benefits of options under the ventilation standard

Present values discounted over 15 years at 4%

	Security window stays	New bathroom fans	New kitchen fans
Number of properties	143,500	252,560	212,380
Benefits PV$'000			
Unquantified benefits for property maintenance, health, mental health, school attendance, subjective well-being and comfort			
Producer surplus on new suppliers	1,353	3,033	2,551
Project costs PV$'000			
Landlords' capital cost	17,549	39,326	33,072
Increase in tenants' energy costs	0	18,257	37,792
Net present value PV$'000	**-16,196**	**-54,550**	**-68,313**
Total benefits PV$'000	**1,353**	**3,033**	**2,551**
Total cost PV$'000	**17,549**	**57,583**	**70,863**
Benefit cost ratio	**0.08**	**0.05**	**0.04**
NPV per affected house $	**-$113**	**-$216**	**-$322**

Source: NZIER Draft CBA

Table 12 shows what value of unquantified benefits would be needed for the standards to break-even. It divides the present value of the shortfall of benefits against costs by the number of houses affected and annualises this over the 15-year period at the discount rate of 4%. Window stays would require unquantified benefits of around PV $16 million to break-even, around $113 per house affected and $10.15 per house per year. Bathroom and kitchen fans require larger unquantified benefits to break-even.

The results suggest that all these options would require relatively little additional benefit to break-even. Whether maintenance and cleaning costs around wet areas in houses would be sufficient is a technical question to be determined. The temperature gain and energy saving from removing moisture in indoor air are unlikely to be large. But if, for instance, tenants and/or landlords spent upwards of $50 per year countering the effects of excess moisture, and if these options have a material effect on removing that moisture, these measures could break-even.

Table 12 Break-even conditions for the ventilation standard

Present values discounted over 15 years at 4%

	Security window stays	New bathroom fans	New kitchen fans
Number of properties	143,500	252,560	212,380
Size of unquantified benefit needed to break even PV$'000	16,196	54,550	68,313
Unquantified benefit per house affected PV$	113	216	322
Annual value per house affected PV $/year	-$10.15	-$19.43	-$28.93

Source: NZIER

All of these options are variants under Option 2 for ventilation in the Healthy Homes Standards discussion document. The new kitchen fans appear costlier and require a bigger additional benefit. This result depends partly on the size of the fan, and as kitchens are larger than bathrooms the cost of a kitchen fan may be higher still.

These measures also depend on behavioural input from occupants to use fans and window stays where provided. The more that behavioural response is missing across the affected houses, the less likely it is for these options to break-even.

3.4. Moisture ingress standard

The moisture ingress and drainage standards have a similar purpose to ventilation although starting from the other end – reducing the likelihood of moisture build-up under houses penetrating the interior, rather than expelling it from inside the house.

BRANZ research shows moisture rising from the ground can amount to 40 litres of water per day under a 100 square metre home[51] even if the soil appears dry.[52] Most rental homes with subfloors (81%) do not have a ground cover that could protect against moisture rising from the ground,[53] and an estimated 44% of rental homes with subfloors have insufficient subfloor ventilation[54] due to too few vents or vents blocked by plants and clutter in the subfloor that obstructs airflow.

Option 1 (status quo) is for landlords to continue to meet their existing legal obligations under the Building code, Residential Tenancies Act and Building Code H1 Regulations.

Option 2 under the proposed standard would target the identified issue of substantial subfloor moisture in New Zealand rental properties by requiring all landlords to:

51 McNeill, S. (2015). BRANZ Build 149 August/September 2015: Ventilation and subfloors.

52 Trethowen H.A. (1988): A survey of subfloor ground evaporation rates. BRANZ Study Report SR13. BRANZ Ltd.

53 McNeil S, Li Z, Cox-Smith I, Marston N. (2016): Managing subfloor moisture, corrosion and insulation performance. BRANZ study report SR354. BRANZ Ltd.

54 White, V. BRANZ information provided to MBIE (27 Feb 2018), Analysis of the 2015/16 House Condition Survey data.

- Ensure a suspended floor has either:
  - adequate open and unblocked ventilation openings to ensure proper ventilation under the home to protect against moisture build up or
  - install a moisture barrier over the soil under the home to protect against moisture ingress and dampness; or where a moisture barrrier cannot be installed because of insufficient access to the subfloor space, install additional subfloor ventilation to ensure adequate air flow.

Under Option 3, landlords must provide a moisture barrier under all rental homes with a suspended floor (even for rental homes that meet the New Zealand standard for subfloor ventilation without a moisture barrier).[55]

The critical matters additional to the status quo are the requirements for landlords to ensure adequate ventilation into the subfloor space, and/or installation of ground moisture barrier under the house for Option 2 and in addition to provide ground moisture barrier if they have not already done so under Option 3.

3.4.1. Assumptions on moisture ingress

As shown in Table 13, it is estimated 76% of rental homes have a subfloor and 44% of these have insufficient ventilation. Around 11% have subfloors with insufficient access to fit moisture barriers but could have vents placed on the subfloor walls. So, 56% of houses with subfloors already comply with the proposed Option 2 requirement to either have adequate subfloor ventilation or have a ground cover.[56] An on-ground cover installation typically costs about \$695 excluding GST per 100m^2 house.[57]

It is also estimated that under Option 3 up to 81% of rental homes with subfloors would require a ground cover to be installed, and up to 26% would require additional ventilation openings to be installed[58] – unless the rental home is exempt. Table 13 suggests 353,354 houses would require a ground moisture barrier installed under Option 3, of which 69% would already have sufficient ventilation.[59]

55 After this analysis was prepared, Option 3 for moisture ingress was removed from the proposed standards.

56 White, V. BRANZ information provided to MBIE (27 Feb 2018). Analysis of the 2015/16 House Condition Survey data.

57 Assuming a cost of \$8 per m^2 incl. GST for supply and professional installation of a ground cover, and an average area of 100 m^2 to be covered.

58 White, V. BRANZ information provided to MBIE (27 Feb 2018). Analysis of the 2015/16 House Condition Survey data.

59 Estimated from houses with subfloors less those with insufficient ventilation: – 436,240-191,946=244,294

Table 13 Subfloor vent requirements

	Properties affected	Sources
Total rental properties	574,000	
Of which, rentals with concrete slab floors	137,760	24% of houses BRANZ SR372
Rental houses with subfloors	**436,240**	76% of houses
Subfloors with insufficient ventilation	191,946	44% of houses with sub-floors BRANZ Housing Condition Survey
Subfloors with insufficient accessibility for fitting moisture barriers	47,986	11% of houses with sub-floors BRANZ SR372
Accessible with insufficient ventilation for treatment under Option 2	143,959	33% of houses with sub-floors
Subfloors with fitted moisture barriers	39,262	9% of houses with sub-floors
Subfloors of unknown condition	43,624	10% of houses with sub-floors
Subfloors needing moisture barriers under Option 3	353,354	81% of houses with sub-floors
Subfloors with sufficient ventilation	244,294	69% of 353,354 houses under Option 3
Subfloors with insufficient ventilation	109,060	31% of 353,354 houses under Option 3

Source: NZIER

To comply with the subfloor ventilation requirements a house requires an opening area of 3500 mm^2 (such as a 100 x 35 mm vent grate) provided for each square metre of floor area with vents located within 750 mm of corners and then evenly spaced around the building at 1.8 m centres maximum. No part of the subfloor should be further than 7.5 m from a ventilation opening.[60] A relatively low number of vents are required to meet the vents per square metre requirement but the 1.8 m spacing requirement boosts that number, increasing the cost of complying with Option 2.

To estimate what the cost might be, we postulate three rectangular house footprints of $80m^2$, $100m^2$ and $120m^2$, and divide the perimeter by 1.8m spacing to work out the number of vents likely to be required per house.

We then calculate a standard cost of installing the number of vent grates required for each size of house, based on a builder's quote of $220 ex GST per three grates installed in a concrete base and the number of ventilation grates required for each house size, with low and high vent prices drawn from building supplier websites. This gives an estimate of the cost of fitting all the grates required, not of the additional grates needed to reach the required level.

Older houses that have fewer grates than implied by Table 13 would need to top up the number of grates. On the current assumptions, a ground moisture barrier would be less costly than fitting vents to an $80m^2$ house with less than 66% of the required

60 https://www.renovate.org.nz/bungalow/foundations-and-subfloors/insufficient-subfloor-ventilation/

vents, a 100m^2 house with less than 62% of required vents and a 120m^2 house with less than 60% of the required vents.

Table 14 below shows the aggregate costs of meeting the standards for all rental properties potentially affected, with unit costs per grate or barrier fitted.

Table 14 Input assumptions for moisture ingress standard

All prices exclusive of GST; figures subject to rounding

Item	$/unit	Number of properties retrofitted	Aggregate property cost at low unit cost $m
Unit charge $/vent grate	7.83		
For 120m^2 house	1,037	11,996	11.7
For 100m^2 house	924	16,795	15.7
For 80m^2 house	812	19,195	15.6
Option 2 properties fitting vents		**47,986**	**43.0**
Ground moisture barrier instead of vents	**696**	**143,959**	**100.1**
Option 2 All properties affected		**191,946**	**143.2**
Ground moisture barrier installed $/m^2	6.96		
For 120m^2 house	835	88,339	73.7
For 100m^2 house	696	123,674	86.0
For 80m^2 house	557	141,342	78.6
Option 3 All properties affected		**353,354**	**238.4**

Source: NZIER

For illustration purposes we assume houses on average have 50% of the required grates, so in Option 2, 143,959 would choose fitting a ground moisture barrier as the least costly option, and 47,986 would choose vents because the subfloor is inaccessible for barrier fitting. We assume the appropriate number of grates and the ground moisture barrier are roughly equivalent in their effect in keeping moisture out of the house, although we have not seen evidence to support either proposition (or any alternative).

3.4.2. Results of moisture ingress standard components

The two options examined are installation of adequate underfloor vents in houses (Option 2) and additional installation of moisture ground moisture barriers under those houses, regardless of the adequacy or otherwise of their existing ventilation

(Option 3). Both these options only apply to houses capable of having them fitted i.e. those with suspended floors and sufficient access to work under them.

Table 15 shows the results for Option 2, assuming that for the median house the least cost way of complying with Option 2 is by installing a moisture barrier rather than several additional vents. This option is available for 143,959 affected houses, at an average price of $696 per house. For those 47,986 rental properties without the subfloor access to fit a barrier, vents can be installed at an average cost of $926 per affected house, assuming houses on average already have 50% of the required vents. The combined costs and benefits for both are in the third column.

Table 15 Subfloor ventilation costs and benefits

Present values discounted over 15 years at 4%

	Option 2 fitting barriers	Option 2 vents for inaccessible subfloors	Combined Option 2	Option 3 Barriers for all houses
Number of properties	143,959	47,986	191,946	353,354
Benefits PV$'000				
Unquantified benefits for property maintenance, health, mental health, school attendance, subjective well-being and comfort				
Producer surplus on new suppliers	6,417	2,930	9,346	15,750
Project costs PV$'000				
Landlords' capital cost	83,179	37,987	121,166	204,145
Increase in energy costs				
Net present value PV$'000	**-76,762**	**-35,057**	**-111,820**	**-188,396**
Total benefits PV$'000	**6,417**	**2,930**	**9,346**	**15,750**
Total costs PV$'000	**83,179**	**37,987**	**121,166**	**204,145**
Benefit cost ratio	**0.08**	**0.08**	**0.08**	**0.08**
NPV per house affected $	**-$533**	**-$731**	**-$583**	**-$533**

Source: NZIER

Option 3 is costlier because it applies to all houses with a subfloor. What is less evident from the table is that Option 3 has a marginal benefit that is very low, because by requiring a ground moisture barrier regardless of the existing underfloor ventilation, some houses would be fitted with it even if they did not need it, incurring cost for negligible benefit. Table 13 suggests 69% of houses fitted under Option 3 already have sufficient ventilation.

While the effectiveness of these measures in removing moisture from entering the house is a technical matter to be determined, the marginal benefit of Option 3 will be low if it does not vary according to the adequacy of existing underfloor ventilation, and may lead to some houses being fitted with both vents and ground moisture barrier when only one would suffice.

These measures are passive, so once fitted will provide a benefit without any further intervention by landlords or tenants, except light monitoring to ensure vents remain open.

Table 16 shows the value of unquantified benefits, such as savings in damp-related property maintenance, health and subjective well-being, would need to be for the options to break-even. Because the ground moisture barrier is the least cost option for the Option 2 for houses with accessible sub-floor, results per house and per year are the same for those houses under Option 2 as for Option 3.

Table 16 Underfloor moisture ingress

	Option 2 barrier retrofits	Option 2 subfloor vent retrofits	Option 2 combined barriers and vents	Option 3 Moisture barrier
Number of properties	143,959	47,986	191,946	353,354
Size of unquantified benefit to break even PV$'000	76,762	35,057	111,819	188,396
Unquantified benefit per house affected PV$	533	731	583	533
Annual value per house affected $/year	-$47.96	-$65.71	-$52.40	-$47.96

Source: NZIER

3.5. Draught stopping standard

Draught stopping has a similar purpose to insulation in reducing the escape of heat from the house, which should reduce the cost of heating and make it more feasible to sustain healthy temperatures. One New Zealand study reports observed temperature gains of 1-1.5°C from draught stopping,[61] but this was limited to 5 one-bedroom dwellings in a south-facing Wellington apartment block which is far from representative of rental properties across the country at large. The number of houses that might benefit from draught stopping, and the frequency with which they will need to be re-stopped, are indeterminate.

The proposed standard on draught stopping would consider options of:

- Option 1: continue with the status quo in which landlords are required to maintain their properties in a good or reasonable state of repair
- Option 2: require landlords to stop any unnecessary gaps or holes that cause noticeable draughts and a colder home and:
  - are 3 mm or greater around windows and doors

[61] Lara Rangiwhetu, Nevil Pierse & Philippa Howden-Chapman, Effects of minor household interventions to block draughts on social housing temperatures: a before and after study | Kōtuitui: New Zealand Journal of Social Sciences Online, Volume 12, 2017 - Issue 2**Published online:** 14 Sep 2017 Pages 235-245

– are 3 mm or greater around walls, floors, ceilings and internal access hatches
– block decommissioned chimneys or fireplaces.

3.5.1. Input assumptions on draught stopping

We assume that draught stopping can be complied with by applying sealant to fill gaps around windows and doorframes, also by removing ceiling coving and sealing the junction of walls and ceiling plus the addition of draught excluders for external doors.

Table 17 shows the assumptions for the draught stopping Option (Option 2). The number of houses that might benefit from draught stopping, and the frequency with which they will need to be re-stopped, are indeterminate, so we illustrate this with an assumption that 30% of rental houses would need draught stopping.

Table 17 Input assumptions for draught stopping

All prices exclusive of GST; figures subject to rounding

Item	Low $/unit	High $/unit	Properties affected (30%)	Low aggregate property cost $m	High aggregate property cost $m
Option 2: 2 sealants@$11.56, ,[62] 2hr labour@$42.67	108	217	172,200	18.6	37.5

Source: NZIER

3.5.2. Results of draught stopping standard options

To illustrate the options' potential impacts, we assume potential health benefits from a temperature gain of 1°C across 30% of rental properties.

We assume that for houses where it is needed, draught stopping is applied in equal amounts over the first five years (i.e. a fifth of houses each year), and thereafter the stopping is replaced at five yearly intervals so there is a continuous level of activity throughout the analysis period. We also assume tenants maintain their existing heating behaviour and hence there are no changes to energy or CO_2 costs or benefits to consider, and all quantifiable benefits come through reductions in health costs.

Table 18 summarises the results. Assuming draught stopping can achieve a 1°C rise in internal temperature, this option would yield a net benefit and a healthy benefit cost ratio of 3.37 on the base assumptions. This ratio is the same regardless of what proportion of houses it is applied to – the benefit cost ratio is the same if only 30% of houses fit draught stopping or if 100% do. The table also shows that, on the assumptions used here it would break even with a benefit:cost ratio of 1.0 if it can be demonstrated to raise indoor winter-time temperatures in a house by 0.28°C or more.

The net present value would be $550 per house affected. The present value cost is $232 per house affected, higher than the one-off figures in Table 19 because all houses

[62] Costs of sealant from advice from BRANZ.

have one initial and two replacement applications of draught stopping in the analysis period, discounted to present value terms.

Draught stopping is a passive measure at relatively low cost. The benefit cost ratios would be higher with a less frequent replacement cycle, or if unquantifiable benefits could be shown to have significant additional value.

Table 18 Draught stopping costs, benefits and break-even

Present values discounted over 15 years at 4%

	30% houses and 1°C gain	30% houses and 0.28°C gain	100% houses and 1°C gain
Number of properties	172,200	172,200	574,000
Benefits PV$'000			
Unquantified benefits for school attendance, mental health and subjective well-being and comfort			
Tenants reduced costs from ill-health	131,649	36,862	438,829
Producer surplus on new suppliers	3,081	3,081	10,269
Project costs PV$'000			
Landlords' capital cost	39,943	39,943	133,108
Net present value PV$'000	**94,787**	**0**	**315,989**
Total benefits PV$'000	**134,729**	**39,943**	**449,097**
Total cost PV$'000	**39,943**	**39,943**	**133,108**
Benefit cost ratio	**3.37**	**1.00**	**3.37**
NPV per house affected $	**$548**		**$548**

Source: NZIER

3.6. Inter-linkages between standards

There are inter-linkages between proposed standards. International and New Zealand literature has established the complementarity between insulation, heating and draught: insulation alone is unlikely to lift indoor temperatures to healthy levels without additional heating, and heating alone is a costly way of reaching them. But a combination of insulation and approved heating appliances provide a means of doing so and reaching health benefits at lower cost.

There are also complementarities in the ventilation and moisture ingress standards to provide drier and healthier indoor environments. There may also be some overlaps in the sense that a house with secure windows and good ventilation may gain less benefit from addition of internal fans than one where window ventilation is restricted.

4. Impacts and variations

4.1. Accounting for government administration

Our CBA has not included government administration costs, which would be shared across the different standards being implemented. We understand government's costs on promoting, advising and enforcing the standards will be in the region of $4.147 million a year over the first 5 years of the standards being implemented, with provision for further $2.567 million a year in the years thereafter. Regulations could be in place for more than ten years similar to the Housing Improvement Regulations, but we expect the bulk of monitoring and enforcement will be in the initial retrofitting stage when the number of houses affected is highest.

These figures are based on providing for monitoring and enforcement of 2,000 new disputes arising over the standards each year, 500 being disputes arising from complaints and 1,500 being pro-active interventions.

The Treasury's Guide to Social Cost Benefit Analysis recommends multiplying government expenditure by 1.2, to represent the deadweight cost of raising taxation from the economy. This would raise the above sums to $4.976 million per year for the first 5 years and $3.080 million per year thereafter.

The present value of these sums discounted at 4% over a 15-year period would be $42.69 million. Such a cost would be large enough to outweigh the positive net present value of the Insulation standard Option 2 affecting 10,000 homes, but the insulation net benefits would exceed the government costs if the option affected 62,736 or more houses. With Insulation standard Option 3, net benefits cover government costs.

Other impacts on government administration include calls made on the Tenancy Tribunal to mediate disputes. While clearer standards might reduce disputes arising, we understand from officials that new standards are likely to increase the range of disputes in the short term until standards are bedded in and understood. We have no way of modelling this but note that there may be short-term increases in government costs with the introduction of Healthy Home Standards. These mechanisms already deal with a large volume of disputes. We understand that disputes may become potentially more complex and that agencies are anticipating future demand on dispute resolution services and planning accordingly in terms of capacity and capability.

4.2. Sensitivity to differences in values

We present results in this report mostly using assumed values at the lower end of ranges suggested by sources used.[63] The net benefit results are weakly positive or negative in all instances and using higher cost values would only accentuate those results.

Applying Treasury's 6% default public sector discount rate tends to accentuate the front-end costs and discount the future benefits more strongly, lowering the present

[63] This is not to suggest these are the lowest possible costs that individual landlords might face, as our figures represent an average across the stock of affected houses. The cost of measures exceeds the cost of do-it-yourself materials because of the opportunity cost of time taken in installation.

value of the net benefit. As for most of these standards the up-front costs of retrofitting houses dominate the cost and benefit flows, a slightly higher discount rate worsens the net benefit.

The results are more significant to changes in the values attached to individual inputs in the analysis than to variations in discount rate, as illustrated in Table 19.

Table 19 Effect of variations in key inputs

Present values discounted over 15 years at 4%; italicised numbers are variants from the original inputs

	Heating standard option: 18°C in living rooms only				Insulation standard Option 2: retrofit insulation below 2001 benchmark		
	Base results	Break-even if energy saving 40% less	BCR with mortality benefit reduced by 67%	Break-even if Health benefits 73% less	Base results	Addition of govern-ment costs	Break-even if Mortality benefit 40% less
Benefits	**PV$'000**	**PV$'000**	**PV$'000**	**PV$'000**	**PV$'000**	**PV$'000**	**PV$'000**
Tenants' health benefits	129,805	129,805	129,805	*34,725*			
Mortality benefits	100,245	100,245	*33,081*	*26,817*	78,372	78,372	*33,081*
Energy savings	476,188	*307,680*	476,188	476,188	67,387	67,387	67,387
Environmental (CO^2) benefits	9,136	9,136	9,136	9,136	1,027	1,027	1,027
Producer surplus	-45,424	-45,424	-45,424	-45,424	-2,251	-2,251	-2,251
Costs							
Landlords' capital cost	456,444	456,444	456,444	456,444	93,857	93,857	93,857
Landlords' operating costs	44,999	44,999	44,999	44,999	0	0	0
Government costs					0	*42,689*	0
Net present value PV$'000	**168,508**	**0**	**101,344**	**0**	**50,677**	**7,988**	**5,386**
Total benefits PV$'000	**669,950**	**501,443**	**602,786**	**501,443**	**144,534**	**144,534**	**99,243**
Total cost PV$'000	**501,443**	**501,443**	**501,443**	**501,443**	**93,857**	**136,546**	**93,857**
Benefit cost ratio	**1.34**	**1.00**	**1.20**	**1.00**	**1.54**	**1.06**	**1.06**

Source: NZIER

This shows that, other things held constant, the base analysis of having heaters to reach 18°C in living room would break-even if energy savings were 40% smaller, or if the combined health and mortality benefits were 73% smaller than initially assumed.

It also shows the reduction in the benefit cost ratio for both heating and insulation if mortality benefits were 67% smaller, as indicated by recent OECD reports.[64] Table 19 also shows variations in key inputs to the base analysis of the insulation standard option 2 for 70,000 homes. The net present value is sufficiently large to absorb all the costs of government administration identified above. Both insulation options 2 and 3 would cover all government costs if more than 58,970 houses get new insulation.

Table 20 illustrates the effects of higher cost inputs on the draught stopping and ventilation options. The biggest difference compared to the low cost inputs is in Kitchen fans, which uses a cost of $800 fitted compared to $260 in the base estimates.

Table 20 Effect of high input costs on draught stopping and ventilation options

Present values discounted over 15 years at 4%

	Draught stopping	Window stays	Bathroom fans	Kitchen fans
Benefits				
Number of properties	172,200	287,000	252,560	212,380
Benefits	***PV$'000***	***PV$'000***	***PV$'000***	***PV$'000***
Tenants reduced costs from ill health	110,509			
Producer surplus on new suppliers	5,280	3,338	4,028	10,418
Project costs				
Landlords Capital cost	68,455	43,281	52,219	135,051
Increase in energy costs	0	0	15,325	31,723
Net present value	**47,334**	**-39,943**	**-63,517**	**-156,356**
Total benefits	**115,789**	**3,337**	**4,027**	**10,418**
Total cost	**68,455**	**43,281**	**67,544**	**166,774**
Benefit cost ratio	**1.69**	**0.08**	**0.06**	**0.06**
Size of unquantified benefit needed to break even **PV$'000**	-47,334	39,943	63,517	156,356
Unquantified benefit per house affected **PV$**	-275	139	251	736
Annualised value per house affected **$/year**	$24.72	-$12.52	-$22.62	-$66.22

Source: NZIER

The benefit cost ratio on draught stopping is about half what it was in the low cost input analysis, due to the draught stopping cost per house rising from $108 to $217. It still yields a positive net benefit and highest benefit cost ratio of all the options on the assumptions used in this analysis. The other three ventilation options all yield a net

[64] Navrud, S., Braathen, N. A., Biausque, V. (2011) Valuing mortality risk reductions from environmental, transport and health policies: Policy Implications. Paris: OECD.

cost, but as shown in the table, when averaged across houses and annualised, the net cost could be offset by unquantifiable benefits valued between around $13 and $66 per house affected per year.

Table 21 shows the results of higher input costs on Option 2 components and Option 3 of the sub-floor moisture ingress standard. These result in net costs that are all slightly higher than in the low input cost assumptions. However, when averaged across houses and annualised these costs could be offset by unquantified benefits of a value of around $56-$63 per year.

Table 21 Effect of high input costs on sub-floor moisture ingress

Present values discounted over 15 years at 4%

	Option 2 barrier	Option 2 vents	Option 2 combined	Option 3 barrier
Number of properties	143,959	47,986	191,946	353,354
Benefits	***PV$'000***	***PV$'000***	***PV$'000***	***PV$'000***
Tenants' reduced costs from ill health				
Producer surplus on new suppliers	7,446	2,792	18,276	18,276
Project costs				
Landlords' Capital cost	96,522	36,211	236,897	236,897
Increase in energy costs				0
Net present value	-89,077	-33,419	-218,621	-218,621
Total benefits	7,445	2,792	18,276	18,276
Total cost	96,522	36,211	236,897	236,897
Benefit cost ratio	0.08	0.08	0.08	0.08
Size of unquantified benefit needed to break even **PV$'000**	89,077	33,419	122,495	218,621
Unquantified benefit per house affected **PV$**	619	696	638	619
Annualised value per house affected **$/year**	-$55.65	-$62.64	-$57.40	-$55.65

Source: NZIER

4.3. Effects on rents

In a CBA, items like rents are generally regarded as transfer payments with no impact on the analysis outcome: what tenants pay as costs landlords receive as benefits, having no effect on the balance of costs and benefits. We consider them in this analysis to illustrate the potential effect of standards on tenants' disposable incomes. We estimate rents by annualising the capital costs for landlords of meeting the standards, dividing by the number of houses affected to get an annual average which can then be divided by 52 to give a weekly average.

Table 22 Annualised and weekly costs of measures per property

Annualised over 15 years at 4% real interest rate

GST exclusive	Annual $	Weekly $	Affected rental properties
Insulation Options	$130.23	$2.50	10,000-190,000
Heat Option Living rooms only	$274.18	$5.27	285,219
Heat Option Bedrooms	$28.33	$0.54	125,951
Ventilation – Window stays	$25.67	$0.49	143,500
Ventilation – Mechanical bathroom fans	$16.35	$0.31	252,560
Ventilation – Mechanical kitchen fans	$19.67	$0.38	212,380
Moisture ingress Option 2 – Subfloor vents	$166.30	$3.20	47,986
Moisture ingress Options 2 and 3 – Barrier	$60.71	$1.17	353,354
Draught stopping – Option 2	$9.75	$0.19	126,280

Source: NZIER

Depending on what counts as compliance, the different measures could accumulate to a significant imposition on some properties (especially the multiple measures under the ventilation standard), although we expect most properties will be partly compliant and not need to implement all these requirements. But it is unlikely that landlords would pass these costs through in full. Most private landlords hold property in hope of capital gain as much as for rental income, and will likely be reluctant to incur the opportunity cost of vacancy and expense of recruiting new tenants by raising rents for works when other properties may not be doing so.

The tighter the rental supply relative to demand the more likely it is that costs can be passed through. Tight supply is most likely in main cities or smaller centres experiencing significant growth, such as tourist centres where short-term holiday lets may be more lucrative than long-term tenancies. In rural and provincial areas where supply is more abundant relative to demand, that may not be the case. Where market conditions do not allow the pass through of full costs, landlords will bear some of the cost in anticipation of future capital gain.

On current estimates used here it would cost in the region of $7,500 to $10,000 excluding GST to outfit a house to comply with all the standards (assuming it was deficient in all of them to begin with). GST is not chargeable on residential rents so GST on installations or retrofits in complying with standards is a business expense, which landlords may try to recover from tenants through rents if supply and demand conditions allow them to do so.

The figures above are not a prediction of what landlords will seek to recover in rent. Landlords will have their own expected pay-back periods and cost of borrowing to factor into their decisions, as well as their assessments of external market conditions. The figures simply indicate the scale of costs that are implied by complying with the standards, on the current cost assumptions.

4.4. The impacts on rental markets

Apart from impacts on rents, it is possible that new regulatory impositions, if substantial for individual houses, may prompt some landlords to dispose of them or divert them to some other use not covered by the residential tenancy standards. If they sell them to some other would-be landlords there would be no net change in the market. If they sell them into the owner-occupier market there could be a reduction in rental properties but possibly a removal of one potential client from the demand for rental properties. More significant would be if properties get redeveloped for purposes entirely removed from the long-term rental market, for instance conversion to holiday homes or tourist accommodation.

This CBA is not designed to estimate the effects on long term rental housing supply. We simply note the possibility of some houses being withdrawn from the market if the cumulative effect of standards appears excessive to their owners.

4.5. Distributional matters

The primary purpose of a cost benefit analysis is to examine whether a proposal is worthwhile in the sense that its aggregate benefits exceed its costs. In identifying where such costs and benefits fall it provides some information on the distributional impacts of what is being proposed.

The cost benefit tables in this report outline the main distributional consequences of introducing healthy homes standards. They are:

- Tenants and members of their households receive the benefits of warmer and drier homes, such as lower health costs and reduced mortality risk, and possibly reduced moisture damage and cleaning/replacement costs. They may also enjoy energy cost savings if insulation, draught stopping or more efficient heaters allow them to achieve the same or better temperatures and comfort for less energy input
- Insulation and appliance supply industries and parts of the building trades will face an increased demand for their services, particularly during the retrofit boom. There will be opportunities for improving their capacity utilisation and earning additional profit or producer surplus although probably not large in the overall impact of the standards.
- Landlords face the costs of complying with the standards in the first instance, which includes both the cost of retrofitting changes to property and also the costs of understanding their obligations and resolving disputes that may arise.
- The wider community, and taxpayers, benefit from any reduction in greenhouse gas and other emissions that arise from improvements in insulation and heating efficiency, with a financial value that accrues to those holding obligations for emissions (e.g. electricity generators) and the government to the extent that improved health reduces pressure on

publicly funded health services, and carbon price caps and other measures under emissions trading arrangements shift some responsibility for emissions to the government.

The costs to landlords may be passed on to tenants to varying degree in different parts of the country (see above). Government and taxpayers also benefit to the extent that healthier homes reduce demands on publicly funded services in health and other social support. These are difficult to predict and not covered in our modelling.

4.6. Effects on employment

The proposed standards would require a large proportion of the rental housing stock to undertake retrofitting to comply. This will create demand for certain skills and material supplies and stimulate employment in the industries that supply them.

That may lead to price increases for some skills and services, particularly at a time when other policies are aiming to increase the construction of new homes. It would also be relatively short-lived until the hump of retrofits is completed, as meeting standards can more easily be accommodated within building of new houses. For this reason, a phased introduction of standards may be less disruptive than a short introduction all at once.

4.7. Caveats and limitations

This report has been prepared within a short period of time, and with a deficiency of information on which to assess the costs and benefits of the six[65] standards and their options being considered. This means a number of the standards produce negative net benefits under this analysis, raising the question of whether there are other unquantified matters that would have economic value sufficient to outweigh the deficit and overturn these results.

The principal drivers of results are the large number of houses potentially affected by the ventilation and moisture ingress standards and the absence of reliable monetary values for benefits from removing moisture from homes.

Costs are usually more tangible and readily quantified than benefits, particularly where the benefits involve matters such as health or other social outcomes. This analysis has used updated values used in previous analyses to provide continuity in how such matters have been viewed in the WUNZ studies.

The report is not a forecast of what will happen, rather it is intended to indicate the scale of impacts that may arise if standard compliance is rolled out in the form and scale reflected in the modelling.

[65] The sixth standard concerns drainage, which is combined with moisture ingress in the Healthy Homes Standards Discussion Document and not analyses separately in this cost benefit analysis

Appendix A Characteristics of New Zealand housing

There is no detailed inventory of the heating and insulation characteristics of housing in New Zealand, so a model of the stock of housing and its heating capabilities must be built from existing sources. Principal sources on the heating characteristics of residential housing in New Zealand are the Census and the BRANZ Housing Condition Survey and Household Energy Efficiency Project (HEEP) reports.

Key characteristics of the housing stock and differences between owner occupied and rented properties are illustrated in Table 23. This shows that compared to owner-occupied homes, rental properties tend to be smaller (with a much higher proportion of 1 and 2 bedroom houses), older (with a much smaller proportion of houses built since 1980), are less likely to have fixed heaters and are more likely to lack ceiling insulation. As some rental houses may have been upgraded since 2015, and all are required to comply with existing legislation concerning insulation, not all of these characteristics are part of the issue to be addressed by the new standards.

Table 23 Characteristics of New Zealand Housing Stock

	Owner occupied	Rented
Bedrooms in median house	3	3
Bedrooms at 16th percentile	3	2
Bedrooms at 83rd percentile	4	4
Share of 1 & 2 bedroom houses	16%	40%
Share of houses built after 1980s	41%	25%
Share of houses built 1950-1980	40%	53%
Share of houses built pre-1950	19%	22%
Houses without fixed electric heaters	41%	57%
Houses without flued gas heaters	86%	90%
Houses without solid fuel heating	51%	64%
Houses without fixed heaters	7%	23%
Houses having no ceiling insulation	2%	6%
Houses having no underfloor insulation	21%	21%
- without fixed heating & roof insulation	0.3%	2%
- without fixed heating & floor insulation	4%	7%

Source: NZIER, drawing from Census 2013 and BRANZ Housing Condition Survey 2015

Appendix B Literature review

Internationally it is recognised that when indoor living area temperatures fall below 16°C in winter months there is increased risk of exacerbating cardiac, circulatory and respiratory ailments. Cooler houses tend to experience higher relative humidity, increasing the likelihood of dampness and condensation which in turn can result in growth of moulds whose spores can aggravate allergies and conditions like asthma. Warmer, drier houses therefore have the potential to reduce a range of adverse health effects as well as affecting energy efficiency and associated emissions from energy sources. Measures to achieve warmer houses, including retrofitting insulation in existing houses that form the bulk of the housing stock and improve heating capacity, therefore appear to offer multiple benefits which may not all be recognised by those directly affected, and could warrant public intervention.

The UK has a higher rate of excess winter mortality than most of its European neighbours and has developed Cold Weather Plans for England which previously recommended minimum indoor temperature thresholds of 21°C for living rooms and 18°C for bedrooms. These recommendations were derived from a number of policy and research papers including the World Health Organization's (WHO) report 'Health Impacts of Low Indoor Temperatures'.[66] In 2014, Public Health England revisited the evidence on indoor temperature thresholds and reviewed whether the recommendations should be updated.[67] This was in recognition of the importance of protecting health whilst reducing carbon emissions and avoiding unnecessary expenditure on fuel, and the guidance on which these original thresholds were based now being over 30 years old.

Whilst there is strong indication that cold homes have a harmful effect on health, the findings of this literature review demonstrated that there is very limited robust evidence on which to base these recommendations. Accordingly, the cold Weather Plan for 2016[68] was revised to focus on 18°C as the critical threshold, particularly for people 65 years and over or with pre-existing medical conditions who may find benefit with temperatures slightly above this threshold. It also noted healthy people below 65 years who are active and wear appropriate clothing may heat their homes to slightly less than 18°C.

Building on an earlier review[69], Fenwick et al (2013)[70] reviewed 45 international studies on the relationship between housing and health, of which 25 included some details on

66 World Health Organisation (WHO) 1987: Health Impact of Low Indoor Temperatures. Available at: http://www.theclaymoreproject.com/uploads/associate/365/file/Health%20Documents/WHO%20-%20health%20impact%20of%20low%20indoor%20temperatures%20(WHO,%201985).pdf

67 Public Health England (2014) Minimum home temperature thresholds for winter: a systematic literature review; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/468196/Min_temp_threshold_for_homes_in_winter.pdf

68 Public Health England (2016) The Cold weather Plan for England; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/652564/Cold_Weather_Plan_2017.pdf

69 Thomson H, Thomas S, Sellstrom E & Petticrew M (2009) The health benefits of housing improvements – a systematic review of intervention studies from 1887 to 2007; American Journal of Public Health Am J Public Health. 2009 November; 99(Suppl 3): S681–S692

70 Fenwick E, MacDonald C and Thomson H (2013) Economic analysis of impact of housing improvement studies – a systematic review; J Epidemiol Community Health. 2013 Oct; 67(10): 835–845

intervention and/or recipient costs only. They find that, despite sufficient data, opportunities to conduct economic analysis have most often been missed. Four studies conduct evaluations of costs and benefits but most of these reported analyses they describe as a 'balance sheet' rather than a true cost benefit analysis.

Fenwick et al summarise results of several studies that provide numerical estimates of different health outcomes from home improvements, mostly from the UK but also some from New Zealand. The international studies include Mackenzie et al (2000), Eick et al (2004) and Barton et al (2007),[71] which include estimates for various avoided costs for the health service and values for changes in days off school. These studies are not all widely available from web sources and the basis of their calculations and relevance for New Zealand (coming from the UK where central heating is widespread) are unclear.

Somerville et al (2000) report an evaluation of health outcomes in the UK following specific housing improvements from the installation of central heating.[72] This improved energy efficiency of heating, raised indoor temperatures and controlled moisture: initially 92% of children's bedrooms in affected houses were unheated and 61% were damp, but these proportions dropped to 21% and 14%, respectively after central heating was installed. However, indoor temperature gains were not reported. After intervention, occupants' respiratory symptoms of all types were significantly reduced, and school-days lost to asthma for school-age children fell from 9.3 days per 100 days before intervention to 2.1 days afterwards; but days off school for other reasons rose from 1.4 days per 100 days to 3.2. Lack of a comparison group means that effects of age, season and reporting bias could not be controlled for.

In New Zealand such analysis has been more oriented towards insulation against heat loss and noise, as in analysis prepared by BRANZ regarding changes in the Building Code in 2007. A few studies have specifically examined the effect of heating on vulnerable sub-sets of the population (e.g. asthmatic children)[73]. More recently, a set of analyses have been prepared around the Warm Up New Zealand: Heat Smart (WUNZ) programme for upgrading insulation and heating appliances.

Heating characteristics of New Zealand housing are available from BRANZ's Housing Condition Surveys and its Household Energy End-use Project (HEEP), the final report from which was completed in 2010. Drawing from that report, Table 24 shows that in the winter-time months of June through to August, living room temperatures are generally below 18^{o}C and bedroom temperatures are below 16^{o}C, but both fluctuate over the day, falling below 14^{o}C in bedrooms overnight (12pm-7am) and early morning (7-9am). Temperatures in the evening (5pm-11pm) are a couple of degrees warmer than the rest of the day (9am-5pm), and temperatures in bedrooms tend to be around 1-2 degrees below those in living rooms. In the summer months of December through

71 Mackenzie IF, Buckingham K, Somervile M, et al. Housing & Health Paper 2: A health economic study to estimate the costs and benefits of the use of NHS funds to install heating in the houses of children with asthma. *Housing & Health—the Cornwall intervention study: a report to the trustees of EAGA charitable trust* St Austell: Cornwall and Isles of Scilly Health Authority, 2002

Eick SA, Houghton N, Richardson G. The breath of fresh air project: draft report for comments September 2004. Plymouth: AC & T England Ltd, 2004

Barton A, Basham M, Foy C, et al. The Watcombe Housing Study: the short term effect of improving housing conditions on the health of residents. J Epidemiol Community Health 2007;61:771–7[PMC free article] [PubMed]

72 Somerville M, Mackenzie I, Owen P & Miles D (2000) Housing and health: does installing heating in their homes improve the health of children with asthma? Public Health, 114(6) 434-9

73 Howden-Chapman P, Pierse N, Nicholls S, et al.(2008) Effects of improved home heating on asthma in community dwelling children: randomised controlled trial. BMJ 2008;337:1411a [PMC free article][PubMed]

to February, mean temperatures are comfortably above 18°C, although there are small proportions of houses either below 16°C or above 25°C.

Table 24 Mean temperatures by room and period through the day

°C	Morning 7am-9am	Day 9am-5pm	Evening 5pm-11pm	Night 12pm-7am
Winter-time Living Room	13.5	15.8	17.8	14.8
Winter-time Bedroom	12.6	14.2	15.0	13.6
Winter Ambient	7.8	12.0	9.4	7.6
Summer time Living Room	19.2	21.8	23.1	20.3
Summer time Bedroom	19.1	21.2	22.6	20.1
Summer Ambient	15.8	20.1	17.9	14.5

Source: BRANZ HEEP Final Report (2010), Table 34 and Table 48

A BRANZ paper by Boulic et al (2007) monitored 36 houses in the Hutt Valley participating in the Otago University Medical School's Housing, Heating and Health Study (HHHS) during the winter of 2006, of which 21 had a higher capacity heater installed (flued gas, heat pump or pellet burner) and 15 continued with their existing heaters. Those with new heaters operated them for longer than those with old heaters, attaining average winter-time living room and bedroom temperatures that were 17.8°C and 15.6°C, respectively – an increase of 2.3°C and 1.3°C over houses with old heaters.[74]

Lloyd et al (2008)[75] examined the physical effects of a government-sponsored residential insulation upgrade programme in New Zealand with data gathered from 100 houses in Dunedin over a two-year period, finding upgraded houses had increases of 0.4°C in annual average temperatures and 0.6°C increase in the average for winter months, but indoor temperatures remained well below WHO guidelines of 16°C minimum, and were less than 12°C for nearly half of the 24 hour day during the three winter months. They concluded that upgrading insulation without also addressing the adequacy of heating contributed to this result of limited temperature increase, a finding that is reflected in international literature.[76]

Reporting on the HHHS, Howden-Chapman et al (BMJ 2008) found that replacing old heaters with clean heating devices in a randomised controlled trial of 369 houses in families with asthmatic children resulted in an average heating rise in winter of 1.1°C in living rooms and 0.57°C in bedrooms and reduced symptoms of asthma in the children: compared to a control group, children in houses with new heaters had 1.8

[74] Boulic,M, Fjallstrom P, Phipps R, Cunningham M, Cleland D, Howden-Chapman P, Chapman R & Viggers H (2007) "Cold homes in New Zealand – Low Heater Capacity or Low Heater Use?" http://www.branz.co.nz/cms_show_download.php?id=fe9084ea793a665fc66be4d14907b2ccde10d4a3

[75] Lloyd CR, Callau MF, Bishop T & Smith IJ (2008) "The efficacy of an energy efficient upgrade program in New Zealand"; *Energy and Buildings* 40, 1228-1239

[76] Gustafsson S (2000) "Optimisation of insulation measures on existing buildings, *Energy and Buildings* 33 1459-1471

fewer days off school and made 0.4 fewer visits to the doctor and 0.25 fewer pharmacy visits per year.[77]

Viggers et al (2013) examine the health effect of paying $500 into household accounts to cover the cost of winter-time heating on people with Chronic Obstructive Pulmonary Disease (COPD). Part of a Warm Homes for Elderly New Zealanders study, no results are recorded in this paper.[78]

The University of Otago Wellington Medical School provide estimates of health effects and their value in the evaluation and subsequent cost benefit analysis of the Warm Up New Zealand: Heat Smart (WUNZ) programme.[79] This involved an ex post evaluation of the scheme, in which specific properties that received "treatment" by installing new insulation and/or heating systems were compared against a control population of similar housing across the country. It concluded that retrofitted insulation had a significant impact on reducing hospitalisation and pharmaceutical costs for occupants, and also contributed considerable benefit per household in reduced. The evaluation estimated the change in monthly hospitalisation costs of $5.37 across all treated households, ranging up to $8.96 for those households including people with respiratory illness and asthma, and slightly higher savings for households with Community Services Card holders who initially had poorer health than households as a whole (total hospitalisation costs savings of $9.15 per month).

The WUNZ evaluation found installation of new heaters after insulation was in place did not significantly reduce hospitalisations. The authors suggest this could be because receiving the subsidy for improved heating was conditional on adequate insulation already being installed, so the incremental gain from heating appliances would be small. More importantly, it attributes no benefit to new heaters for the value of reduced mortality, so the value of heating is limited to its small contribution to additional benefits, such as reduced days off work and school. These conclusions are to be expected: insulation is a passive measure which, once installed, improves the heat retention of any heat emitting appliances in the room, including heaters, stoves (in open plan kitchen/living areas) audio equipment and so on. Improved heaters require the active participation of occupants to use them in ways that boost internal temperatures, so the heat improvement is not only marginal over the heat that would have been provided by existing heaters, but also dependent on behavioural responses of occupants.

A broader evaluation was provided in the *Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Programme*.[80] Drawing on the health benefits of the WUNZ evaluation, this attributed no health benefits from avoided hospitalisations or deaths to new heaters, and found their net benefits to be marginal across a range of assumption variants.

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77 Howden-Chapman P et al (2008) Effects of improved home heating on asthma in community dwelling children: randomised controlled trial; BMJ 2008;337:a1411

78 Viggers H, Howden-Chapman P, Ingham T, Chapman R, Pene G, Davies C, Currie A, Pierse N, Wilson H, Shang J, Baker M, Crane J (2013) Warm homes for older people: aims and methods of a randomised community-based trial for people with COPD; BioMed Central *BMC Public Health* 2012, 13:176

79 Telfar-Barnard LT, 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*

80 Grimes A, Denne T, Howden-Chapman P, Arnold R, Telfar-Barnard L, Preval N & Young C (2012) *Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Programme;* Report for Ministry of Business Innovation and Development

Table 25 Annual health benefits per household from WUNZ study

	All households		Community Service Card -holder households		Non-Community Service Card households	
Full sample	**Insulation**	**Heating**	**Insulation**	**Heating**	**Insulation**	**Heating**
Hospitalisation and pharmaceutical use related	$75.48	$0.00	$109.80	$0.00	$11.04	$0.00
Additional benefits imputed from previous studies	$95.49	$9.27	$95.49	$9.27	$95.49	$9.27
Value of reduced mortality	$465.36	$0.00	$649.11	$0.00	$229.11	$0.00
	$636.33	**$9.27**	**$854.40**	**$9.27**	**$335.64**	**$9.27**

Source: NZIER, drawing from Grimes et al 2012 (Table 20)

A factor contributing to this result is that under the WUNZ programme there was a lower uptake of new heaters amongst those on low incomes than by those in other income categories. Low income households, who might be expected to gain more from improved heating because of higher occupancy and lower initial heating capacity, accounted for 40% of insulation installations under the programme, but only 33% of new heater installations. The WUNZ study assumed that 74% of installations of insulation and heaters were additional to installations that would have happened anyway without intervention, i.e. 44,870 of the over 60,000 houses that received installations would not have occurred without the programme.

The WUNZ evaluation and CBA provide a large observational study of the effects of changing the insulation and heating equipment of a cross section of houses.[81] The studies do not assess the change in overall heating capacity of the houses, nor do they calculate changes in average or winter-time indoor temperatures. But they do reflect some behavioural change, as installation of new heating capacity capable of reaching higher indoor temperatures would be determined for individual houses by the approved quotes for new heater installation customised for each house.

A subsequent *Warm-up New Zealand evaluation rental sector sub-analysis: differences in health events and costs by existing insulation status*,[82] examined whether, after insulation, there was any difference in the costs of health service utilisation between the subset of treated households and their control households compared to the period before the new installations. It identified a rental cohort of 12,432 properties receiving treatment under WUNZ, of which 2,012 had some existing insulation and 11,886 had no existing insulation. It also concluded there were too few rental households installing ground ground moisture barriers or draught-stopping separately from other interventions to measure their effects independent of other interventions.

That analysis found there was no statistically significant change in hospital events for the total rental population, irrespective of whether it had existing insulation or not,

[81] Grimes A, Denne T, Howden-Chapman P, Arnold R, Telfar-Barnard L, Preval N & Young C (2012) *Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Programme;* Report for Ministry of Business Innovation and Development

[82] Telfar Barnard L & Preval N (2018) *Healthy Homes Guarantee Standard Cost Benefit Input: Warm Up New Zealand evaluation rental sector sub-analysis: differences in health events and costs by existing insulation status*; Housing and Health Research Programme, University of Otago Medical School, Wellington May 2018

but there were statistically fewer hospitalisations among children aged under 5 years. This produced a saving in hospitalisation costs for households with children under 5 of $73.21 per household treated, or $91.66 for properties without prior insulation. The rental property cohort was too small to produce meaningful results for mortality analysis, so this analysis looked at the full cohort but limited to people over 64 with a prior circulatory hospitalisation, and further limited it to those who received ceiling insulation. This found there was a significant benefit from reduced mortality for this sub-group compared to the control group, which was valued at $759.11 per household treated. That was counter-intuitively higher for households with some existing insulation ($934.72) than for households with no existing insulation ($733.90), although that difference was not statistically significant. Overall this report found there was no statistically significant difference in benefits of ceiling insulation between those houses with existing insulation and those without it.

The major health benefit from the WUNZ studies comes from reduced winter-time mortality. This is based on the notion of averting premature death valued at $150,000 per life year gained. That value is derived from the value of prevented fatalities (VPF) used in transport appraisals in New Zealand, which is based on drivers' willingness to pay to achieve small reductions in probability of fatal accident, scaled across the population to indicate a societal willingness to pay to avoid the death of anonymous individuals on the roads. The life year value is calculated by treating the VPF as the discounted present value of life years lost at the average age of accidental death, i.e. if the "average aged" fatality is around 40 a further 40 years of life expectancy is lost, which can be annualised by treating the VPF as its capitalised value. While it is pragmatic to calculate life years from VPF in this fashion, it is a practice without sound theoretical or empirical justification, and recent reviews by the OECD recognise that direct estimation of WTP for variations in expected longevity is the appropriate way to value life years (OECD 2012).

Lindhjem et al (2010)[83] undertook a meta-analysis of estimates of VPF across OECD countries, identifying methods used and the range of values obtained. Navrud et al (2011)[84] built on this to recommend that if a value of life year is to be used it should be based on primary surveys valuing gains in life years on the same basis as the VPF. They found only a few such surveys have been done to date: one by Chilton et al (2004) estimated values per life year of £29,000 for people of normal health and £15,000 for people of poor health that was used by the UK government to assess measures to improve air quality; another by Desaigues et al (2009) estimated values across 9 European countries in the range of €25,000 to €100,000, on which the Norwegian government based its general guidelines. In all cases the value of a life year is under 3% of the corresponding VPF, much smaller than is implied by the $150,000 annualisation of VPF. At the discount rates and years usually employed, annualisation is likely to overstate value per life year when compared against estimates of willingness to pay to reduce life years lost using the same process as the estimation of VPF.

Treasury's CBAx model cites a figure used by Pharmac of around $45,000 per life year (in 2012 dollar terms, contemporaneous with WUNZ) which is more in keeping with

83 Lindhjem, H and S Navrud (2010) Meta-analysis of stated preference VSL studies: Further model sensitivity and benefit transfer issues Paris: OECD.

84 Navrud, S., Braathen, N. A., Biausque, V. (2011) Valuing mortality risk reductions from environmental, transport and health policies: Policy Implications. Paris: OECD

overseas studies that directly estimate willingness to pay in the same way as the VPF.[85] On that basis the mortality benefits would be about 1/3 of those used in the WUNZ analysis, reducing its benefit cost ratio from 3.9 to 1.2 – still positive, but less robust to changes in input assumptions.

We value mortality following the approach in WUNZ, as a value in proportion to the number of houses treated, rather than changes in degree of temperature. Although a value of $60,000 per life year gained would be more in keeping with the international literature on valuation approach, we use an updated value of WUNZ of $1,120 benefit per household receiving heating or insulation improvements.

Table 26 Annual health benefits per household adjusted from WUNZ study

Mortality benefits estimated at lower value per life year; 2012 values updated to 2018 by CPI

	All households	Community Service Card -holder households		Non-Community Service Card households		
Full sample	**Insulation**	**Heating**	**Insulation**	**Heating**	**Insulation**	**Heating**
Hospitalisation and pharmaceutical related	$80.01	$0.00	$116.39	$0.00	$11.70	$0.00
Additional benefits imputed from previous studies	$101.22	$9.83	$101.22	$9.83	$101.22	$9.83
Value of reduced mortality	$164.43	$0.00	$229.35	$0.00	$80.95	$0.00
	$345.66	**$9.83**	**$446.96**	**$9.83**	**$193.87**	**$9.83**

Source: NZIER, drawing from Grimes et al 2012 (Table 20)

Davie et al (2007) examined New Zealand mortality records over the period 1980-2001, finding an excess of 1600 deaths in winter time over that period with little variation according to region, ethnicity or other socio-economic characteristics.[86] Hales et al (2015) examined mortality in the three years following four Census years (1986-2001) and found increased risk of dying in winter for most New Zealanders, but more so among low-income people, those living in rented accommodation and those living in cities, but causal mechanisms are unknown although could include poor housing and indoor temperatures.[87] The literature on excess winter mortality identifies an effect but not a quantitative relationship that can inform this CBA.

85 Desaigues, B, D Ami, A Bartczak, M Braun-Kohlová, S Chilton, M Czajkowski and J Urban (2011) Economic valuation of air pollution mortality: a 9-country contingent valuation survey of value of a life year (VOLY). *Ecological Indicators 11*, no.3: 902–910

86 Davie GS, Baker MG, Hales S and Carlin JB (2007) Trends and determinants of excess winter mortality in New Zealand: 19080-2000; BioMed Central BMC Public Health 2007, 7:263

87 Hales S, Blakely T, Foster RH, Baker MB, Howden-Chapman P (2010) Seasonal patterns of mortality in relation to social factors, JECH Online First, 10.1135/jech.2010.111864

Beyond heating and insulation

In 2014 Sapere Research Group prepared for MBIE a Cost benefit analysis for 29 separate requirements for rental properties to meet with respect to insulation and dryness, safety and security fittings and essential amenities (e.g. functioning doors and wired power points). This included a minimum temperature requirement from installation of insulation or a heat pump, assuming that, contrary to the WUNZ studies from which health benefit values were drawn, installation of a heat pump provided the same health benefits as insulation. There is little detail on specific measures for dryness in this report and it provides no new insight into the benefit from degrees of indoor temperature improvement.

Also, in 2014, MBIE issued a report by Marcus Bosch on a Trial of a Rental Housing WOF, which found in its sample of 400 properties 17 (4%) were Fully Compliant, 193 (48%) Non-Compliant but remediable within 2 days; 127 (32%) Non-Compliant but remediable within 10+ days; and 63 (16%) Non-Compliant but on Low or Moderate risk criteria. Extrapolated to 60,000 properties, the total estimated cost to remediate all noncompliant Warrant of Fitness criteria was $34,573,837.

A number of studies have looked at airtightness and ventilation. BRANZ SR341 (2015) examined the role for acceptable ventilation in modern houses which are more airtight than formerly, and found that some houses are under-ventilated when closed up and do not provide the acceptable range of air changes per hour (0.3-0.5 m^3/hour). Reports from two test houses yielded some results showing small heat gains from improved moisture control with supplementary ventilation, but this provides too little information on which to extrapolate across the wider rental housing stock.

Another BRANZ report from 2015 (SR333) examined the value of sustainability and resilience features in housing, using an econometric technique known as hedonic pricing to examine how much house prices reflected such features. This found that solar power capacity added $7000 to the value of houses in Nelson but its small sample size and large range of other explanatory variables that needed to be accounted for meant that little weight could be placed on this result.

BRANZ SR389 (2018) examines to what extent low indoor temperatures determine high moisture levels in houses. It tests how relative humidity could be lowered by increasing the heating level inside homes, rather than the inverse question of managing relative humidity by reducing moisture ingress to enable healthier temperatures to be more easily and affordably attained.

A recent study of tenants in a newly upgraded social housing complex who complained of being cold examined effects on temperatures before and after minor household interventions to block draughts.[88] These interventions included sealing strips around doors and baffles in rangehoods. Indoor temperatures were measured subjectively and objectively and were found to be on average 1-1.36°C warmer post-intervention after adjusting for outdoor temperature. This study was however confined to a survey

[88] Lara Rangiwhetu, Nevil Pierse & Philippa Howden-Chapman, Effects of minor household interventions to block draughts on social housing temperatures: a before and after study | Kōtuitui: New Zealand Journal of Social Sciences Online, Volume 12, 2017 - Issue 2 **Published online:** 14 Sep 2017 Pages 235-245

of 5 single bedroom flats in Wellington with south facing aspects – a weak base for extrapolating across the entire rental housing stock.

Even more so than with heating and insulation, the literature on residential ventilation, draught stopping and controlling moisture ingress is limited by small sample sizes and studies that do not provide information on relationships between house condition and beneficial outcomes ideally suited to cost benefit analysis.