BRANZ

Study Report

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Warm, dry, healthy?

Insights from the 2015 House Condition Survey on insulation, ventilation, heating and mould in New Zealand houses

Vicki White and Mark Jones

1222 Moonshine Rd
RD1, Porirua 5381
Private Bag 50 908
Porirua 5240
New Zealand
branz.nz

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Preface

This report presents results from the 2015 BRANZ House Condition Survey on the presence of insulation, ventilation, heating and mould.

Acknowledgements

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- the assessors who undertook the house assessments.

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Abstract

The BRANZ House Condition Survey (HCS) provides a snapshot of the state of New Zealand housing at a point in time. The latest round of the survey, completed in 2015/16, surveyed a total of 560 houses throughout the country. The data has been weighted to be proportionally representative of owner-occupied and rented stock in New Zealand. This report presents findings from the 2015 HCS on key factors associated with, and indicative of, a warm, dry, healthy home: insulation, ventilation, heating and mould.

Insulation: Results suggest just under half of houses (47%) have less than 80% coverage of 120 mm insulation in the roof space. Just under one-fifth of houses (19%) have less than 80% coverage of subfloor areas. Combined, this suggests over half (53%) of houses could benefit from retrofitted insulation in the roof space and/or subfloor.

Ventilation: Mechanical extract ventilation in kitchens and bathrooms is important to prevent problems of damp and mould. Half of main bathrooms and half of all kitchens did not have mechanical extract ventilation to the outside.

Heating habits: Overall, 5% of households did not usually heat living areas at all in winter, and almost half did not usually heat any occupied bedrooms in winter. Without any heat input in winter, it is unlikely the indoor temperature would always achieve the World Health Organisation minimum recommended level of 18°C.

Heating appliances: Results suggest rental households have less access to more cost-effective heating appliances (heat pumps, wood burners and flued gas heaters) than owner-occupiers. Instead, rental households were more reliant on portable

heaters, which are typically more expensive to run and less effective for heating larger living spaces. These included unflued gas heaters, which are known for their risks to occupant health. Portable unflued gas heaters were more common in rental properties, being used for winter heating in 17% of living areas and 6% of bedrooms. Use of unflued gas heaters in bedrooms goes against Ministry of Health advice.

Damp and mould are key indicators of poor-quality indoor environment. Rental properties were twice as likely to smell damp than owner-occupied houses and nearly three times as likely to feel damp. Mould was visible in nearly half of all houses surveyed and was slightly more common in rentals. Mould was observed less frequently in houses where insulation and ventilation were present and heating was used. However, further analysis of the HCS is needed to explore these findings, as there will be many interrelating factors affecting these results.

Keywords

House Condition Survey, insulation, ventilation, heating, mould.

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Executive summary

The BRANZ House Condition Survey (HCS) provides a snapshot of the state of New Zealand's housing at a point in time. The latest round of the survey, completed in 2015/16, surveyed a total of 560 houses throughout the country. The data has been weighted to be proportionally representative of the owner-occupied and rented housing stock. This report presents results on key factors associated with, and indicative of, a warm, dry, healthy home: insulation, ventilation, heating and mould.

Insulation – minimising heat loss

New Zealand studies have shown insulation delivers tangible health benefits. The 2015 HCS showed 830,000 houses (53%) had suboptimal roof insulation and/or subfloor insulation.[1] These houses would benefit from retrofitted insulation.

- Although ceiling insulation is present in most New Zealand houses, it is generally at a level that could be considered suboptimal.
- 47% of houses (representing 740,000 dwellings) had less than 120 mm and/or less than 80% coverage of insulation in the roof space. 120 mm is the minimum recommended by New Zealand Government's home insulation retrofit programme.
- 23% of rentals had less than 70 mm insulation in the roof space, which is a proxy for the minimum thickness of existing insulation in rentals under the Residential Tenancy Act insulation requirements.
- Two-thirds of houses had a subfloor cavity. Of these, around one-fifth (19%, 290,000 dwellings) had less than 80% insulation coverage of floor space.
- Approximately 240,000 houses (23%) had underfloor foil insulation. The installation or repair of foil insulation was banned in existing homes in New Zealand in 2016 due to safety concerns. It also performs very poorly as a thermal barrier.

Ventilation – moisture management

Mechanical extract ventilation in kitchens and bathrooms is important to remove moisture to help prevent damp and mould. Half of main bathrooms and half of all kitchens did not have mechanical extract ventilation to the outside.

- As houses become more airtight through changing construction practices, the need for effective ventilation increases. While nearly all main bathrooms had an openable window, only around half (49%) had an extractor fan venting to outside.
- When combined with effective ventilation, heating is also important in managing moisture, to reduce the risk of condensation. Around half of households (48%) did not have heating in the main bathroom.
- Cooking can produce up to 3 litres of water vapour per day. Only around half (49%) of houses surveyed had an extractor fan in the kitchen extracting to outside.

Heating habits

The World Health Organisation recommends a minimum indoor temperature of 18°C. Achieving this in winter is likely to require some heat input into the home. 5% of households did not usually heat living areas in winter, and almost half (46%) did not usually heat occupied bedrooms, including those occupied by children and older people.

[1] This number excludes properties where it is difficult to retrofit insulation due to lack of access.

- While most households heated the main living area at some time in winter, this was most commonly in the evening only. 8% did not usually heat the main living area on weekdays. 5% did not usually heat living areas at all in winter.
- Heating of bedrooms was far less common. 46% of households did not usually heat any occupied bedrooms in winter. These included bedrooms occupied by children and older adults. The WHO-recommended minimum indoor temperature (18°C) is unlikely to be achieved without any heating in winter.

Heating appliances

Tenants have less access to cost-effective heating appliances than owner-occupiers. Instead, rental households are more reliant on portable heaters that are typically more expensive to run and less effective at heating larger areas.

- One-fifth of rentals (20%) had only portable heating appliances (no fixed heating).
- Heat pumps, one of the most efficient and cost-effective heating appliances, were present in 46% of owner-occupied dwellings and 27% of rentals.
- Wood burners were present in 43% of owned and 28% of rented properties.
- Overall, the more cost-effective heating appliances (heat pumps, wood burners, flued gas) were more common in owned (88%) than in rented houses (62%).

Unflued gas heaters

Unflued gas heaters are known for their risks to occupant health. They were present in 15% of houses (228,000 dwellings). Portable unflued gas heaters are also expensive to run. These were more common in rentals, used in 17% of living areas and 6% of bedrooms.

- Unflued gas heaters release dangerous gases and water vapour directly into the home. Unflued gas heaters were present in 11% of owned and 21% of rentals (15% overall). These were being used by around 175,000 households (11%).
- Portable unflued gas heaters, the most common type of unflued gas heater used in New Zealand, are one of the most expensive heating appliances to run. For 6% of rental houses, this was the only heating recorded as present in the home.
- In rented houses, portable unflued gas heaters were being used to heat 17% of living areas and 6% of bedrooms. Use of unflued gas heaters in rooms where people sleep goes against Ministry of Health advice.

Damp and mould

Damp and mould are key indicators of a poor-quality indoor environment. Rental properties were nearly three times as likely to feel damp than owner-occupied houses. Mould was visible in nearly half of all houses surveyed.

- Rental houses were twice as likely to smell damp than owner-occupied houses (12% compared to 6%) and nearly three times as likely to feel damp (31% compared to 11%). Mould was visible in nearly half (49%) of all properties surveyed and observed in a slightly higher proportion of rentals (56% compared to 44% in owner-occupied).
- Studies have shown that improvement measures such as effective heating, ventilation and insulation can help reduce the risk of damp and mould and benefit occupant health. Results from the 2015 HCS suggest mould was more commonly observed in houses where one or more of these features were missing or less than optimal. Further analysis of the HCS is needed, however, to explore these findings further, as there will be many interrelating factors affecting these results.

1. Introduction

1.1 Background

The BRANZ House Condition Survey (HCS) has been carried out every 5 years since 1994, with the latest round of surveying completed in 2015/16. The HCS provides insights into the condition of New Zealand's housing stock including:

- assessments of the condition of different property features and building component defects
- the types of materials used in construction
- the presence of heating and ventilation systems
- indicators of damp and mould.

The HCS has evolved over the years to broaden its coverage both geographically and in scope, expanding the information collected and number and types of houses surveyed. The 1994, 1999 and 2005 surveys covered predominantly owner-occupied houses in main urban areas, largely Auckland, Wellington and Christchurch. The 2010 and 2015 House Condition Surveys were extended to include rented properties, and the sample was broadened to include houses in provincial and rural areas. The HCS is, at present, still limited to houses – apartments are not included.

The HCS aims to capture a representative sample of stock at a point in time. It is designed and intended to develop a reliable information base, offering insight into the condition and underlying maintenance, materials trends and issues affecting New Zealand housing.

1.2 The 2015 House Condition Survey

1.2.1 Survey tools

The 2015 BRANZ House Condition Survey incorporated three survey tools:

- **Telephone interview with a household occupant**
  The purpose of this part of the survey was to collect information on maintenance and repair work undertaken by the householder. It also collected some key socio-demographic information about household occupants and explored householder perceptions of house condition. This aspect of the HCS was managed by CRESA, with telephone interviews undertaken by an external consultancy (Research NZ).
- **Self-completion householder questionnaire on appliance use**
  This component was new to the 2015 HCS. Commissioned by EECA, this self-completion householder questionnaire collected information about the use of different appliances in the home, including lighting, heating and electronic products.
- **On-site physical house assessment**
  This is the main tool for collecting detailed information about the condition of houses. The survey is completed by independent, trained assessors through an on-site home visit. This component of the HCS was managed by BRANZ, with the actual house assessments (data collection) undertaken by teams of surveyors throughout the country, trained and coordinated by the HCS national coordinator.

1.3 Survey sample

The sample structure for the 2015 House Condition Survey was designed to capture a representative sample of owner-occupied and rental properties throughout New Zealand. Surveying took place from September 2015 to June 2016. While a total of 560 houses were successfully surveyed in this time, recruitment challenges prevented the full target sample quota from being fulfilled. As a result, the achieved sample of 560 was subject to post-sampling weighting to maintain representativeness of the owner-occupied and rented sector. Further details on the sampling, recruitment and weighting process are provided in Appendix A and in White, Jones, Cowan and Chun (2017).

All results presented in this report are based on the surveyed sample of 560 houses. These were weighted to represent the estimated total number of owned and rented houses in New Zealand at the time of the survey. The sample sizes, sampling errors and weighted counts are shown in Table 1. While the sample was designed to be broadly representative by tenure, the margins of error associated with the data should be considered when interpreting the results presented in this report.

Table 1. Sample errors for the owner-occupied and rented houses surveyed and used for analysis in this report. (Source: HCS 2015)

Sample used for analysis	Owned	Rented	Total
Surveyed houses[1]	411	149	560
Precision	±6.1%	±10.8%	±5.5%
Weighted count[2]	1,011,121	550,652	1,561,773

1. Total number of houses surveyed.
2. Count of houses in the sample with the weighting applied. All analysis is undertaken using weighted data.

1.4 Report scope and structure

The volume of data collected in the HCS is extensive. This report focuses on four key factors associated with warm, dry and healthy houses, namely insulation, ventilation, heating and the presence of mould. While these are by no means exhaustive in terms of the factors that affect indoor environmental quality and the risk of a damp, mouldy home, they provide a useful starting point.

This analysis starts by looking at the presence of insulation, windows and curtains as these are fundamental to controlling heat loss from the home.

Results are then presented on the presence of openable windows and mechanical ventilation due to their importance for controlling moisture in the home. It is acknowledged that there is a substantial occupant behaviour component to managing moisture in the home. Habits such as drying clothes indoors, not using extractor fans or opening doors and windows to fully air out the home every day can have a detrimental impact on moisture levels. The HCS appliance-use survey provides some insight into occupant use of mechanical ventilation and clothes dryers, but beyond that does not capture the occupant behaviour component. A separate BRANZ project is looking specifically at aspects of this by monitoring the frequency and extent of opening doors and windows (see Plagmann, 2016; Plagmann & White, 2017).

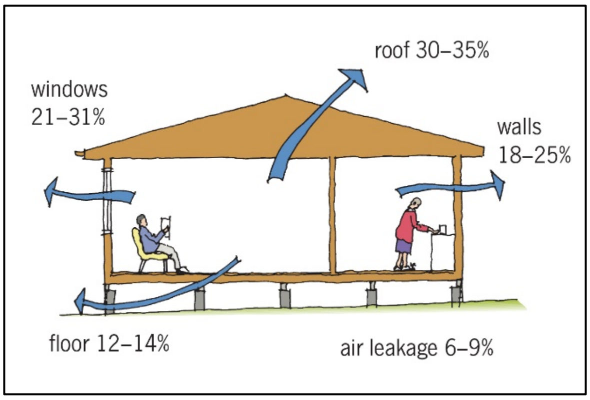
Moving on from insulation (minimising heat loss) and ventilation (controlling moisture), the report then looks at heating in the home. This includes the presence of different heating appliances (recorded through the house assessment) and occupants' reported use of heating in different areas of the home (collected in the appliance-use survey).

Finally, results from the HCS assessments of mould and damp are presented. Mould is a key indicator of poor indoor environmental quality and has implications for occupant health, including links to asthma, respiratory infections and rheumatic fever (see, for example, Mendell et al., 2009). Mould and damp arise through a combination of inadequate warmth (heat loss through an uninsulated fabric and/or insufficient heating) and lack of ventilation (insufficient control and removal of moisture in the home). The results from the HCS on the prevalence of damp and mould are therefore considered alongside some of the factors explored previously.

Source: HCS 2015

2. Managing heat loss

2.1 The thermal envelope and managing heat loss



A home's thermal envelope is the critical barrier between outdoor and indoor temperatures. Without insulation and other measures, such as draught proofing and thick, lined curtains on windows, heat loss can result in a cold, draughty indoor environment.

Insulation became mandatory in all new houses in New Zealand from 1978. Houses built before then are unlikely to have insulation unless it has been retrofitted. In an uninsulated house, 30–35% of heat can be lost through the roof, 18–25% through walls and 12–14% through the floor (see the drawing above, taken from Elkink, 2012a). The benefits of insulating these areas have been well documented over the years and include reduced heat loss, improved thermal comfort, benefits to the health of occupants and lower energy bills. (See, for example, Howden-Chapman et al., 2007; Grimes et al., 2011.)

2.2 HCS and insulation data

The House Condition Survey physical house assessment records information about the presence, depth, coverage and type of insulation of the roof space, subfloor and walls. Collecting this data is dependent on the assessor having access to the space. In the case of walls, they need to be able to ascertain the information by other means such as asking the householder or accessing building documents. Insulation data is therefore subject to limitations to a greater extent than other HCS data. Missing data (unknowns) have been included in the analysis for transparency.

2.3 Roof space insulation

When assessing insulation levels and possible need/opportunity for top-up/retrofit insulation, both the depth of insulation and the area of the roof space covered are key considerations. A depth of at least 120 mm insulation covering all accessible roof space areas is recommended by EECA. Insulation less than 120 mm thick is recommended for top-up.[2] This threshold is used in the New Zealand Government's home insulation retrofit programme Warm Up New Zealand (WUNZ) – see Discussion box 1. It is also used in the housing warrant of fitness (NZGBC and University of Otago, 2014).[3]

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[2] www.energywise.govt.nz/at-home/insulation/ceiling-insulation/checking-ceiling-insulation/

[3] Minimum recommended levels for retrofitting ceiling insulation into existing homes are also specified in R-values – see https://www.energywise.govt.nz/at-home/insulation/ceiling-insulation/installing-ceiling-insulation/

39% of houses (610,000 dwellings) had at least 80% coverage of 120 mm ceiling insulation.

Applying this threshold to the HCS data shows that just under two-fifths (39%, 610,000 dwellings) have at least 120 mm insulation covering at least 80% of the accessible roof space area (Figure 1).[4] However, 3% of houses (52,000 dwellings) had no insulation in the roof space, and a further 41% had less than 120 mm. A small proportion (2%) were insulated to a depth of 120 mm but the insulation covered less than 80% of the accessible roof space. All these properties (47% overall, representing 740,000 dwellings) could benefit from retrofit.

47% of houses (740,000 dwellings) could benefit from more insulation in the roof space.

There was little difference in ceiling insulation levels between owned and rented houses, although a slightly higher proportion of rentals had less or no insulation in the roof space.

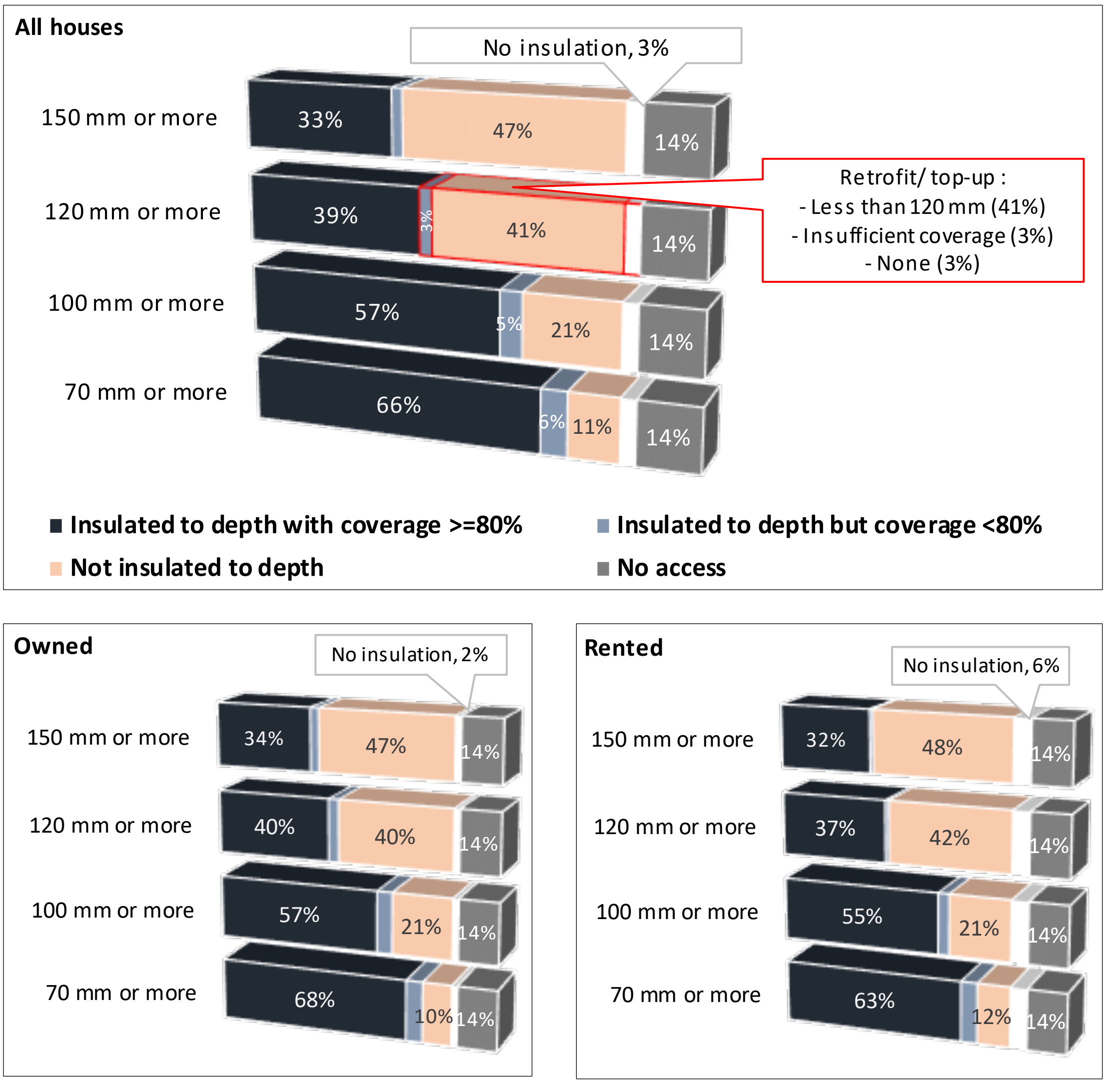


Figure 1. Proportion of houses with ceiling insulation to specified depths and coverage (Source: HCS physical house assessment)

[4] An 80% coverage threshold has been applied to allow some contingency for estimates of accessible roof space.

2.3.1 Insulation defects

Insulation was present in most houses with an accessible roof space and to a depth of at least 120 mm in almost two-fifths of cases. However, there was a relatively high incidence of defects recorded. Damaged or poorly fitted insulation can have a substantial impact on its efficacy in reducing heat loss. Defects recorded in the HCS included gaps in insulation (31%) and insulation settling (22%), not fitted properly (16%) and displaced (11%).[5] Overall, of those houses that had insulation, in just under half at least one defect was recorded.

Around half of houses had at least one defect with insulation in the roof space, which could reduce its effectiveness.

Depending on the extent of defects and damage, replacement of existing insulation may be warranted to maintain performance and, in the case of rentals, ensure compliance. Discussion box 1 and Discussion box 2 provide further information on ceiling insulation requirements.

2.3.2 Downlights

Downlights, which are increasingly common in New Zealand houses, also impact on the thermal performance of the dwelling, providing a route for heat and moisture to escape to the roof space. While a roof space may appear to have 100% coverage of insulation, where downlights are present, this is not strictly the case. It is in fact 100% of the space available for insulation. Results from the surveyor's assessment show overall just under two-fifths of houses (38% of houses that had an accessible roof space) had an average of 15 downlights open to the roof space. These were more common in owner-occupied houses – twice the proportion of owner-occupied houses had downlights open to the roof space compared to rental properties.[6] Unless the downlight is of a specific, modern type,[7] the insulation must be laid with sufficient clearance of the light to avoid risk of fire. While an essential safety requirement, such gaps will increase heat loss through the roof.

Downlights open to the roof space were present in 38% of properties. Downlights can reduce the effectiveness of insulation and provide a route for heat and moisture transfer from the living space to the roof.

Discussion box 1. Ceiling insulation requirements and retrofit

In an uninsulated home, approximately 30–35% of heat is lost through the roof (Elkink, 2012a). Insulating the roof space therefore offers substantial benefits in improved thermal comfort and reduced energy bills.

NZBC insulation requirements

The New Zealand Building Code requires new houses, additions and alterations to be insulated to achieve minimum performance requirements. Insulation standards were first introduced in New Zealand 1978 and have been revised over the years.

[5] Percentages as a proportion of houses with insulation in the roof space.
[6] 46% of owner-occupied compared to 23% of rentals, based on houses in which the assessor could access the roof space (i.e. excluding 14% of dwellings).
[7] Downlights undermine effectiveness of ceiling insulation although improved technology has reduced air movement and now, for certain types, allows for insulation to cover the fitting (IC, IC-4 or IC-F rated).

Figure 2 below illustrates different depths of insulation relative to different requirements. As the Building Code specifies the required level of insulation performance as an R-value (a measure of the resistance to heat flow), the depths shown are intended to be indicative only. The percentages show the proportion of 2015 HCS houses that had insulation to that depth (with at least 80% coverage of the roof space). Most houses have some insulation, with 66% having at least 70 mm and 57% having at least 100 mm. Only around one-third (33%) have insulation to a depth similar to that required under the current Building Code for new construction. As the requirements have increased over the years, this presents an opportunity to retrofit existing dwellings to improve the thermal performance in line with current specifications.

Warm Up New Zealand

From a retrofit perspective, the ceiling or roof space is often one of the easier and more accessible parts of the house to insulate. The Warm Up New Zealand (WUNZ) programme offers grants for home energy efficiency improvements. This is historically for heating and insulation and, at the time of writing, for ceiling and underfloor insulation for rental properties occupied by low-income tenants. The programme applies a minimum benchmark for ceiling insulation of 120 mm covering the accessible roof space area. Any property with less than 120 mm or insufficient coverage would be considered eligible for top-up. This is consistent with the advice given by EECA.[8]

Results from the HCS 2015 suggest around two-fifths (39%) of houses (including owned and rented) meet this threshold of 120 mm (with at least 80% coverage). However, 47% (740,000 dwellings) have suboptimal levels (less than 120 mm and/or less than 80% coverage) of ceiling insulation and could therefore benefit from retrofit.

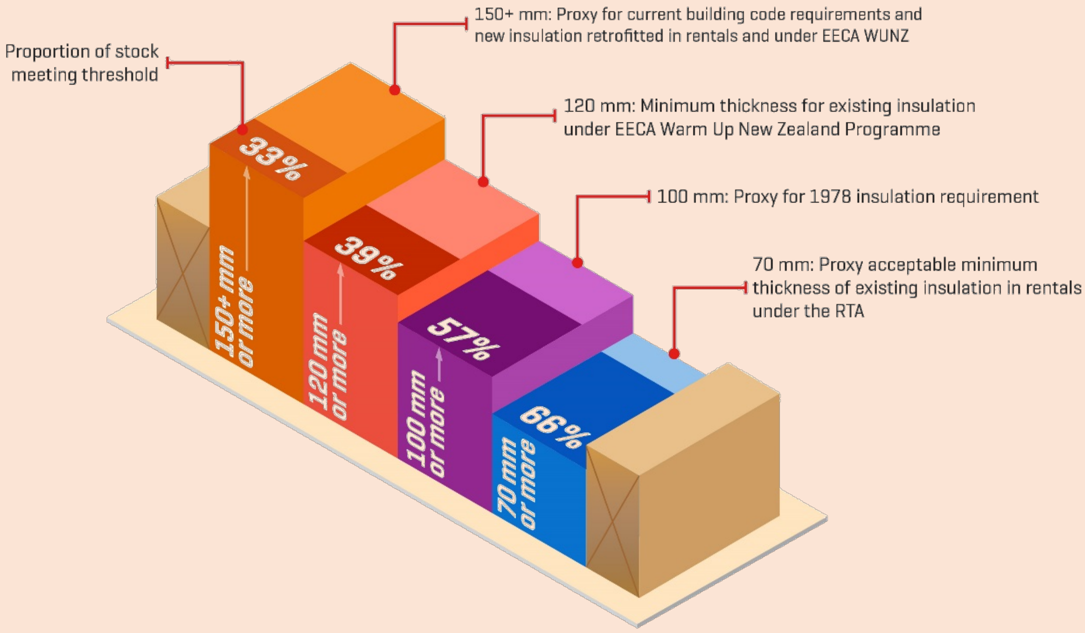


Figure 2. Ceiling insulation depth relative to different requirements and proportion of houses insulated to depth based on 2015 HCS data.

[8] https://www.energywise.govt.nz/at-home/insulation/ceiling-insulation/checking-ceiling-insulation/

Discussion box 2. Ceiling insulation requirements in rental properties

Residential Tenancies Act (Smoke Alarms and Insulation) Regulations 2016

New requirements were introduced in 2016 (to be met by 1 July 2019) for ceiling and underfloor insulation in rental properties. The requirements are specified in R-values by climate zone. As a rule of thumb for existing insulation in the roof space, guidance suggests a thickness of greater than 70 mm is required to comply (MBIE, 2015). Areas of ceiling insulation that are less than 70 mm thick will require upgrading in accordance with the retrofit requirements.[9]


(BRANZ HCS 2015)

Results from the 2015 HCS suggest three-fifths of rental properties (63%, 350,000 dwellings) have at least 70 mm insulation covering at least 80% of the roof space. However, 23% (130,000 rentals) had less than 70 mm and/or insufficient coverage (less than 80% of the accessible area) (Figure 1). The remainder were unknowns (14%) where the roof space was inaccessible and therefore retrofit may not be possible.

It should be noted that these figures are based on depth and coverage of insulation only. The condition of the insulation is a key consideration of the new Residential Tenancies Act (RTA) requirement. Damaged insulation (including but not limited to rips, tears, mould and vermin) may result in insulation failing requirements and needing to be replaced. While some of the defects recorded in the HCS align with those considered under the regulations (see section 2.3.1), the HCS was carried out before the RTA requirements were set. A defect recorded in the HCS cannot therefore be assumed to equate to a fail on requirement. Some of those rental properties that had 70 mm insulation covering the roof space may still require upgrading if the insulation is not in adequate condition.

2.4 Subfloor insulation

Overall, around one-third of houses surveyed did not have any area of subfloor cavity – the house was entirely concrete slab foundation. This foundation type was more common in owner-occupied houses than rentals (Figure 3).

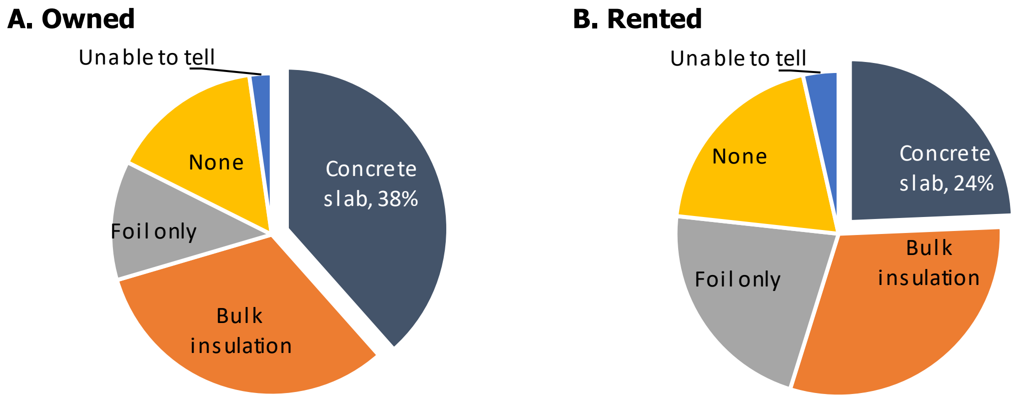


Figure 3. Presence of subfloors and insulation type by tenure. (Source: HCS 2015 physical house assessment)

[9] The requirements for insulation installed after 1 July 2016 are given in R-values by climate zone (see MBIE, 2015, p. 11).

When considering the effectiveness of subfloor insulation and the potential for retrofit, the coverage (area of habitable floor space insulated) and accessibility of the subfloor are important considerations. Figure 4 takes both these factors into consideration. This shows that, of those houses that did have a subfloor cavity, the extent of insulation could not be ascertained in 4% of cases. In a further 6% of cases, subfloor insulation was lacking (non-existent or covered less than 80% of the habitable floor area) but access was limited. In the analysis that follows, these cases have been assumed to be inaccessible and therefore impractical or not possible to retrofit.[10]

Bulk insulation was present (at 80% coverage or more) in 43% of houses that had a subfloor cavity (450,000 dwellings, 29% of all houses). A further 18% of houses that had a subfloor had at least 80% coverage of foil insulation (at 80% coverage or more) (190,000 dwellings, 12% of all houses).

450,000 dwellings (43% of those with a subfloor cavity) had bulk insulation covering at least 80% of the subfloor area.

Bulk insulation was more common in owner-occupied houses while foil was more common in rentals. See Discussion box 3 for information on subfloor insulation requirements in rental properties and Discussion box 4 for information on foil insulation regulations.

290,000 dwellings – 28% of houses with a subfloor cavity – could benefit from retrofit insulation.

Allowance has been made for those without access to the subfloor. Overall, the data suggests that 28% of houses with a subfloor cavity (290,000 dwellings, 19% of all houses) could benefit from additional insulation of the subfloor. Most of these (210,000, 14% of all houses) had no insulation, while a small proportion had suboptimal levels (less than 80% coverage) (Figure 4, middle section of chart).

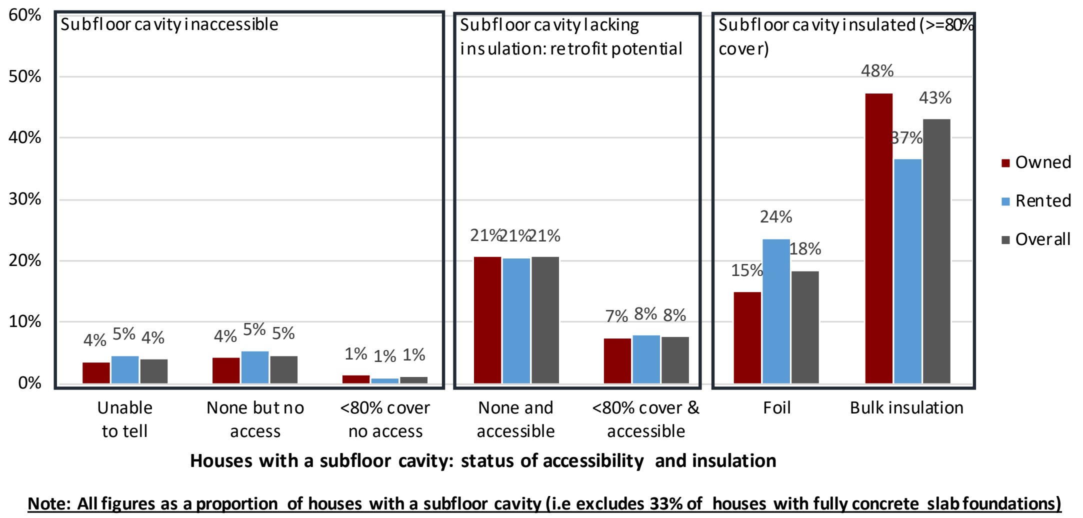


Figure 4. Coverage of and retrofit opportunity for subfloor insulation in houses with a subfloor cavity. (Source: HCS 2015 physical house assessment)

[10] In these cases, the HCS assessor was able to visually assess the subfloor – for example, by looking through vents and gaps. They could not gain full access due to there being no entry point, the entry point being blocked or the floor too low to the ground.

Discussion box 3. Subfloor insulation requirements in rental properties

The floor is another key route for heat loss from the home. In an uninsulated house, around 12–14% of heat can be lost through the floor (Elkink, 2012a). As with the roof space, insulating the subfloor can offer benefits in improved warmth and lower energy bills.

As described above, recent changes to the Residential Tenancies Act require all rental homes to have ceiling and underfloor insulation from 1 July 2019. For subfloors, insulation must cover all accessible areas below habitable spaces, with clearances as required (such as for pipework) and must be in reasonable condition. Where existing insulation is damaged, degraded, missing or incomplete, new underfloor insulation must be installed (the specifications for which are given as an R-value of at least R1.3) (MBIE, 2016).

Results from the 2015 HCS showed 26% of rental properties with a subfloor cavity had no insulation (110,00 dwellings, 20% of rentals overall). A further 9% of rentals with a subfloor had some insulation but covering less than 80% of the area. Overall, this equates to around 150,000 rentals that have suboptimal subfloor insulation. Most of these, 120,000 (22% of all rentals) had an accessible subfloor and therefore could in theory be retrofitted. By comparison, 17% of owner-occupied houses (180,000 dwellings) had an accessible subfloor with less than 80% coverage of insulation and could therefore benefit from retrofit. For more on retrofitting underfloor insulation, see Galloway (2016).

It should be noted that the condition of the insulation is a key part of the RTA requirements. For example, foil insulation installed before July 2016 is accepted under the RTA insulation requirements only if it is free from rips and tears. The RTA guidelines acknowledge that "it is common to find damage to underfloor foil insulation", and where this is the case, it must be replaced with a non-foil product (MBIE, 2016). Overall, 22% of rental properties surveyed had foil insulation in the subfloor.


(BRANZ HCS 2015)

The HCS did not assess the condition of subfloor insulation. Therefore, the figures presented here cannot be considered a direct representation of the number of houses that are likely to meet or fail the RTA requirements.

2.4.1 Subfloor foil insulation

The repair and installation of foil was banned in New Zealand in 2016 due to health and safety risks associated with its electrically conductive properties (Discussion box 4). It also performs very poorly as an insulating barrier (McNeil, Li, Cox-Smith & Marston, 2016).

23% of houses with a subfloor cavity had foil insulation.

As shown above, bulk insulation was more common in owner-occupied houses and foil more so in rentals. Overall, 15% of dwellings had foil in the subfloor (23% of houses with a subfloor). In 22% of rental properties (29% of those with a subfloor), foil was the only insulation present in the subfloor.

Discussion box 4. Subfloor foil insulation

As of July 2016, the installation or repair of subfloor foil insulation was banned in all existing residences (with an existing electrical installation) due to risks associated with its electrically conductive properties.


(BRANZ HCS 2015)

Research has also shown draped foil insulation performs poorly, particularly in windy or cold conditions (see McNeil, 2016) and is susceptible to rips and tears.

Because of the risks, performance and durability concerns, foil insulation has never been used under the government's Warm Up New Zealand insulation retrofit programme.

Results from the 2015 HCS suggest that around one-quarter (23%) of houses with a subfloor cavity had foil insulation. This represents approximately 15% of the whole sample, some 240,000 dwellings.

2.5 Ceilings and subfloors: retrofit opportunity

As discussed in section 2.3 and 2.4, the ceiling and subfloor are typically two of the easier and more cost-effective areas of the house to retrofit with insulation.

Results from the 2015 HCS suggest that around 47% of houses (740,000 dwellings) could benefit from additional insulation in the roof space. 19% (290,000 dwellings) could benefit from additional insulation of the subfloor.

Combining these measures suggests around 13% of dwellings could benefit from both ceiling and subfloor insulation, while over half (53%) could benefit from one or the other or both (Figure 5). Houses with less than 120 mm and/or less than 80% insulation coverage in the roof space and houses with less than 80% coverage of subfloor insulation have been considered candidates for retrofit.

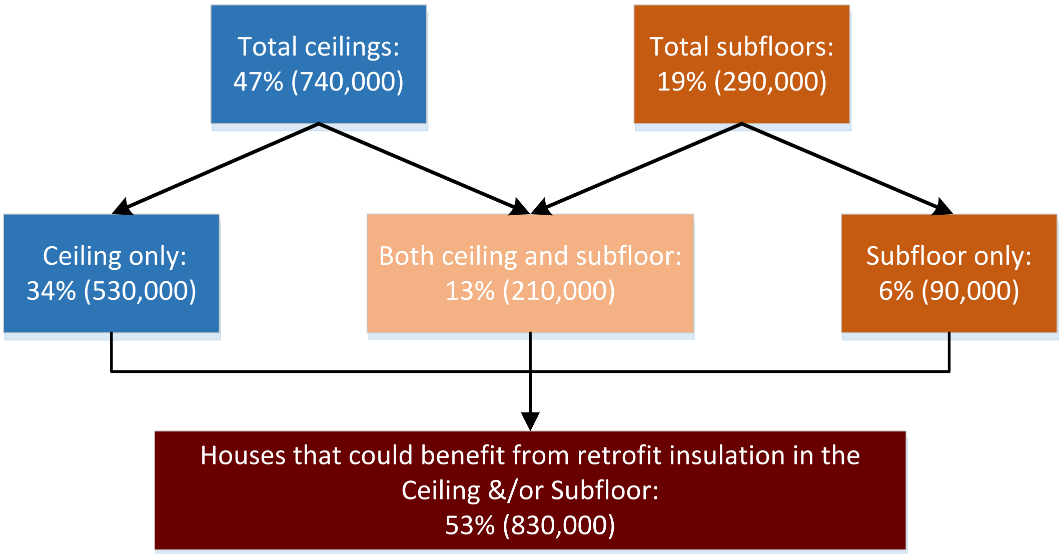


Figure 5. Potential for retrofit: proportion and estimated number of houses that could benefit from ceiling and/or subfloor insulation. (Source: HCS 2015, figures may not sum due to rounding)

Discussion box 5. Insulation requirements and retrofit opportunity in rentals

As outlined in the previous sections (Discussion box 2 and Discussion box 3), new requirements were introduced under the RTA in 2016 for ceiling and underfloor insulation in rental properties. These must be met by 1 July 2019.

Analysis of the 2015 HCS showed the following:

- Around one-quarter of rental properties (24%, 130,000 dwellings) had less than 70 mm and/or less than 80% coverage of the accessible area of insulation in the roof space. 70 mm is given as an indicative minimum depth for meeting the RTA requirements. (This compares to 17% of owner-occupied dwellings (170,000) that had less than 70mm and/or less than 80% coverage of insulation in the roof.)
- 22% of rentals (120,000 dwellings) had an accessible subfloor with less than 80% coverage of insulation of the subfloor. (This figure only includes houses where the subfloor was accessible and therefore in theory could be retrofitted.) This compares to 17% of owner-occupied dwellings (180,000) that had less than 80% coverage of insulation of the subfloor.

Combining these measures suggests around 35% of rentals (190,000 dwellings) may need, and have access to, upgrade insulation in the roof space and/or subfloor to align with the new requirements. This includes 11% (60,000) needing subfloor insulation only, 13% (70,000) for roof insulation only and 11% (60,000) possibly needing to upgrade insulation of both the roof and subfloor.

It should be noted that these figures are only a proxy indicator of the RTA requirements:

- They are based on an assessment of depth and coverage of insulation and are only indicative of likelihood of meeting the ceiling and subfloor insulation requirements, which are specified in R-values.
- They do not take account of the condition of the insulation, which is a key consideration of the new RTA requirement.
- They only include houses that had an accessible roof space and subfloor. Inaccessible spaces were excluded on the basis that retrofit may not be practical.

2.6 Wall insulation

Ascertaining the extent (coverage) and type of wall insulation is difficult without intrusive techniques to look inside the cavity. Such techniques were not permitted in the 2015 HCS due to health and safety concerns. There is therefore a high degree of uncertainty in this section of the survey, which will increase the margin error with these results.

In over half of properties surveyed, the extent of wall insulation could not be determined. This was higher among rental houses, possibly due to tenants being less likely to know whether the walls were insulated than owners and/or having limited access to building documents. One-third (33%) of owner-occupied houses surveyed were deemed to have wall insulation (and mostly 100% coverage) – over twice the proportion of rentals (15%) (Figure 6).

Building age can be used as an indicator of the presence of insulation, since it became mandatory in all new homes in 1978 (NZS 4218P:1977 *Minimum thermal insulation requirements for residential buildings*). The age profile of houses surveyed as part of the 2015 HCS showed 43% of owner-occupied and 32% of rentals were built post-1978. They could therefore be assumed to meet minimum insulation requirements. Combining the age profile with the assessor's record of insulation levels shows two-thirds (66%) of rental properties are estimated to have uninsulated walls compared to less than half (46%) of owner-occupied properties. These results can give an indication only, however, and should be treated with caution due to the lack of actual data on the status of wall insulation.

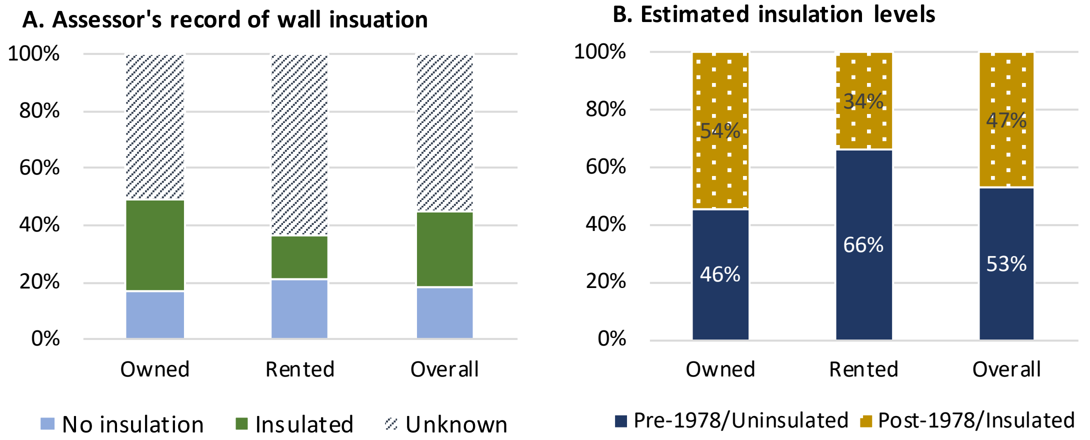


Figure 6. (A) Presence of wall insulation recorded in the HCS and (B) estimated wall insulation based on HCS and age of property. (Source: HCS 2015 physical house assessment)

2.7 Windows and curtains

Windows have the lowest thermal performance of any part of the house, with around 21–31% of heat being lost through windows in a typical uninsulated dwelling (Elkink, 2012a). Both the type of glass and the framing are important and affect performance.

Only 10% of houses had all double-glazed windows.

In only 10% of houses surveyed were all windows double glazed, with a further 8% having a mix of double and single glazing (Figure 7). Double glazing was more common in owner-occupied houses, while in 90% of rentals, all windows were single-glazed.

Not only did rental houses have a higher proportion of single glazing, but windows in rented houses were also in a poorer condition and showed more defects (White et al., 2017).

Source: BRANZ HCS 2015

Defects were more common with timber-framed windows, which were present in around two-fifths (42%) of properties. However, nearly three-quarters (73%)[11] of houses had aluminium-framed windows, and these typically offer the lowest thermal performance of all window frame types.

[11] Percentages sum to more than 100% as a single dwelling can have more than one frame type.

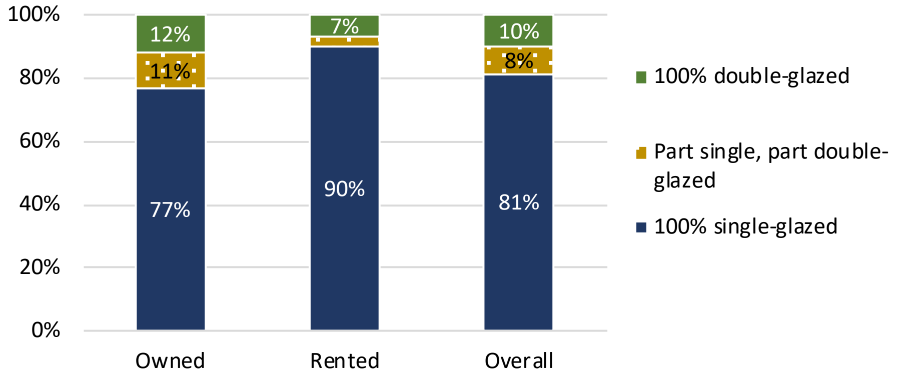


Figure 7. Proportion of single and double-glazed windows. (Source: HCS 2015 physical house inspection)

Curtains can offer an effective and simple solution to help reduce heat loss through windows. Results from the HCS suggest 85% of houses had curtains or blinds in all living areas and bedrooms. The quality (material, layers, thickness) and fit of the curtains (closed off at top and bottom, close fitting to the wall) are critical to their effectiveness as an insulating layer (EECA, 2017a). Householder use of curtains also impacts their effectiveness at keeping heat in. Information on the quality, fit and use of curtains was not collected in the HCS. The presence of curtains in most houses is therefore not necessarily an indication of a good thermal barrier.

2.8 Discussion, key points and section summary

Roof space

Results from the 2015 HCS showed that two-thirds of houses (66%, representing around 1.02 million dwellings) had at least 70 mm of insulation covering at least 80% of the roof space. However, far fewer, (39%, representing around 610,000 dwellings) had 80%(+) coverage at a depth of 120 mm, as recommended by the New Zealand Government's home insulation retrofit programme. While some insulation is better than none, there is a risk of complacency with suboptimal levels. Applying a depth/coverage threshold of 120 mm and 80% suggests around 740,000 dwellings do not meet these requirements and could therefore benefit from retrofit insulation.

This figure does not take account of the condition of the insulation. If the insulation is not installed and fitted correctly – for example, it has gaps between pieces or the frame – or is damaged, its effectiveness can be significantly diminished. Downlights also undermine the effectiveness of insulation. Apart from very recently developed fittings and bulbs, downlights provide a route for heat and moisture transfer between living areas and the roof space. Downlights open to the roof space were found in 46% of owner-occupied houses – twice the proportion of rentals.

Changes to the Residential Tenancies Act require all rental properties to have ceiling and underfloor insulation by July 2019. A depth of 70 mm insulation covering the accessible roof space is a suggested proxy measure for the requirement, providing the insulation is in good condition and free from damage. Results from the HCS suggest that around one-quarter of rental properties (25%, representing around 140,000 dwellings) have less than 70 mm and/or the insulation covers less than 80% of the roof space.[12] This figure does not take account of the condition of insulation, however.

Subfloors

Two-thirds of houses surveyed had a subfloor cavity. Over two-fifths of these (43%, representing 450,000 dwellings) had bulk insulation covering at least 80% of the habitable floor area. Nearly one-fifth of all houses surveyed had an accessible subfloor without any insulation (14%, representing around 210,000 dwellings) or less than 80% coverage of insulation (5%, 80,000 dwellings). These (290,000) properties could benefit from retrofit subfloor insulation.

Foil has commonly been used for underfloor insulation, but regulations introduced in 2016 banned the installation or repair of foil insulation in all residential properties, due to health and safety concerns. Foil was present in nearly one-quarter (23%) of all dwellings surveyed that had a subfloor cavity (15% of all houses, 240,000 dwellings).

As noted above, changes to the RTA require all rental properties to have subfloor insulation by 2019. Results from the HCS suggest that around 150,000 rental houses (28%) had none or less than 80% coverage of subfloor insulation. Most of these (22%, 120,000 dwellings) had an accessible subfloor and could therefore benefit from retrofit.[13]

Foil installed before July 2016 is accepted under the RTA insulation requirements only if it is in reasonable condition. Overall, 22% of rental properties surveyed had foil insulation in the subfloor.

Retrofit opportunity

Combining the data on insulation in the roof space and subfloor from the 2015 HCS suggests over half the housing stock (around 830,000 dwellings) could benefit from one and/or the other.

[12] It should be noted that the HCS did not set out to assess insulation against the requirement. Therefore, the presence of damage and defects recorded in the survey cannot necessarily be considered representative of the requirements. For this reason, when considering the proportion of houses that are unlikely meet the RTA requirements, only the depth of insulation has been included here.

[13] These figures do not take account of the condition of the insulation, which is a key consideration under the RTA requirements.

3. Ventilation and moisture control

3.1 Why ventilation is important

Not only does New Zealand have a relatively wet and humid environment, but daily activities in the home also generate moisture in varying quantities (see Appendix B). Changing habits can help reduce the amount of moisture generated, such as not drying clothes indoors and using lids when cooking (the 'prevent' or 'eliminate the source' approach). The next important step is to ventilate. Some ventilation occurs passively in houses through infiltration and draughts. However, active ventilation is typically needed to remove moisture generated in the home to minimise the risk of damp and mould and maintain a healthy, comfortable indoor environment.

When sized, fitted and used correctly, openable windows and extractor fans provide effective means of removing moisture from the indoor environment and replacing it with dry air from outside. The House Condition Survey records the presence of openable windows and mechanical ventilation in the kitchen, bathroom(s), laundry and all other areas of the house.[14] The age of the property is an important consideration in the context of ventilation due to changes in construction practices over time (see Discussion box 6).

Discussion box 6. Ventilation and airtight construction

Construction practices have moved towards building increasingly airtight houses (Elkink, 2012b). This reduces infiltration, which provides a means of passive (uncontrolled) ventilation and therefore increases the need for more active controlled ventilation (airing the house and using mechanical ventilation in wet areas). More airtight houses require active ventilation to keep them healthy.

While building more airtight dwellings may seem not to help the problem of damp and mouldy homes, with the right systems in place, airtight homes offer a far more controlled environment. With effective insulation and ventilation, the householder has the tools they need to maintain a healthy and comfortable indoor environment. However, effectiveness relies on the systems being sized and fitted correctly and the occupant understanding how and when to use them.

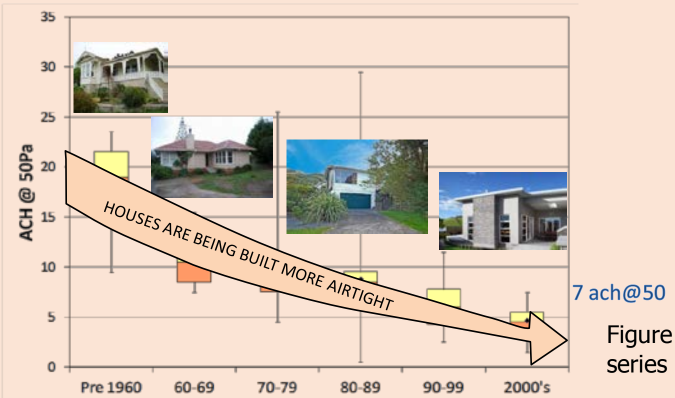
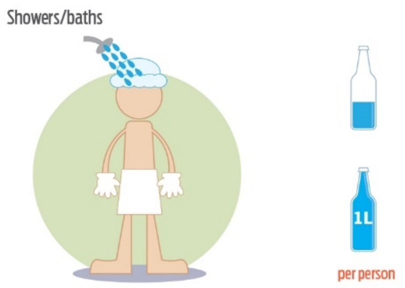


Figure courtesy of BRANZ ventilation seminar series 2017, adapted from Elkink, 2012b.

[14] The HCS captured louvre windows but did not record the incidence of other passive ventilation such as stack and trickle vents. While BRANZ research has shown that these can provide effective background ventilation, they are insufficient for high moisture events such as showering or cooking (McDowall, 2017).

3.2 Bathrooms

The analysis below applies only to bathrooms that had a bath or shower – it excludes rooms with only a toilet. Multiple bathrooms were more common in owner-occupied houses, with 46% having more than one, compared to only 15% of rental properties.



Nearly all main bathrooms had openable windows, but the presence of mechanical ventilation was far less prevalent (Figure 8).

Nearly all main bathrooms had openable windows but only around half had mechanical ventilation.

Only around half of main bathrooms had mechanical ventilation extracting to the outside. An additional 7% of main bathrooms did have mechanical ventilation but were extracting into the roof space. This is poor ventilation practice as it can exacerbate moisture problems in the house rather than help alleviate them.

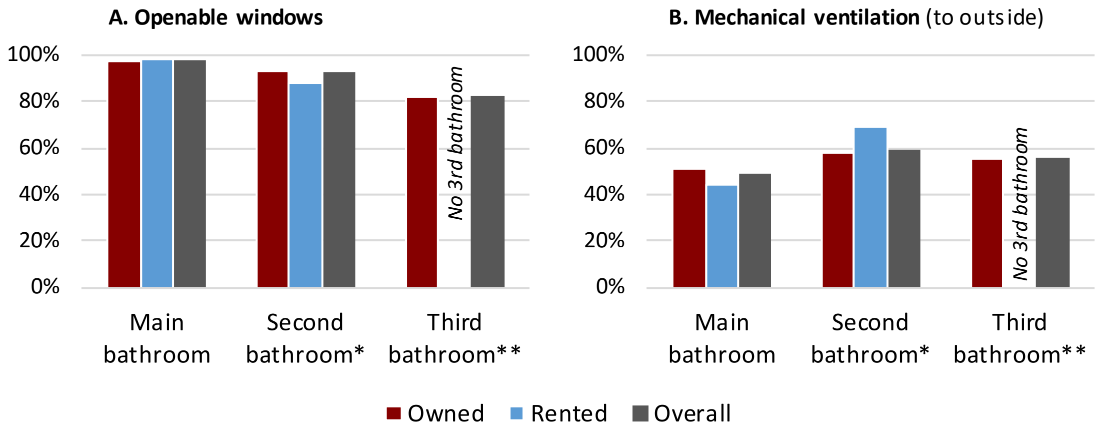


Figure 8. Presence of openable windows and mechanical ventilation in bathrooms. (Source: HCS 2015 physical house assessment)[15]

Effective management of moisture generated in the bathroom relies not only on efficient extraction of the moist air and replacement with drier air from outside, but temperature is also a key factor. Warm air can hold more moisture (Elkink, 2012b), and heating the bathroom before use can reduce the risk of condensation forming on cold surfaces.

Around half of main bathrooms did not have any heating. A cold bathroom increases the risk of condensation and mould.

Results from the HCS show that around half of all households did not have heating in the main bathroom. The proportion was higher in rental houses, at 63% without heating (Figure 9A). Where heating was present, it was most commonly fan heaters and heat bulbs (Figure 9B).

[15] The data on second bathrooms in rentals and third bathrooms in owner-occupied houses should be treated with caution due to the small sample size.

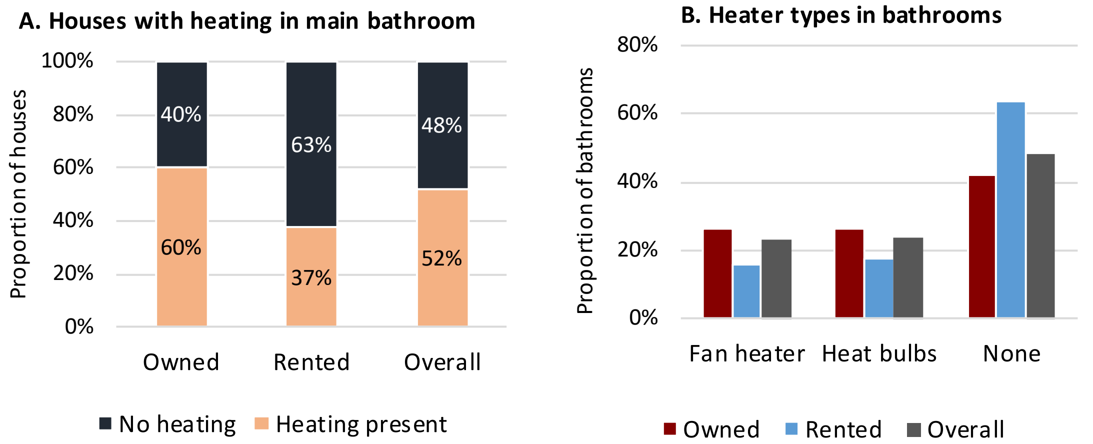


Figure 9. (A) Proportion of houses with heating in the main bathroom and (B) type of heaters found in all bathrooms. (Source: HCS 2015 physical house assessment)

Combining the data on the presence of heating and mechanical ventilation suggests around two-fifths (42%) of main bathrooms in rental houses had neither heating nor mechanical ventilation (Figure 10). This compares to less than one-quarter of owner-occupied houses (24%) having neither, while a third (33%) of owner-occupied houses had both heating and ventilation.

Around two-fifths of main bathrooms in rental properties had neither heating nor mechanical ventilation.

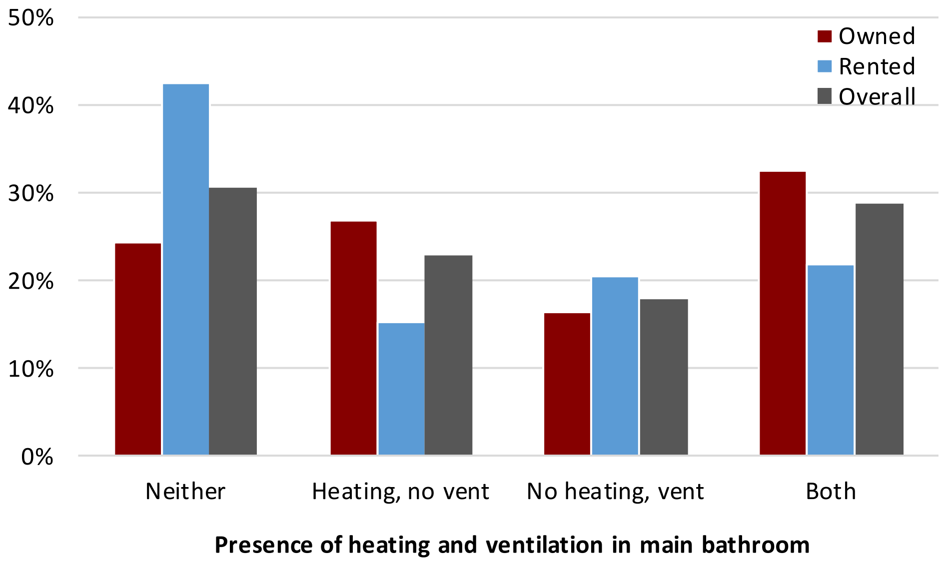
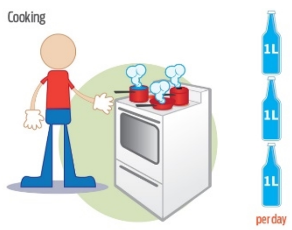


Figure 10. Presence of heating and/or mechanical ventilation in the main bathroom. (Source: HCS physical house assessment)

The lack of heating and extractor fans suggests a high proportion of householders have limited means for controlling moisture levels in the bathroom. Therefore, the bathroom may be more susceptible to damp and mould. Section 6 of this report looks at the extent of mould recorded in bathrooms, alongside availability of heating and ventilation.

Occupant behaviour can have a major impact on moisture levels in the home. This is not only through activities that produce moisture (such as bathing, cooking and clothes washing and drying) but also in how householders control and manage the home. The presence of mechanical ventilation and windows does not necessarily equate to use. A well ventilated home is reliant on the behaviour of occupants and the systems being sized, fitted and functioning correctly. A separate BRANZ study explored occupant ventilation behaviour by monitoring opening of windows and doors and asking occupants about their use of extractor fans (see Discussion box 7). Additional BRANZ research has also demonstrated the importance of extractor fans being sized correctly, duct length and bends minimised and the type of duct used – flexible versus rigid. Rigid ducts have proved more effective.

3.3 Kitchens



Cooking is one of the biggest (occupant behaviour-related) sources of moisture generation in the home, releasing up to around 3 litres per day (Pringle, 2016). New buildings are required by the New Zealand Building Code to have some means of removing fumes and odours generated by cooking (MBIE, 2014).

19% of kitchens in rental properties had neither an openable window nor mechanical ventilation.

Results from the HCS suggest nearly one-fifth of kitchens in rental properties had neither an openable window nor mechanical ventilation, compared to 11% of owner-occupied houses (Figure 11). Only around half (49%) of houses surveyed had mechanical ventilation in the kitchen that was venting to the outside. Others had a form of mechanical ventilation, recirculating air (18%) or extracting to the roof space (5%), but these do not offer an effective solution to removing moisture from the home. The former simply moves the air within the home, and the latter moves it to the roof, which can exacerbate damp and moisture problems elsewhere. The most common form of mechanical ventilation in the kitchen was a rangehood (59%). Effectiveness not only depends on where the extracted air is vented to, but the size, fitting, duct length and material are again important factors.

As discussed for bathrooms, the effectiveness of even the most efficient forms of mechanical ventilation in the kitchen depends on the occupants using it. Responses to the appliance-use survey showed 87% of those with some form of mechanical ventilation in the kitchen said they used it regularly.

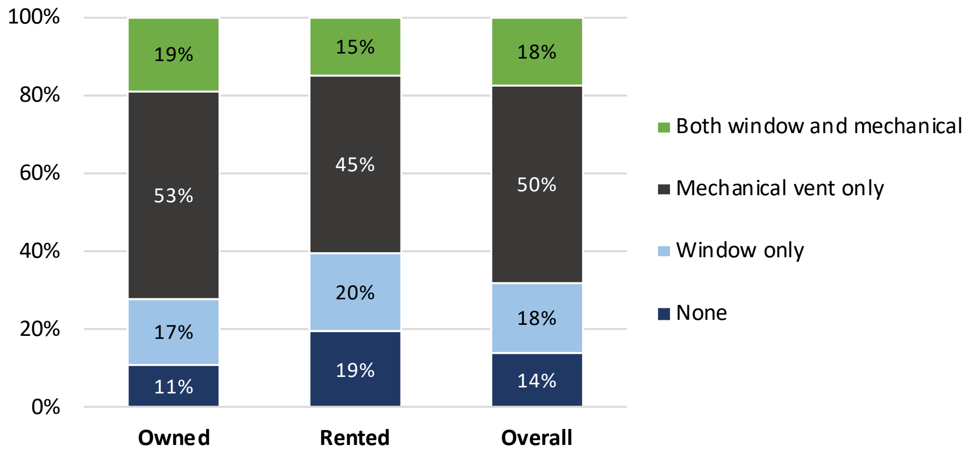


Figure 11. Presence of openable windows and mechanical ventilation in the kitchen. (Source: HCS 2015 physical house assessment)

3.4 Laundry and clothes dryers

Most houses had a laundry room (74%) or the laundry was located separate from the house in a garage/shed (15%). Most laundry rooms had an openable window (82%), but very few (7%) had mechanical ventilation venting to the outside.

Clothes dryers were present in just under half (49%) of households but were more common in owner-occupied houses (54%) than rentals (38%).

These appliances can release up to 5 kg of moisture per load into the indoor environment if not vented properly to the outdoors (McNeil, 2016). Results from the HCS suggest less than one-quarter (23%) of all dryers were vented to the outside, while the majority (72%) were not vented (Figure 12). Results from the householder appliance-use survey also showed that, of those with a dryer, a high proportion (78%) said they used them regularly.

Around half of households had a clothes dryer, and 72% of these were not vented.

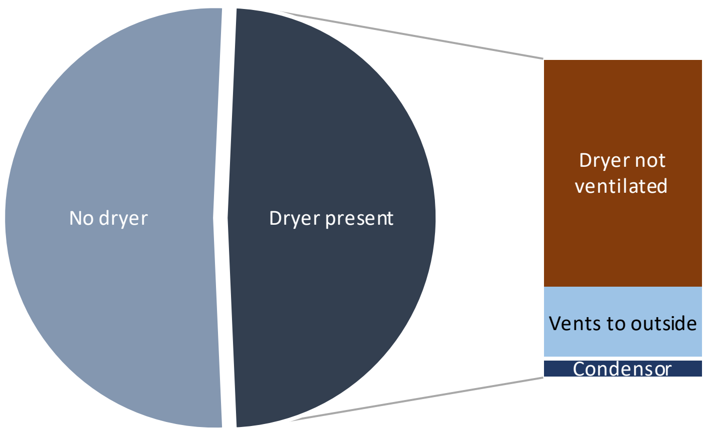


Figure 12. Presence of clothes dryers and dryer ventilation. (Source: HCS 2015 physical house assessment)

3.5 Ventilation in the rest of the house

Overall, some 9% of houses did not have openable windows in at least one living area or bedroom. A small proportion of houses (7% overall, but these were mostly owner-occupied) had mechanical systems for ventilating living areas and bedrooms.

Other air treatment systems present in houses surveyed included:

- 14% with ventilation from the ceiling space (forced-air ventilation)
- 3% with heat recovery ventilation
- 5% with dehumidifiers.

All these systems were more common in owner-occupied houses, particularly whole-house ventilation systems, with 21% in owner-occupied houses compared to just 2% of rentals.

Do householders install whole-house ventilation systems without good insulation or heating?

Where whole-house ventilation had been installed, most also had an effective heating system (heat pump, wood burner or flued gas). However, only around two-fifths had roof insulation to a depth of 120 mm or more and (where applicable) bulk subfloor insulation. While based on a relatively small sample, this suggests some households may be lacking the basics in good insulation but still opting for mechanical ventilation systems. Good practice would be to install/top up insulation first to minimise heat loss, manage sources of moisture (fix leaks, install extractor fans and air the house) and ensure there is efficient heating. If all these practices have been followed and are being used correctly but a problem with moisture remains, a whole-house mechanical ventilation system may be warranted.

Discussion box 7. Ventilation and occupant behaviour

Opening windows are a common accepted solution for complying with New Zealand Building Code clause G4 *Ventilation* (MBIE, 2014).[16] BRANZ research has demonstrated that opening windows fully for 10–15 minutes can provide sufficient ventilation after a high moisture event. This does not adversely impact on indoor temperature as most of the heat stored in wall linings and furniture will be retained in this time (McDowall, 2017).

However, opening windows as an effective means of ventilation relies on occupants doing so regularly, for long enough and wide enough. Previous BRANZ research, which measured actual ventilation rates in combination with a survey of occupant behaviour, suggested householder practices were providing insufficient ventilation in around one-third of cases (McNeil, 2016). This was particularly pertinent in newer, more airtight houses.

These findings prompted further BRANZ research to monitor window opening behaviour. Around 60 houses throughout the country were fitted with sensors to measure how often, for how long and by how much windows and doors were opened. Temperature and relative humidity sensors were also fitted throughout the home. A short questionnaire supplemented the monitoring data to collect information on householder-reported ventilation habits.

Detailed analysis of this data, from the window sensors in particular, is still in progress. Initial findings from analysis of questionnaire responses and relative humidity data in the bathroom (Plagmann & White, 2017) suggest a high proportion of occupants reported good ventilation habits. This includes always opening windows and using extractor fans when taking a bath/shower. However, these reported practices did not always align with a well ventilated space. Several cases showed consistently high relative humidity, despite occupants saying they ventilated the bathroom when in use. This could be for a number of reasons. These include windows not opened wide enough and/or for long enough and extractor fans not used for long enough, at the right times and/or not functioning effectively. Analysis of the window sensor data will provide important insights, particularly in comparing the data with the results from the questionnaire. External conditions, which can be very humid in New Zealand, also need to be taken in to account.

3.6 Moisture control and subfloors

In houses with a suspended timber floor, the subfloor environment can be a major source of moisture in the home. Research has shown up to 40 litres of water vapour per day can evaporate from the area under a 100 m^2 house (McNeil et al., 2016). If not controlled, this moisture can have a significant impact on the building and its

[16] For new homes, openable window and door areas in the building envelope must meet or exceed 5% of the floor area.

occupants. Installing a ground cover, an impermeable polythene sheet on the area below the house, has been shown to be an effective way to control ground-sourced moisture (McNeil et al., 2016). Results from the HCS showed that only 17% of houses with a subfloor cavity had a ground cover.

Subfloor ventilation is another key factor in managing moisture in the subfloor environment (McNeil et al., 2016). The HCS collects data on the presence, size, location and condition of subfloor vents. Analysis of this data has not been included here but will be incorporated into a separate report focusing on subfloors and moisture.

3.7 Discussion, key points and section summary

The results from the 2015 House Condition Survey suggest that, while nearly all main bathrooms had an openable window, only around half had mechanical ventilation. Opening windows are considered an accepted solution under Building Code clause G4 *Ventilation*, but this relies on occupants opening windows at the right time, for long enough and wide enough. Previous BRANZ research has suggested this is not always common practice (McNeil, 2016).

Mechanical extraction of moist air from high moisture areas of the house, such as bathrooms, is more effective if the air is warm as warm air can hold more moisture. Heating a bathroom before and during showering, for example, means much of the moisture will be held in the air and that air can then be extracted via the fan(s). If a bathroom is cold, the moisture will be more likely to condense onto cooler surfaces. Once condensed, these droplets of water are much more difficult to remove with mechanical extraction. Results from the HCS showed around half of households did not have heating in the main bathroom. The proportion was higher still in rental properties, with over 60% without heating in the main bathroom. Combining the data on mechanical ventilation and heating showed 42% of rental properties had neither in the main bathroom, compared to 24% of owner-occupied houses. A bathroom with neither heating nor mechanical ventilation is likely to be at greater risk from condensation and mould. However, even where heating and ventilation appliances are present, managing moisture generated in the bathroom is reliant on the systems being sized, fitted and functioning effectively and occupant use of these systems.

Cooking is one of the highest sources of moisture generation in the home. The Building Code requires new buildings to have some means of removing fumes and odours generated by cooking (MBIE, 2014). Around half (49%) of all households had mechanical ventilation in the kitchen that was extracting to the outside. This proportion increases if extractors recirculating air or venting to the roof space are included, but these do not represent an effective solution to removing moisture and fumes from the house. As with controlling moisture generated in the bathroom, the effectiveness of ventilation systems depends on correct sizing, fitting, functionality and occupant use.

Mechanical ventilation was very rare in laundry rooms, but most had an openable window. Half of households had a clothes dryer. While 23% of these were vented to the outside, most (72%) were not. Clothes dryers can emit up to 5 kg of water per load into the indoor air (McNeil, 2016). The impact of these appliances on the indoor environment therefore depends heavily on the extent of occupant use in combination with good practices. These include keeping the door to the laundry closed and opening the window while a non-vented dryer is in use.

4. Heating appliances

4.1 Why heating is important

Maintaining a comfortable, healthy indoor environment is dependent on the thermal envelope (section 2) and moisture management (section 3) and hinges on the availability and use of heating in the home.

The World Health Organisation and New Zealand's Ministry of Health recommend maintaining an indoor temperature of at least 18°C (EECA, 2017b). An inability to maintain adequate warmth in the home can detrimentally affect the health of occupants.

As discussed briefly in section 3.2, warmer houses are better able to deal with moisture, and a warmer, drier indoor environment reduces the likelihood of damp and mould. Living in a cold, damp, mouldy home has negative impacts on occupant health and wellbeing. Asthma, respiratory infections, cardiovascular diseases, mental health problems, educational attainment and emotional wellbeing have all been associated with cold, damp housing (Marmot Review Team, 2011; Mendell et al., 2009).

The type of heater and fuel used will have varying efficiencies and affect how much it costs to heat the home.[17] More-efficient heating appliances such as heat pumps produce more heat for the same energy input (cost). Heaters that use more expensive fuel, such as portable cabinet LPG heaters, cost more to operate per unit of heat produced.

Heating interacts with insulation. Houses that are insulated will require less heat input to reach a certain temperature than houses that are not insulated and will retain the heat for longer. The discussion below explores the prevalence of different heating types in New Zealand houses, before looking at the extent to which these are used by household occupants. Section 5 then looks at heating alongside insulation levels.

4.2 HCS heating data

The BRANZ House Condition Survey collects data on the presence of different heating appliances in the home. In addition, the 2015 HCS included a householder appliance-use survey, commissioned by EECA, to capture information on occupant use of these appliances.

Both data sources have been used in this report to first look at the types of heating present and then at what occupants said they use to heat living areas and bedrooms.[18]

[17] In combination with the thermal performance of the dwelling and household income, these are key factors that affect the likelihood of a household being in 'fuel poverty'. While no official definition of fuel poverty has been adopted in New Zealand, the concept broadly relates to the cost to heat the home to an adequate level relative to household income. In the UK, the definition first adopted for a fuel poor household was if it would need to spend more than 10% of its annual income on fuel to maintain adequate warmth. This definition is still used in Wales, Scotland and Northern Ireland.

[18] The presence of heating appliances in the bathroom is discussed in section 3.2.

4.3 Heating systems present in the home

4.3.1 Overview of heating types

The results from the HCS on heating types present in the house (excluding those in the bathroom and laundry) showed that, overall, 1% (2% of rentals) had no heating appliances.

One-fifth of rental properties had no fixed heating system and were reliant on portable heating only. Portable heaters are typically more expensive to run and less effective for heating larger living spaces than fixed heaters.

One-fifth (20%) of rental properties had no fixed heating system and were reliant on portable heating only (Figure 13). Fixed heating systems in this context included any non-portable device. These include heat pumps, wood burners, flued gas fires and electric resistance heaters (such as convection or radiant heaters) that are fixed to the wall or floor.

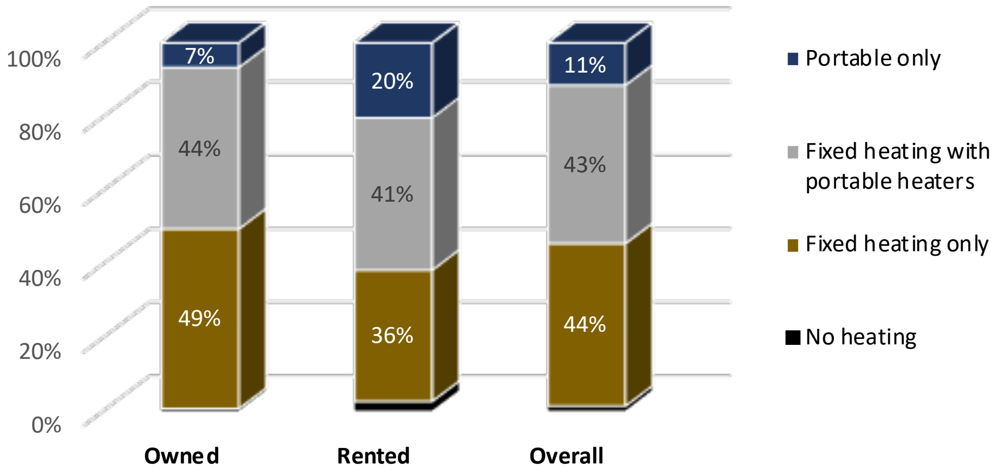


Figure 13. Presence of different heating types. (Source: HCS 2015 physical house assessment)

While portable heaters usually incur lower upfront costs than fixed heaters (they are cheaper to buy and there is no installation fee), they are typically more expensive to run.[19] They are also often less effective for heating larger living spaces.

The relative merits of different heating appliances are discussed in section 4.3.2.

In terms of fuel type used for heating, just under 80% of houses had electric heating appliances and 11% mains (natural) gas (Figure 14). Wood-fuelled heating was more common in owner-occupied houses (49%, compared to 36% in rentals).

[19] Fixed electric heaters (excluding heat pumps) are the exception, costing the same to operate as portable electric heaters.

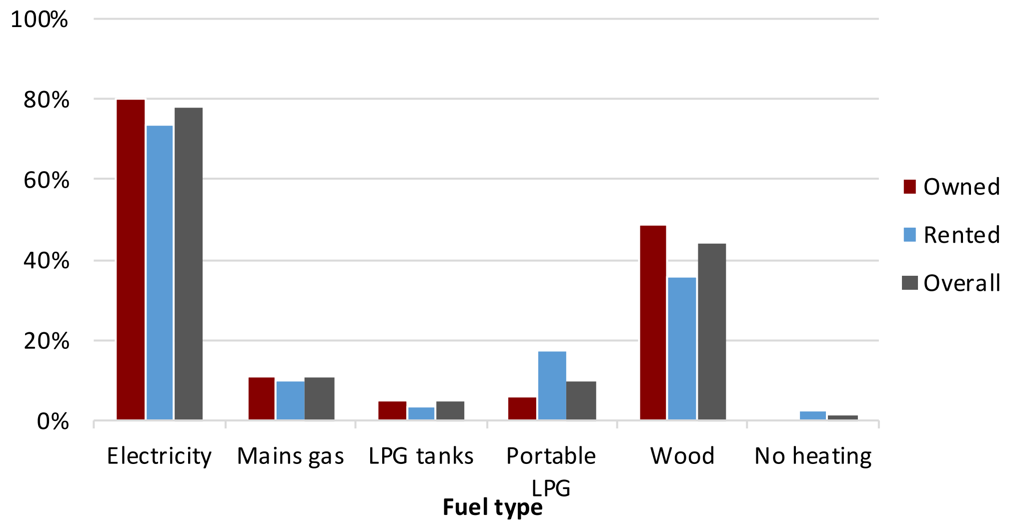


Figure 14. Presence of different heating fuels. (Source: HCS 2015 physical house assessment)

4.3.2 Heating appliances

Figure 15 shows the different types of heating appliance present in houses at the time of the 2015 House Condition Survey, grouped by heating fuel and fixed/portable.

Each of these is discussed in more detail below.

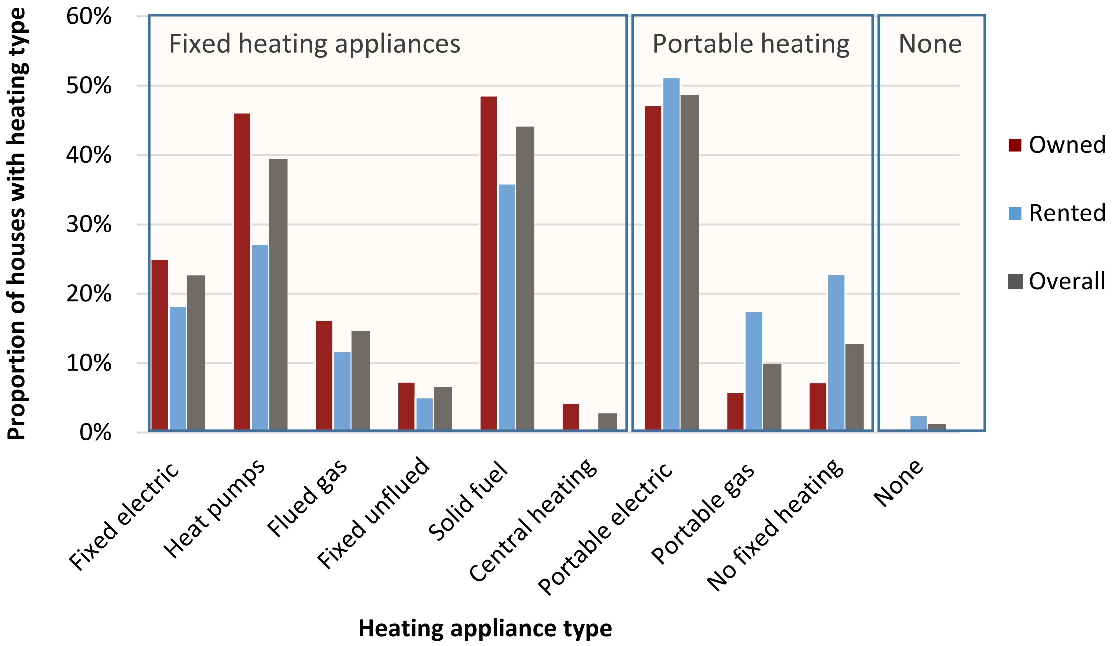


Figure 15. Presence of different heating appliance types. (Source: HCS 2015 physical house assessment)

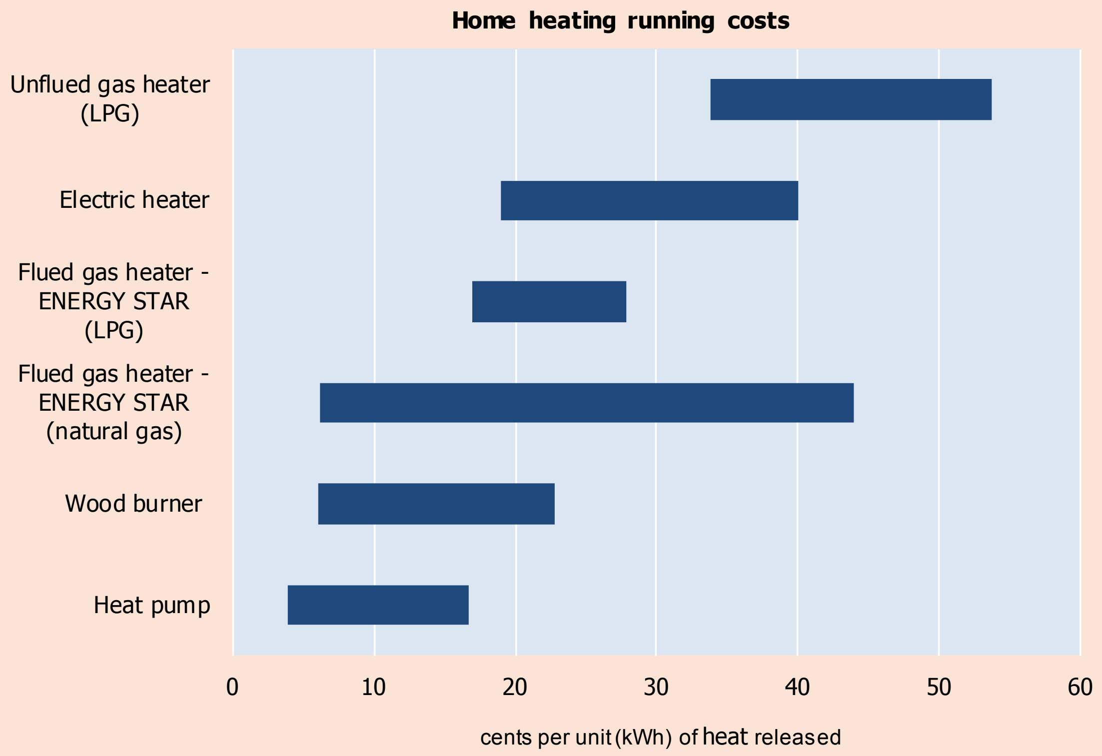
Discussion box 8. Home heating running costs

The figure below shows an indicative range of costs for different heating appliances. All costs are shown in per unit of heat output (cents per kWh). Fuel prices vary by region and provider/plan.

The lower end of the running cost ranges represents the highest efficiency heaters and lowest fuel prices, with no fixed charges attributed to space heating. The higher end of the running cost ranges represents low-efficiency heaters, high fuel prices and fixed charges fully attributed to space heating (for natural gas and LPG (45 kg bottles) only).

Heater efficiencies are based on typical highest and lowest heater efficiencies for new heaters. Non-ENERGY STAR qualified gas heaters and older heat pumps, wood burners and gas heaters may have lower efficiencies, resulting in higher running costs. For unflued gas heaters, 30% of the heat produced is assumed to be lost due to the need to leave a window open.

Purchase, installation and maintenance costs are not included in the costs shown below.



(Figure and data provided by EECA, 2017b)[20]

[20] Fuel cost assumptions: Electricity 19–40c/kWh; firewood \$50–150/m^3; natural gas 5.4–11.2c/kWh variable price; LPG (45 kg bottle) \$92–110 per refill; LPG (9 kg bottle) \$27–42 per refill. No fixed charges have been included for electricity, firewood and LPG (9 kg bottle). For natural gas and LPG (45 kg), fixed charges have only been included for the higher end of the running cost ranges. This assumes a total annual gas consumption of 3,000 kWh, fixed charges of up to \$1.45/day for natural gas and up to \$115 annual bottle rental charge for LPG (45 kg bottles). This represents households where gas is only used for space heating. For the lower end of the running cost ranges, no fixed charges have been included. This represents situations where gas is also used for other purposes than just space heating.

- **Fixed electric heaters** (panel heaters, wall-mounted fan heaters and night stores) were present in 23% of homes overall (slightly more common in owner-occupied dwellings, 25% compared to 18% of rentals (Figure 30). Panel heaters[21] were the most common type of fixed electric heating appliance (13%). Wall-mounted fan heaters, night stores and underfloor heating were present in just 3% of properties.
- **Heat pumps** were prevalent in owner-occupied houses (46%) but less common in rental properties (27%). Heat pumps offer an efficient and, if sized and used correctly, cost-effective source of heating in the home. Unless a ducted system is installed (which were in just 2% of owner-occupied houses only), these are effectively single-room heaters. Having only one heat pump and no other forms of heating limits the potential to maintain an adequate and healthy level of warmth in other areas of the house in winter. Of those houses that had heat pumps, most (80%) had only one. However, most of these (69%) did have other types of heating available in the home.
- **Portable electric** heaters were present in around half of all houses surveyed (Figure 15). Convection heaters (such as oil column heaters) were the most common type of portable electric heater, followed by fan heaters (Figure 31). Electric heaters are an energy-efficient heat source as they convert all the electricity into heat. However, portable electric heaters can be more expensive to run than other fixed heating appliances and are best used to heat a small area for a short period of time.
- **Solid fuel heaters** were the second most common heating appliance in owner-occupied homes, present in nearly half (49%), and not uncommon in rentals (36%) (Figure 15). **Enclosed wood burners** were the most common form of solid fuel heating, present in 43% of owner-occupied homes and 28% of rental properties, Figure 32). **Open fires** were present in 6% of houses. While often an appealing feature, open fires are inefficient as most of the heat goes straight up the chimney, and as a heat source, they are more difficult to regulate. Enclosed wood burners, on the other hand, offer a much more efficient and cost-effective heat source. Heat output is high and can be controlled through managing the airflow to the system, providing a healthy and comfortable level of warmth to large and draughty spaces. Previous research has shown that living areas heated by enclosed solid fuel burners tend to be warmer than living areas heated by open fires and other heater types such as standard electric heaters or LPG heaters.[22]

Heat pumps and enclosed wood burners are two of the more cost-effective sources of heat in the home. These were much more common in owner-occupied houses than rentals.

- One-fifth of houses (20%) had **fixed gas heating**. This was slightly more common among owner-occupied houses (22%) than rentals (16%). Fixed gas heating in this context includes any non-portable gas heater. This is supplied by either reticulated gas (piped from an external source) or LPG tanks outside the property. It does not include portable bottled gas heaters. The most common types of fixed gas heaters were enclosed flame effect (8%) and panel heaters (no visible flame, 7%). Around 70% of fixed gas heaters were flued. Fixed flued gas heaters can provide a convenient heat source for larger areas. Cost to run depends on the

[21] Some wall-mounted panel heaters will have low heat output (~400 W) and are designed to take the chill off an area only.
[22] HEEP Year 8 report (Isaacs et al., 2004). This research was conducted before the significant uptake of heat pumps in New Zealand.

type of gas used (natural reticulated gas or LPG) and, more importantly, on the efficiency of the appliance. The less efficient the appliance, the higher the running costs (see Discussion box 8).

- **Unflued gas heaters**, including fixed and portable, were present in 15% of houses. Unflued gas heating was more common in rentals, present in over one-fifth (21%) of properties surveyed. Unflued gas heaters release harmful emissions and water vapour into the home (see Discussion box 9). If the area is not ventilated properly, this can severely reduce indoor environmental quality, increase the risk of damp and mould and impact on the health of occupants. The most common type of unflued gas was a cabinet heater. **Portable LPG cabinet heaters** were present in 17% of rental homes and 6% of owner-occupied dwellings (Figure 34). These impact on indoor environmental quality and present health risks for household occupants, particularly if the area is not well ventilated. They are also one of the most expensive forms of space heating in the home (see Discussion box 8).

Unflued gas heating was present in over one-fifth of rental properties. 17% had a portable LPG cabinet heater. These release harmful emissions directly into the home and are one of the most expensive heating appliances to run.

Discussion box 9. Unflued gas heaters

Portable LPG heaters – unhealthy, dangerous and expensive but still all too common in New Zealand homes

Unflued gas heaters, most commonly in the form of portable LPG cabinet heaters in New Zealand, pose real health and safety risks where used.

These appliances release harmful gases directly into the home, including carbon monoxide and nitrogen dioxide. They also produce water vapour (up to around 1 litre per hour of use), increasing moisture levels and the risk of mould in the home. Without adequate ventilation to remove these gases and moisture, the air quality is severely diminished and the health of occupants put at risk (Ministry of Health, 2012; Cowan, Burrough & Ryan, 2010). Increased moisture in the home can exacerbate problems of damp and mould, which pose their own health risks, including asthma and respiratory infections (Mendell et al., 2009). Portable LPG heaters also have some of the highest running costs (cost per unit heat produced) compared to alternative home heating appliances (see Discussion box 8).

Photo: BRANZ

In some countries, including parts of Australia and the US, unflued gas heaters have been banned (Cowan, Burrough & Ryan, 2010). Advice on use of these heaters in New Zealand recommends avoiding or at least limiting use and only doing so in a well ventilated space that has a supply of fresh air. Despite such advice and widespread recognition of the risks they pose, portable gas heaters were present in 10% of houses surveyed. They were even more common in rental properties (17%), where they were not only present but being used for heating in winter (see section 5).

4.4 Discussion, section summary and key points

Heat pumps, portable electric heaters and solid fuel heating (predominantly wood burners) were the most common heating appliances in houses surveyed as part of the 2015 HCS. Heat pumps and wood burners were each present in around 40% of homes overall but both were far more common in owner-occupied properties. (Heat pumps 46% in owner-occupied houses compared to 27% in rentals, and wood burners 43% in owner-occupied houses compared to 28% in rentals.) If sized and used correctly, heat pumps and wood burners can provide adequate warmth to large areas of the home. Along with fixed-flued gas heaters, they are also among the more cost-effective heating appliances with a lower cost per unit heat output (see Discussion box 8).

Nearly 80% of houses had a heat pump, wood burner or flued gas heater in the home. These are amongst the more efficient and cost-effective home heating appliances.

Overall, nearly 80% of households surveyed had one or more of these appliances (heat pump, wood burner, flued gas heater) in the home. These were, again, more commonly found in owner-occupied houses (88%) than rentals (62%).

Portable electric heaters, while efficient in that they convert all the electricity into heat, offer varying levels of effectiveness. They are generally best used for heating a small area for short periods. A higher proportion of rented houses had portable heating only, compared to owner-occupiers. This, combined with there being proportionally fewer rentals with heat pumps, wood burners and flued gas heaters, suggests tenants have less access to the more cost-effective heating solutions than owner-occupiers.

The lower running cost heating appliances were less commonly found in rental properties.

Portable LPG gas heaters are among the most expensive heating appliances to run and release harmful emissions and water vapour directly into the home. The moisture released makes the room harder to heat and can exacerbate problems with mould. Portable LPG heaters were found in 17% of rental properties surveyed and in 10% of houses overall. This equates to over 150,000 households having access to an expensive, potentially dangerous and unhealthy heating appliance.

However, as with all the heating types described in this section, the presence of the appliance in the home does not necessarily equate to use. The heating habits of household occupants will be driven by a number of factors including affordability, need and preferences. The availability of other heating appliances in the home will also affect the extent to which any one appliance is used. In the case of portable LPG heaters, this was the only source of heating in the home in 6% of rental properties surveyed. (6% of rentals had only one heating appliance, and it was a portable LPG heater.)

In 6% of rental houses, the only heating appliance present was a portable LPG cabinet heater.

The next section explores the heating habits of HCS participants and the extent to which the different heating appliances recorded as present in the home were actually being used by occupants.

5. Winter household heating habits

The householder appliance-use survey asked when householders usually heated the living area(s) and occupied bedroom(s) in winter and the type of heater used most in each room. For living areas, heating periods were differentiated between weekdays and weekends.

5.1 Heating of main living areas

Frequency of heating

The results show that the evening was the most common time of day for householders to heat the main living area in winter. Around 90% of householders did so on weekdays and at weekends (Figure 16). On weekdays, around one-third (32%) of households heated in the evening only, while 17% would heat in the morning and evening. At weekends, daytime heating was slightly more common, as might be expected with people more likely to be home during the day. While evening-only heating was still the most common (24%), 18% said they would usually heat the main living area all day (morning, afternoon and evening) at the weekend in winter.

Overall, 8% of households said they did not usually heat the main living area at all on weekdays in winter, and 6% did not heat at the weekend. 5% of households said they did not usually heat any living areas at all in winter. Heating was slightly more common among owner-occupiers than renters. 7% of the latter said they did not usually heat living areas at all in winter, compared to 3% of owner-occupiers (Figure 35). While there was some overlap in households not heating and those having no heating appliances in the house, the latter only accounted for about one-quarter of cases. In most households not heating, the assessor's records show heating was present in the home.

5% of households did not usually heat living areas at all in winter.

Nearly 20% of households said they heat the main living area overnight in winter. These households were predominantly using heat pumps (40%) or a wood burner (55%) to heat the living area. 7% of households said they usually used a heat pump constantly (morning, afternoon, evening, overnight) to heat living areas in winter.

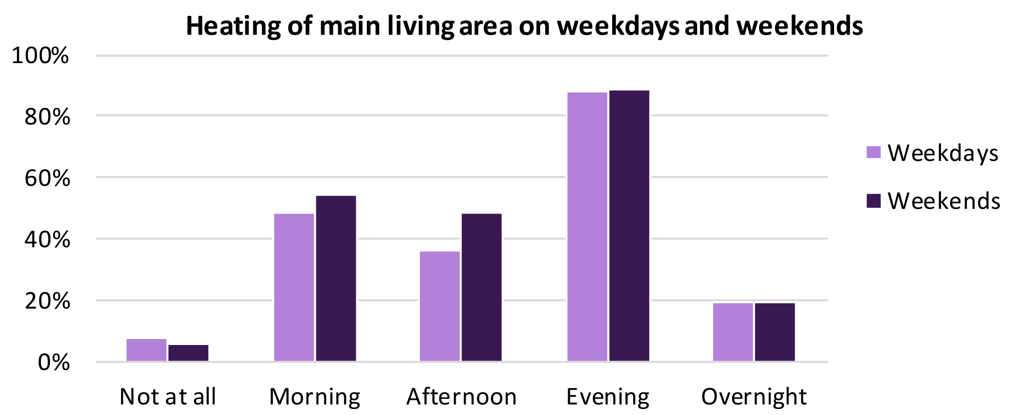


Figure 16. Heating of main living area on weekdays and weekends in winter. (Source: HCS 2015 householder appliance-use survey)

Heating appliances used in living areas

Across all households surveyed, the most common heating appliance used to heat living areas was a heat pump (35%) followed by a wood burner (33%) (Figure 17).[23] Heat pumps and wood burners were each used to heat living areas in just under 40% of owner-occupied houses, compared to around one-quarter of rentals. Electric heaters were the most commonly used appliance in rented houses, used for heating in living areas in 33% of houses. Portable gas heaters were used in living areas in 15% of rental properties.

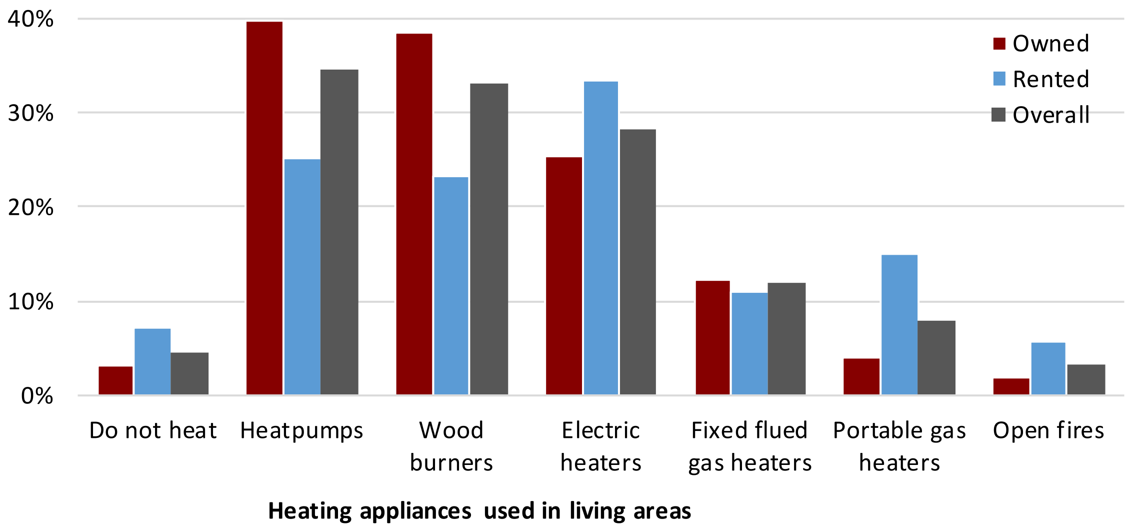


Figure 17. Heater types used in living areas in winter. (Source: HCS 2015 householder appliance-use survey)

5.2 Heating of occupied bedrooms

Frequency of heating

Propensity to heat occupied bedrooms in winter was far lower than heating of the main living area. Only around one-third of households (32%) usually heated all occupied bedrooms in winter (Figure 18A).

46% of households did not usually heat occupied bedrooms in winter. Overnight heating of bedrooms was only reported by 15% of households.

Around one-fifth (22%) heated some bedrooms, while the remainder (46%) said they did not heat any occupied bedrooms in winter. This equates to 57% of all occupied bedrooms being unheated in winter (Figure 18B). Where an occupied bedroom was heated, it was most common to heat in the evening.[24] Only 15% of bedrooms were heated overnight (over half the proportion heated in the evening).

Without any heat input, it is likely that the temperature in unheated bedrooms in winter would fall short of the WHO-recommended indoor temperature of 18°C.

[23] This includes all living areas – the survey asked about heating used in up to three different living areas.
[24] Figure 18B represent bedrooms. Percentages show the number of occupied bedrooms heated at that time of day (or not at all) in winter as a proportion of all occupied bedrooms.

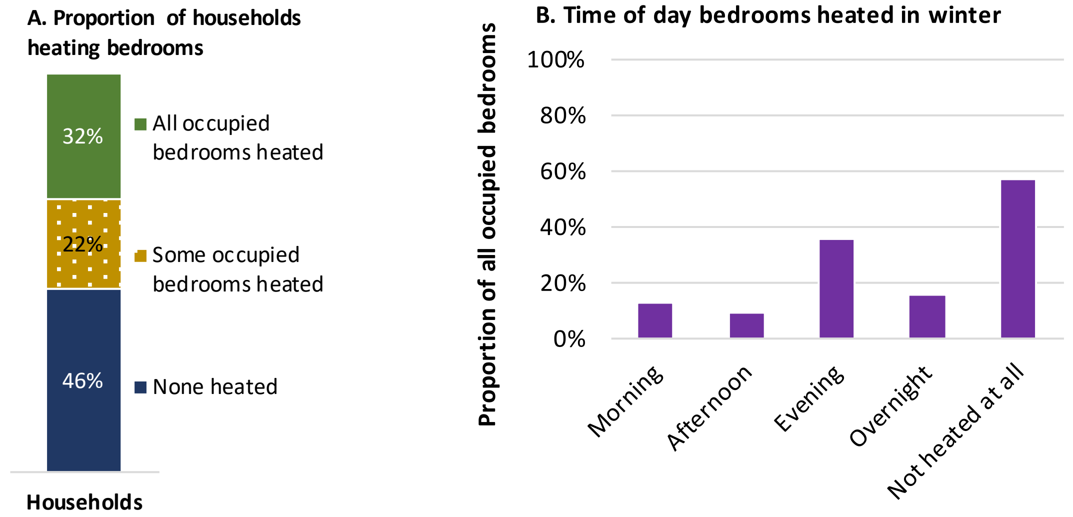


Figure 18. Heating of occupied bedrooms in winter. (Source: HCS 2015 householder appliance-use survey)

Which bedrooms were heated?

There was little difference between the owner-occupied and rental sector in terms of tendency to heat bedrooms in winter (Figure 36). The data suggests there may be a difference between which (or rather whose) bedrooms were heated.

Just over 70% of bedrooms occupied by a child under the age of 2 were heated at some time of day in the winter. Far fewer (43%) were heated overnight (Figure 19). These results need to be treated with caution, however, due to the small sample of households to which they apply. (Only 5% of households surveyed had a child under the age of 2.)

Just under half of bedrooms occupied by children were usually heated at all in winter.

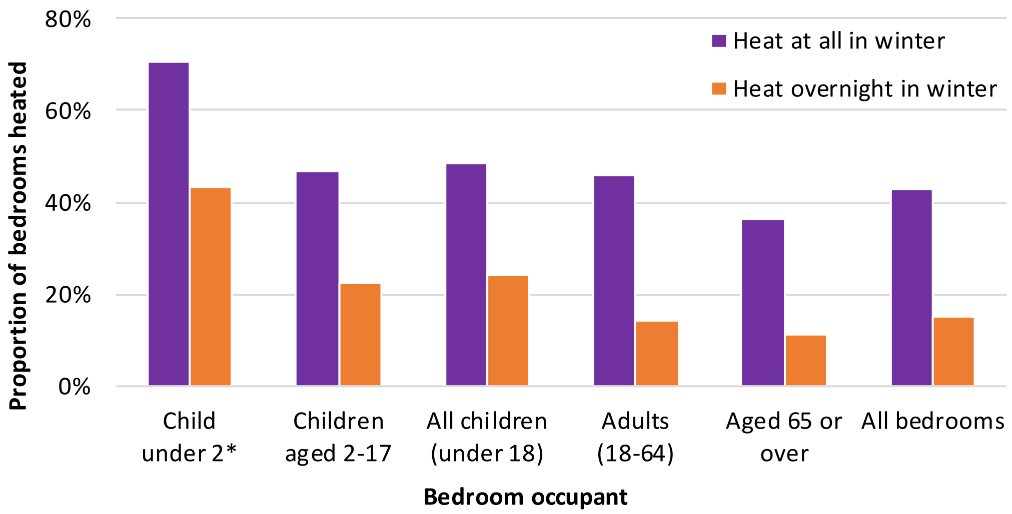


Figure 19. Proportion of bedrooms heated at all and heated at night in winter by bedroom occupant. (Source: HCS 2015 householder appliance-use survey)[25]

[25] * denotes small sample size, and results should be treated with caution. Percentages are as proportion of bedrooms rather than houses.

Bedrooms occupied by adults aged over 65 were the least likely to be heated in winter.

The frequency of heating bedrooms occupied by younger children (under 2) did not extend to bedrooms occupied by any children. Just under half of all bedrooms occupied by a child aged under 18 were heated at some time in winter.

Bedrooms occupied by older people (in this instance, people aged 65 or over) were heated the least.

Young children and older adults are among the groups WHO identifies as potentially vulnerable and may need a warmer bedroom compared to other adults. The lack of heating of bedrooms in general in winter suggests many are unlikely to always achieve the WHO-recommended minimum indoor temperature of 18°C.

Half of the households that did not heat occupied bedrooms at all had only one (or no) heating appliance in the house. Heating appliances of a portable nature that could be used to heat bedrooms (such as oil column heaters) are relatively inexpensive. Therefore, the upfront capital cost of such heaters is unlikely to be a significant barrier to bedroom heating.

The lack of bedroom heating is likely the result of a range of factors. These include the actual and perceived cost of heating, a lack of awareness of the value of bedroom heating and socio-cultural effects (norms and learned behaviours).

Heating appliances used to heat bedrooms

Electric heaters were the most common heating appliance used to heat bedrooms, used in 38% of households overall or 72% of households that said they heated bedrooms in winter (Figure 20). Heat pumps were the second most common heating appliance used to heat bedrooms of owner-occupied houses (10%).

In some of these cases, the data suggests this is not by an individual heat pump in the bedroom but rather indirectly by a heat pump located in the living area.[26] This is similar to the reported use of wood burners to heat bedrooms.

Portable LPG cabinet heaters were used to heat bedrooms in 6% of rental properties.

In rental properties, portable gas heaters were the second most common heating appliance used to heat bedrooms, used in 6% of rented houses. Some of these included use for heating bedrooms overnight.[27]

The use of portable gas heaters in bedrooms poses real health risks for the occupants and goes against Ministry of Health advice on use of these heaters in the home.

[26] This is estimated by looking at the number of rooms (bedrooms and living areas) householders said they heated with heat pumps. This is compared with the number of heat pumps the assessor recorded as being present in the home. Allowing for ducted heat pumps, t in around one-quarter of owner-occupied houses, the number of rooms heated with a heat pump exceeded the number of heat pumps recorded in the house. This suggests some households reported passive heating of their bedrooms from heat pumps located elsewhere. This is unlikely to be very effective.

[27] 22% of the rental properties using portable gas heaters in bedrooms said that they used them at night. It should be noted that this is as a proportion of the rentals that are using these heaters in bedrooms at all (6%). It therefore represents a small proportion (1.3%) of all rented houses.

While use of unflued gas heaters is cautioned against in general in the home, government advice clearly states to "never" use them in areas where people are sleeping (Ministry of Health, 2012; EECA, 2017b).

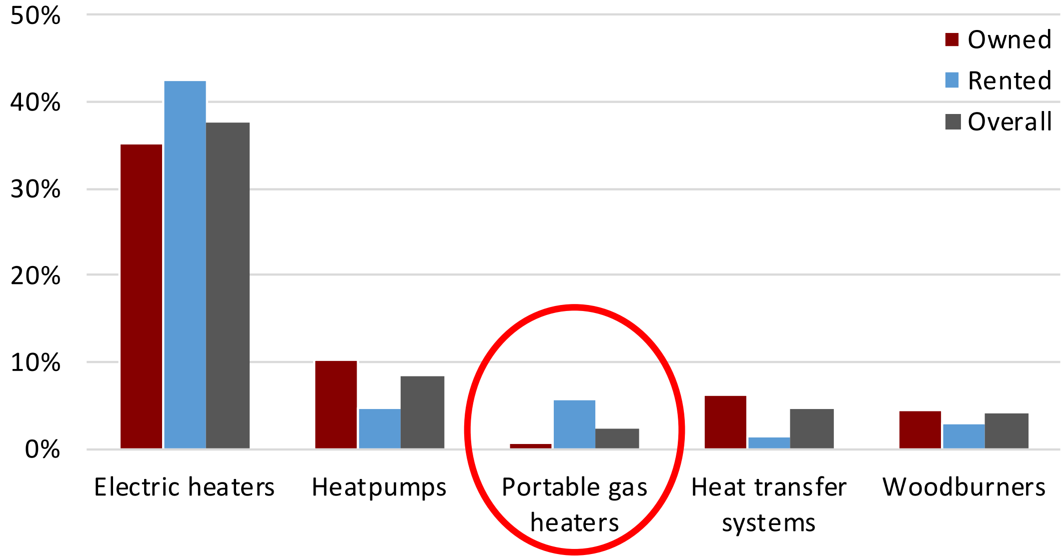


Figure 20. Heating appliances used to heat occupied bedrooms in winter. (Source: HCS 2015 householder appliance-use survey)

5.3 Heating used versus heating available

To what extent do householders use the heating appliances available to them?

Figure 21 shows the HCS data on heating appliances *present* in the home as recorded by the assessor (and reported in section 4.3). This is compared with the results from the householder questionnaire on appliances *used* for heating in winter. The latter includes all appliances the householder said they used in any living area or bedroom.

This shows that in the majority of houses (80–90%) where a heating appliance is present, it is being used for space heating in winter.

In the case of the more efficient, cost-effective appliances such as heat pumps and wood burners, this is a positive finding.

Portable LPG cabinet heaters were used for heating somewhere in the house in 17% of rental properties.

However, this high usage rate also applied to portable LPG heaters, particularly in rental properties. Portable unflued gas heaters were present and being used in 17% of rental properties, which accounts for the majority of where these appliances were present.

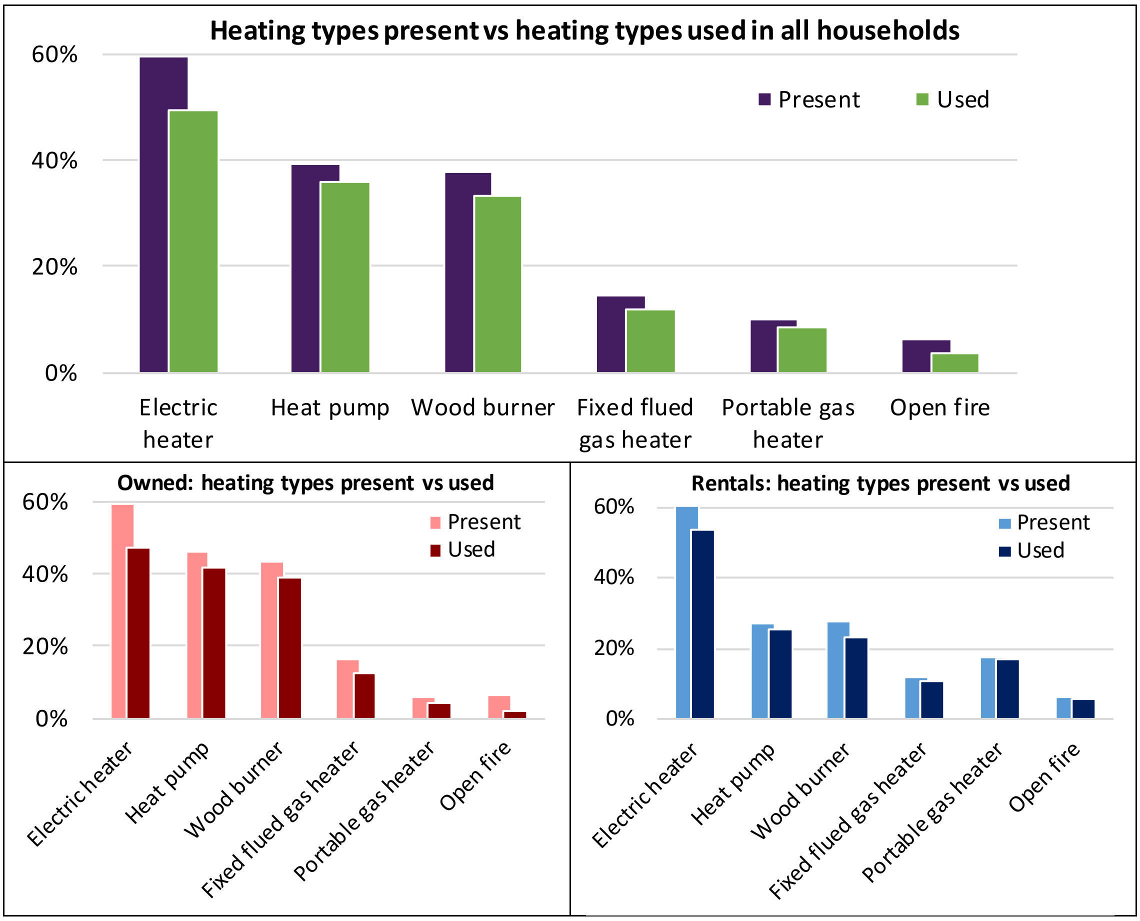


Figure 21. Heating appliances present in the home and heating appliances used for space heating in winter. (Source: HCS 2015 physical house assessment for heaters present, householder appliance-use survey for heaters used)

5.4 Heating at a loss? Heating habits and insulation levels

The analysis presented in this report has explored the extent of heating (appliances present and used) and insulation in New Zealand houses, as recorded in the 2015 House Condition Survey. Consideration of these two factors together can help provide further insight into the extent to which households may be warm and healthy, addressing questions such as these:

- Are households well insulated and using effective heating systems?
- To what extent are households investing in and using good heating systems but lack insulation and are therefore losing heat to the outside?
- What proportion of households lack both effective heating and insulation?

Figure 22 shows different combinations of ceiling insulation, subfloor insulation and heating use and the proportion of households meeting each criteria. For the purpose of this analysis, the following were considered:

- Effective heating systems include heat pumps, flued gas heaters, wood burners and central heating (see section 4.3 and Discussion box 8).
- Roof insulation was counted only where there was at least 120 mm covering at least 80% of the accessible roof space (see section 2.3 and Discussion box 1).

- Subfloor is considered insulated where any insulation covered at least 80% of the habitable floor area or the house had entirely concrete slab foundations (see section 2.4).
- Wall insulation was not considered due to the lack of definitive data in the HCS (see section 2.6).
- Houses where the roof space was inaccessible at the time of the survey, and therefore the status of insulation is unknown, have not been included.[28]

Figure 22 shows the following:

- 28% of houses surveyed had adequate roof and subfloor insulation[29] and were using an effective heating source in winter (box H in Figure 22). This suggests good practice in both minimising heat loss and heating.
- 33% of houses had suboptimal roof space insulation but were using an effective heat source (box B plus box D). These houses would benefit from improved insulation in the roof space to help get the most out of their heating system by minimising heat loss through the roof.
- Of the 210,000 houses (13%) that could benefit from additional subfloor and roof space insulation, over half (120,000) were using an effective heat source (box B). These houses would feel greater benefit from their heating by improving insulation levels.

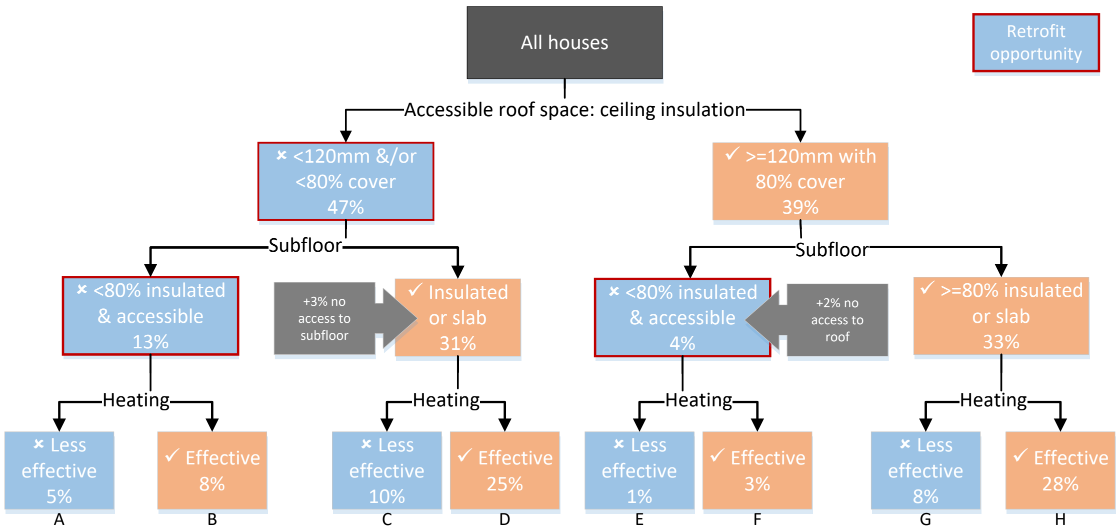


Figure 22. Proportion of houses with different combinations of ceiling insulation, subfloor insulation and heating use. (Source: HCS 2015 physical house assessment and householder appliance-use survey for data on heating use)

5.5 Discussion, key points and section summary

Analysis of householders' responses to the 2015 HCS appliance-use survey showed that most respondents did heat living areas in winter to some extent. Propensity to

[28] An inaccessible roof space might imply the roof is likely to be uninsulated, but it is not possible to make this assumption from the data. The roof space may have been inaccessible to the assessor at the time of the survey only.
[29] At least 120 mm of insulation covering at least 80% of the roof space and at least 80% subfloor insulation coverage or concrete slab foundations.

heat was slightly lower amongst rental properties but still had a positive response of over 80%.

While reported winter heating habits of the main living area varied little between owners and renters, there was a notable difference in the types of appliances used. Owners were typically using heat pumps and wood burners. Renters were more likely to use electric heaters, which could be fixed or portable. The questionnaire did not differentiate other than between heat pumps and all other electric heaters.

Heating of occupied bedrooms in winter was less common than heating of living areas, with 46% of households saying they did not heat occupied bedrooms at all in winter. There was no difference between owners and renters. Bedrooms occupied by a child under 2 were more likely to be heated. However, a high proportion (nearly half) of children's bedrooms (occupied by anyone aged under 18) were not heated in winter. This is contrary to WHO guidelines that recommend a higher indoor temperature for children.

Electric heaters were the most common appliance used to heat bedrooms in both owner-occupied and rental houses, followed by heat pumps for owner-occupiers and portable gas heaters in rentals. Use of portable gas heaters, which are unflued and release harmful gases directly into the home, are not recommended for use at all in bedrooms (Ministry of Health, 2012).

A comparison of heating appliances recorded by the assessor as present in the home was made with those the householder said they used. This suggests that, in most cases where a heating appliance is present, it is being used for heating in winter. In the positive sense, this suggests people are using the systems available to them to help keep warm in winter. However, the type of heating appliance used has implications for cost, comfort and indoor environmental quality. Results from the Household Energy End-use Project (Isaacs et al., 2010) showed average winter evening temperatures in the living room varied by heating appliance used. Rooms heated with open fires or portable electric heaters were the coolest (average of 16°C), while enclosed solid fuel burners achieved the highest temperatures (18.8°C).

The thermal envelope – how well insulated the house is – will affect comfort and warmth in the house. Installing a good heating system is less effective if heat is being lost through an uninsulated building fabric. Analysis of results from the appliance-use survey in combination with data on insulation levels suggest that around one-third (33%) of houses use an effective heating system. However, they have suboptimal insulation in the roof space. In the context of retrofitting to improve the energy efficiency and performance of a house, insulation to keep the heat in should be the first priority (Easton & Blackmore, 2010). Increasing insulation in the roof space would help these houses get the most from their heating use.

The risk of damp and mould can be reduced by:

- keeping the house warm and dry with a well insulated thermal fabric
- good ventilation systems
- regularly opening windows and doors to dry the house out
- heating in winter.

The final section of this report looks at the prevalence of different indicators of damp and mould recorded in the 2015 HCS. It considers these alongside some of the other data explored in earlier sections.

6. Mould and damp

6.1 Overview

The previous sections of this report have looked at some of the most important features that can help ensure a warm, dry and healthy home. In the absence of monitoring data,[30] mould and damp is assessed in the HCS as an indicator of indoor environmental quality.

As highlighted throughout this report, occupant behaviour – how householders live and use the systems available to them in the home – is a key factor in maintaining a healthy indoor environment. A well insulated home with effective heating systems does not necessarily mean a dry house (Plagmann, 2016).

The HCS includes three different measures of mould and damp, all of which are made by the assessor as part of the physical house assessment (Table 2).

Two of these – subjective assessment of damp and interior odour – are applied to the house as a whole. Any signs of visible mould are recorded for each room separately using the scale shown below.

Table 2. Indicators of damp and mould recorded in the HCS 2015 by the assessor.

Subjective interior dampness feel	Subjective interior odour	Prevalence of visible mould (applied to all rooms)
❑ Feels damp throughout ❑ Feels quite damp ❑ Feels damp in places ❑ Feels a little damp ❑ Feels dry throughout	❑ House smells musty	❑ Extensive blackened areas ❑ Large patches of mould ❑ Moderate patches of mould ❑ Specks of mould ❑ No visible mould

The results from the HCS show 31% of rentals felt damp (from 'a little damp' to 'damp throughout'). This is nearly three times the proportion of owner-occupied houses (11%, Figure 23A).

Similarly, twice the proportion of rentals (12%) had a musty smell compared to owner-occupied houses (6%, Figure 23B).

[30] Indoor environmental quality data is not collected as part of the HCS. However, a separate BRANZ study revisited some 60 houses from the HCS to install temperature and relative humidity data loggers and sensors on all windows and doors. This was undertaken in order to monitor the effect of occupant ventilation behaviour on the indoor environment. This data is still being analysed, but some initial findings are available (Plagmann, 2016; Plagmann & White, 2017).

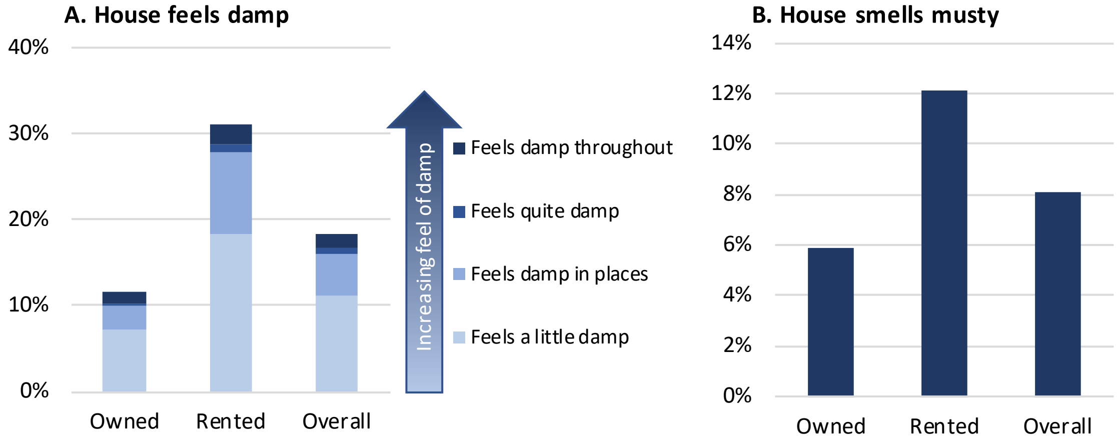


Figure 23. Subjective assessments of (A) feel of damp in the house and (B) musty smell. (Source: HCS 2015 physical house assessment)

31% of rental properties 'felt damp' – twice the proportion of owner-occupied houses.

While rentals were more likely to feel and smell damp, there was less difference between owned and rented houses in visible signs of mould.

Overall, 49% of houses surveyed had some signs of visible mould somewhere in the house. This included 44% of owner-occupied and 56% of rental properties. As noted above and shown in Table 2, visible mould is recorded on a scale from none to 'extensive blackened areas'. In most cases, the level of mould recorded anywhere in the house did not exceed 'specks of mould'.

Half of all properties surveyed had visible mould somewhere in the house.

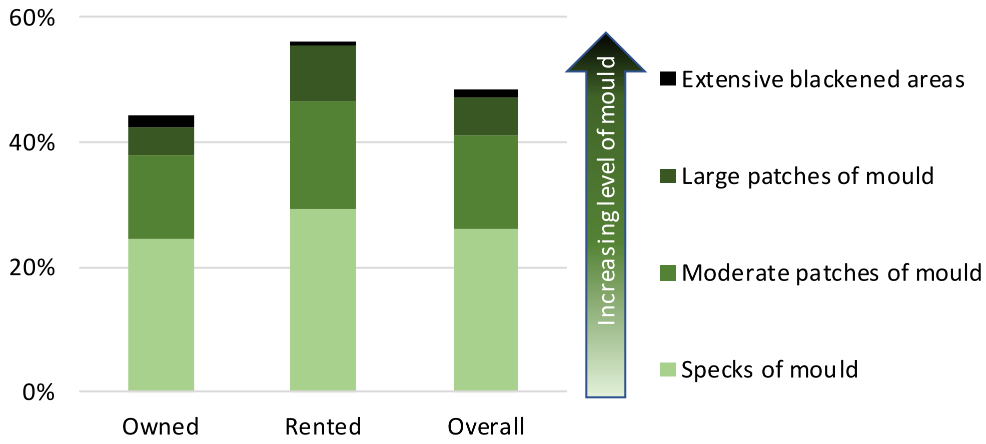


Figure 24. Worst case of visible signs of mould anywhere in the house. (Source: HCS 2015 physical house assessment)

Mould was most commonly recorded in bathrooms, but it was not limited to the high moisture areas of the house of bathrooms, kitchens and laundry (Figure 25).

Mould was visible in around one-fifth of living areas and bedrooms. The latter was notably worse in rentals – almost 30% had visible mould in bedrooms, compared to 18% in owner-occupied houses.

Figure 25. Mould was not limited to high moisture areas of the house. (Source: HCS 2015)

6.2 Mould, heating, ventilation and insulation

A comparison was made of the worst level of mould recorded anywhere in the house with heating and insulation factors. This suggests mould was more prevalent in houses that do not use effective heating systems (heat pumps, wood burners, flued gas) and also lack subfloor and roof space insulation (Figure 26). Mould levels were slightly higher in houses using unflued gas. 30% of households using portable LPG cabinet heaters had moderate to extensive mould compared to 22% of the rest of the sample.

A comparison of mould levels in the main bathroom, kitchen and bedrooms (separately) shows the following:

- Twice the proportion of bathrooms without mechanical ventilation or heating had moderate or worse patches of mould compared to those with extractors or heating (Figure 38).
- Half of households that had neither heating nor mechanical ventilation in the main bathroom (31% of all houses surveyed) had signs of mould. 71% of households with both heating and mechanical ventilation had no visible mould (Figure 38).
- Houses without any mechanical ventilation in the kitchen (32% overall) were three times as likely to have visible mould in the kitchen compared to those with mechanical ventilation.
- There was no pattern in the presence of mould in bedrooms and heating of bedrooms. Visible mould was no less common in bedrooms that occupants said they heated. Less is known about the frequency of ventilating bedrooms, which could be an important factor here.

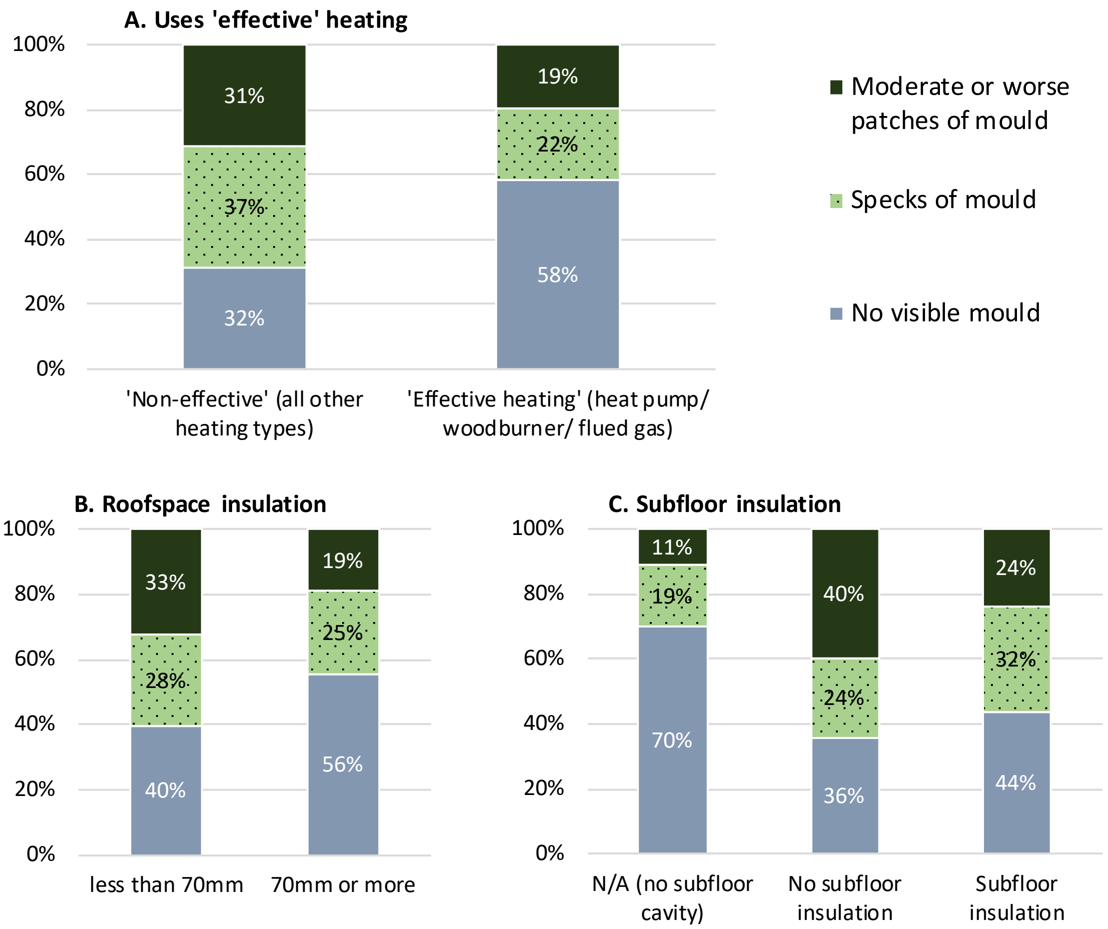


Figure 26. Worst case of mould in the house by (A) use of effective heating, (B) roof space insulation, (C) subfloor insulation. (Source: HCS 2015 physical house assessment for insulation, householder appliance-use survey for heating use)[31]

6.3 Mould and overall house condition

A substantial part of the House Condition Survey involves the assessor rating the condition of various individual components of the house on a 5-point scale from serious to excellent. This is based on the presence of defects and need for repair/maintenance.[32]

In addition to rating the condition of individual components of the house, the assessor also gave an overall assessment of how well maintained they considered the property. This was on a 3-point scale of well, reasonably or poorly maintained.

[31] Mould level refers to the worst level of mould recorded anywhere in the house. Effective heating includes use of a heat pump, wood burner or flued gas. Subfloor insulation includes houses with foil. Despite known health and safety risks and poor thermal performance compared to bulk insulation, foil is accepted under the RTA provided in reasonable condition.
[32] The House Condition Survey condition rating scale definitions are:

- serious: health and safety implications; needs immediate attention
- poor: needs attention within next 3 months
- moderate: will need attention within the next 2 years
- good: very few defects; near-new condition
- excellent: no defects; as-new condition (see White et al., 2017 for further details).

As might be expected, mould levels were higher in houses that had poorer condition ratings and were considered less well maintained overall (Figure 27).[33]

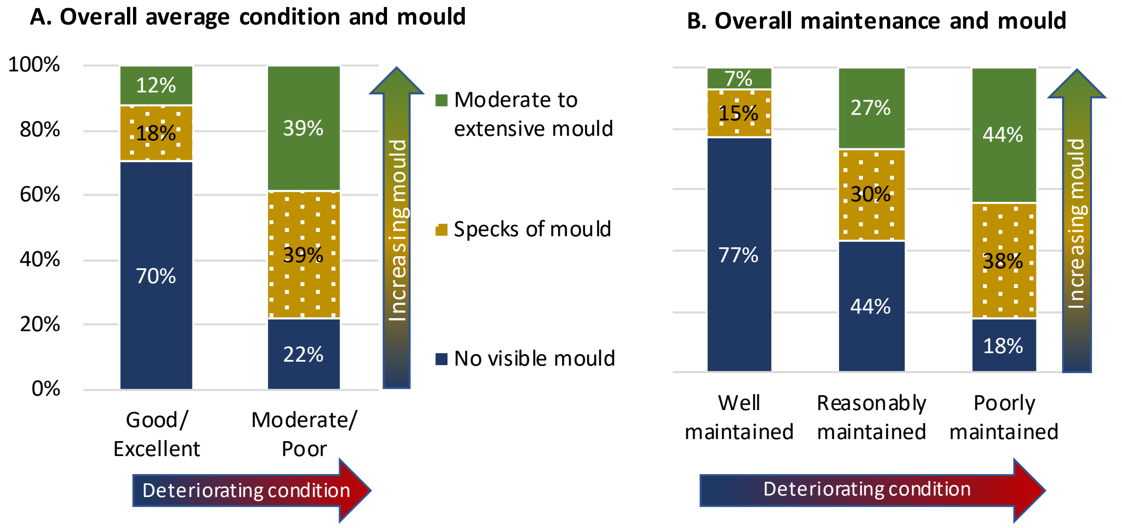


Figure 27. Mould levels and (A) overall average house condition and (B) overall level of maintenance, (Source: HCS 2015 physical house assessment)

6.4 Discussion, key points and section summary

The analysis presented above indicates a relationship between heating, insulation, ventilation and mould levels in the home. Where insulation and ventilation are present and heating is used, mould generally appeared less prevalent. Where one or more of these features were missing or less than optimal, there appeared an increased likelihood that mould would be present.

It should be recognised that the data and analysis undertaken here does not prove a causal link between these factors. Nonetheless, many of the results observed in the HCS align with other research and advice about preventing mould growth in the home (Elkink, 2011). Studies have shown certain improvement measures can help reduce the risk of damp and mould in the home and benefit the health of occupants (Howden-Chapman et al., 2007, Howden-Chapman et al., 2008). These include installing and using efficient heating and ventilation and insulating the building. However, these do not eliminate the need for considering and addressing the impact of occupant behaviour (Plagmann, 2016). Even then, while heating, insulation, ventilation and supporting behaviours are vitally important for managing mould growth, there are wider factors beyond these physical and behavioural attributes that also play a part. These include, for example:

- socio-demographic effects (such as who lives in the house, occupancy patterns, heating needs and preferences)
- income effects (affordability to heat, insulate, repair and maintain)
- a wide range of other building characteristics (materials, age, climate and airtightness).

[33] The HCS condition rating used here is simply an average of all the individual component condition ratings for the house. For further information on this method, see White et al., 2017.

7. Summary of key points

Drawing on data from the 2015 House Condition Survey, the analysis presented in this report has focused on some key features associated with, and indicative of, a warm, dry, healthy home. These are insulation, ventilation, heating and the presence of mould.

Insulation – minimising heat loss

- Although ceiling insulation is present in most New Zealand houses, it is generally at a level that could be considered suboptimal.
- 47% of houses surveyed (representing 740,000 dwellings) had less than 120 mm and/or less than 80% coverage of insulation in the roof space. 120 mm is the minimum recommended by the New Zealand Government's home insulation retrofit programme and the Energy Efficiency and Conservation Authority.
- 23% of rentals had less than 70 mm insulation in the roof space, which is a proxy for the minimum thickness of existing ceiling insulation in rentals under the Residential Tenancy Act insulation requirement, introduced in 2016 (to be met by July 2019).
- Two-thirds of houses had a subfloor cavity. 19% of these (290,000 dwellings) had less than 80% coverage of subfloor insulation.
- Just under one-quarter of properties with a subfloor (23%, 240,000 dwellings) had underfloor foil insulation. Foil insulation is no longer recommended for use in the subfloor due to performance, durability and safety concerns.
- Overall, around 830,000 (53%) New Zealand houses have no or suboptimal insulation in the roof space and/or subfloor.[34] These houses would benefit from retrofitting ceiling and/or subfloor insulation.[35]
- 13% of houses (210,000) could benefit from additional insulation of both the ceiling and subfloor.

Ventilation – moisture management

- As houses become more airtight through changing construction practices, the need for effective ventilation increases.
- Results from the 2015 HCS showed that, while nearly all main bathrooms had an openable window, only around half had an extractor fan extracting to the outside.
- Heating can also help with moisture control, as warmer air can hold more moisture, reducing the risk of condensation forming on cold surfaces. Around half of all households did not have heating in the bathroom. Those with heating would still need to ventilate to let the moist air out and replace it with drier air.
- Kitchens are another high moisture area of the home, due to water vapour produced from cooking. Only around half (49%) of houses surveyed had an extractor fan in the kitchen that was extracting to the outside.
- Mould was visible in a higher proportion of bathrooms and kitchens where mechanical ventilation was not present.

[34] Suboptimal roof space insulation includes houses with an accessible roof space but less than 120 mm depth and/or less than 80% coverage. Suboptimal underfloor insulation includes houses with an accessible subfloor but less than 80% coverage of insulation.
[35] This number excludes properties where access to the roof space and subfloor was not possible at the time of the survey, and therefore the status of insulation is unknown. This lack of access could suggest insulation retrofitting may be limited in these houses.

Heating habits

- Results from the 2015 HCS householder appliance-use survey showed most households heated the main living area at some time in winter, most commonly in the evening.
- Heating of bedrooms was far less common, however, with 46% of households saying they did not usually heat any bedrooms in winter. This included bedrooms occupied by children and older adults. The WHO-recommended indoor temperature of 18°C is unlikely to be achieved without some heat input at least some of the time in winter.

Heating appliances

- While nearly all houses surveyed had at least one heating appliance in the home, the type of heating varied between owner-occupied and rental properties.
- Fixed heating was more commonly found in owner-occupied houses, present in 93% of dwellings, compared to 77% of rented houses.
- Conversely, portable heating was more common in rentals (62%) than owner-occupied dwellings (51%).
- One-fifth of rentals (20%) had only portable heating appliances (i.e. no fixed heating system was present in the home), compared to 7% of owner-occupied houses.
- Heat pumps, wood burners and flued gas heaters are among the more cost-effective appliances and were common in owner-occupied houses (88%) but less so in rentals (62%).
- Overall, results suggest that tenants have less access to the more cost-effective heating solutions than owner-occupiers. Tenants are relying on heater types that are typically more expensive to run and less effective for heating larger living spaces.

Unflued gas heaters

- Portable LPG heaters are known for their risks to occupant health, due to being unflued and releasing dangerous gases and water vapour directly into the home. They are also one of the most expensive home heating appliances to run. These were present and being used to heat living areas in 17% of rental properties and to heat bedrooms in 6% of rented houses. Use of unflued gas heaters in rooms where people sleep goes against government advice, which clearly states these heaters should never be used in this situation.
- Overall, results from the 2015 HCS suggest around 80,000 (8%) owner-occupied and 95,000 (18%) rental households used unflued gas heaters (fixed or portable) somewhere in the home for heating in winter.

Damp and mould

- Damp and mould are key indicators of a poor quality indoor environment and of the need for better management of moisture levels in the home.
- Rental properties were twice as likely to smell damp than owner-occupied houses (12% compared to 6% had a musty smell).
- Rentals were also nearly three times as likely to feel damp than owner-occupied properties (31% compared to 11%).
- Mould was visible in nearly half (49%) of all properties surveyed in the 2015 HCS.
- Mould was observed in a slightly higher proportion of rentals (56% compared to 44% in owner-occupied houses).

Mould and other factors

- Mould was observed less frequently in houses where insulation and ventilation were present and heating was used. Where one or more of these features were missing or less than optimal, there appeared an increased likelihood of mould being observed. Further analysis of the HCS data is needed to further explore these findings and the many interrelating factors affecting the likelihood of mould growth.

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Appendix A. Sampling approach

Sample structure

The sample structure for the 2015 House Condition Survey was designed to capture a representative sample of owner-occupied and rental properties throughout New Zealand. The sampling approach, which followed that used in the 2010 HCS (Buckett, Jones & Marston, 2012), involved dividing the country into 13 parts or strata. 11 of these corresponded to cities, with the remaining two strata being the rest of the North Island and the rest of the South Island (Figure 28). Samples (550 in total) were divided amongst these strata in proportion to the number of houses recorded in the 2013 Census of Population and Dwellings (Table 3).

Table 3. 2015 House Condition Survey target sample.

Group/locality	Target sample			
	Owner-occupiers		Renters	
	%	Houses	%	Houses
Group A				
• Auckland City	18	30	24	25
• Manukau City	13	21	15	15
• North Shore City	11	18	9	9
• Waitakere City	9	15	8	8
• Hamilton City	6	10	8	8
• Wellington City	9	15	10	10
• Porirua City	2	4	2	2
• Lower Hutt City	5	9	4	4
• Upper Hutt City	2	4	1	1
• Christchurch City	18	30	15	16
• Dunedin City	7	11	5	5
Total	*100*	*167*	*101*	*103*
North Island clusters	72	136	76	68
South Island clusters	28	54	24	22
Total	*100*	*190*	*100*	*90*
Grand total	*100*	*357*	*100*	*193*

Sampling within strata

The 11 strata corresponding to the cities were sampled using simple random sampling. The two remaining strata (the rest of the North Island and the rest of the South Island) were sampled in clusters. 69 clusters were selected at random with each cluster being a Census area unit as defined at the 2013 Census. Within each selected cluster, four houses were selected by simple random sampling, with the constraint that between one and three were required to be rental houses. An unbiased random rounding method was adopted.

The sample was designed to generate a self-weighting sample representing New Zealand owner-occupied and rented houses, with an overall sample error of ±5% at a 95% confidence interval.

The 2015 HCS also included an extended sample of houses to be surveyed in Christchurch. This additional sample was funded by the Ministry of Business, Innovation and Employment to provide some insights into the impact of repairs undertaken since the 2010/11 earthquakes. The extended Christchurch sample had a target survey quota of 104 houses. This brought the total number of houses surveyed in Christchurch to 150 (46 were part of the mainstream HCS sample, as shown in Table 3.)

Combining the mainstream HCS sample and the additional Christchurch sample generated a total target sample quota for the 2015 HCS of 654 houses. (This was 550 in the mainstream HCS sample plus 104 in the additional Christchurch sample.)

Figure 28. Location points for surveying in the 2015 House Condition Survey. (Source: HCS 2015 and Google Maps)

Recruitment and post-sampling weighting

Houses were recruited to the 2015 HCS via telephone (landline). While this method successfully secured most of the target sample of houses, the complete target quota could not be fulfilled within the surveying timeframe. A total of 560 houses were surveyed, which included 411 owned and 149 rentals (see Table 1).

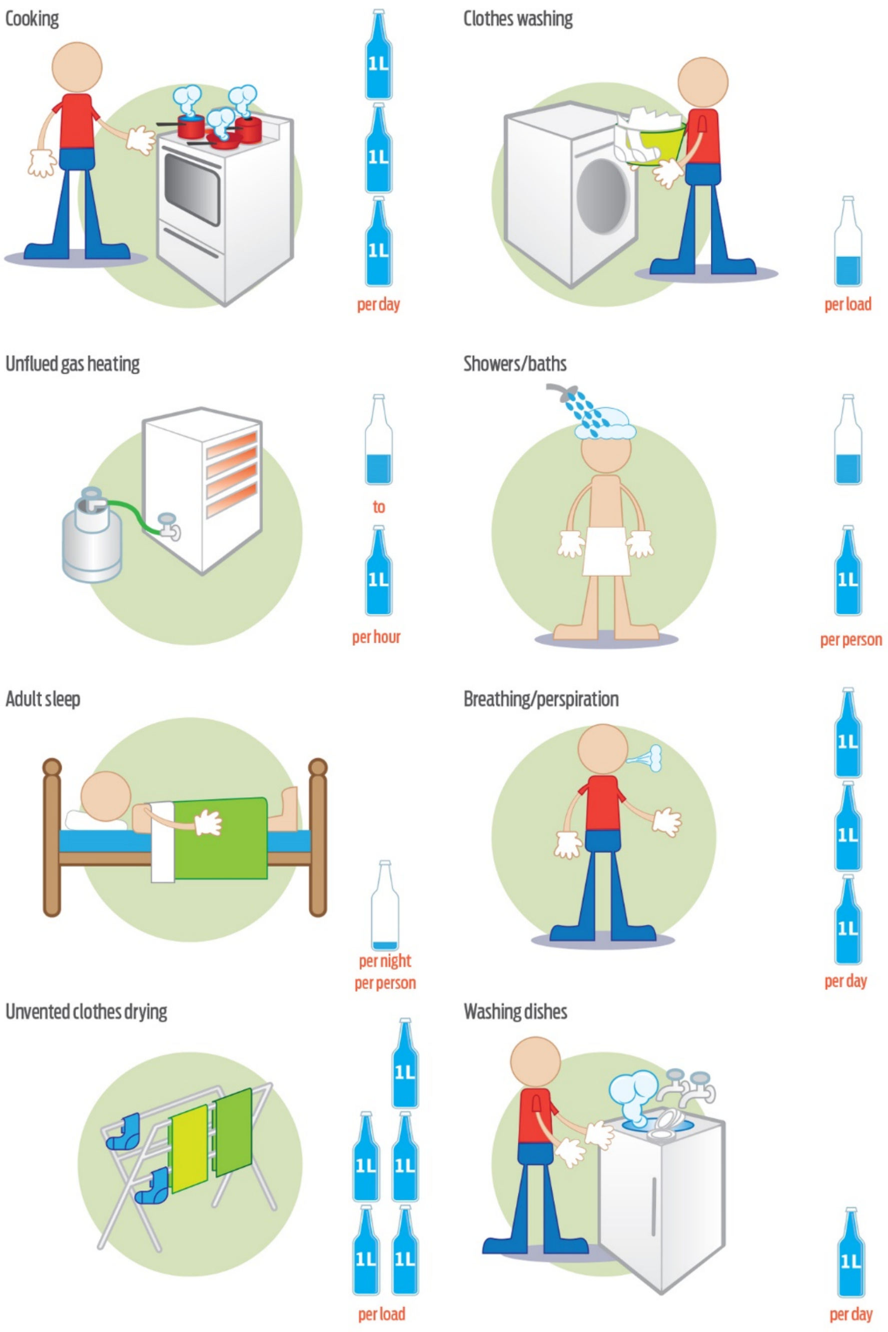
Had the sample quota been achieved as per design, it would have been self-weighting (as it was designed specifically to be representative of the owner-occupied and rental stock). However, due to some under-recruitment, of the rental stock in particular, the sample has instead been weighted to maintain representativeness.

Post-sampling weighting

The weighting effectively realigns the proportion of owner-occupied and rental houses surveyed to be consistent with the 2013 Census. Weights were generated for each surveyed unit within a stratum/cluster based on tenure. For example, if (based on the 2013 Census) there were an estimated 100,000 non-rental houses meeting the HCS criteria in a certain stratum, and 50 such houses were surveyed. Each of the surveyed houses could then be considered as representing 2,000 houses in the population. Each surveyed house would therefore be given a weight of 2,000 (50 x 2,000 = 100,000). This process was applied to all sampling strata and clusters using Census estimates and actual number of houses surveyed.

This weighting method was applied to the mainstream HCS survey sample and the mainstream plus the Christchurch additional sample. The latter has been used for all analysis presented in this report, offering the advantage of a larger sample size. The sample sizes, sampling errors and weighted counts are shown in section 1.3.

Appendix B. Sources of moisture in the home



(From Elkink, 2012b, Figure 13, p. 29).

Appendix C. Additional charts and tables

Insulation levels in the roof space

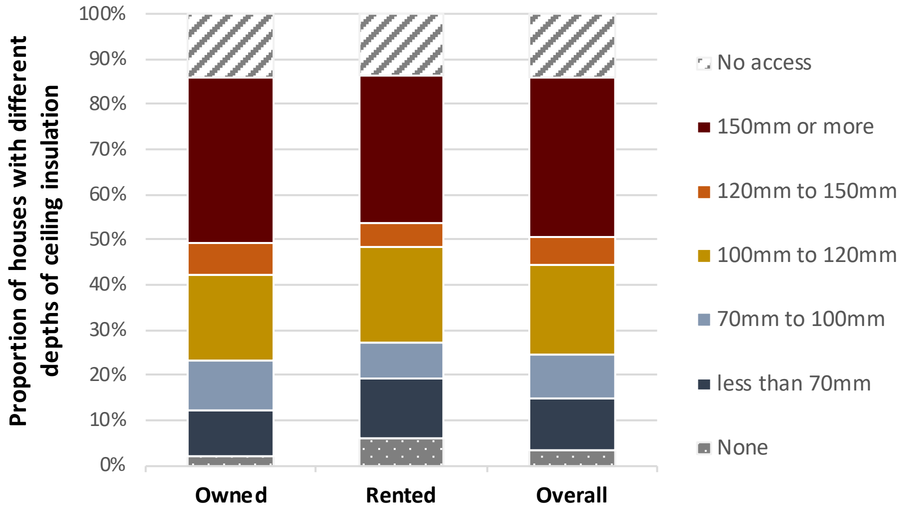


Figure 29. Proportion of houses with different depths of ceiling insulation (excluding consideration of coverage). (Source: HCS 2015 physical house assessment)

Heating appliances in the home

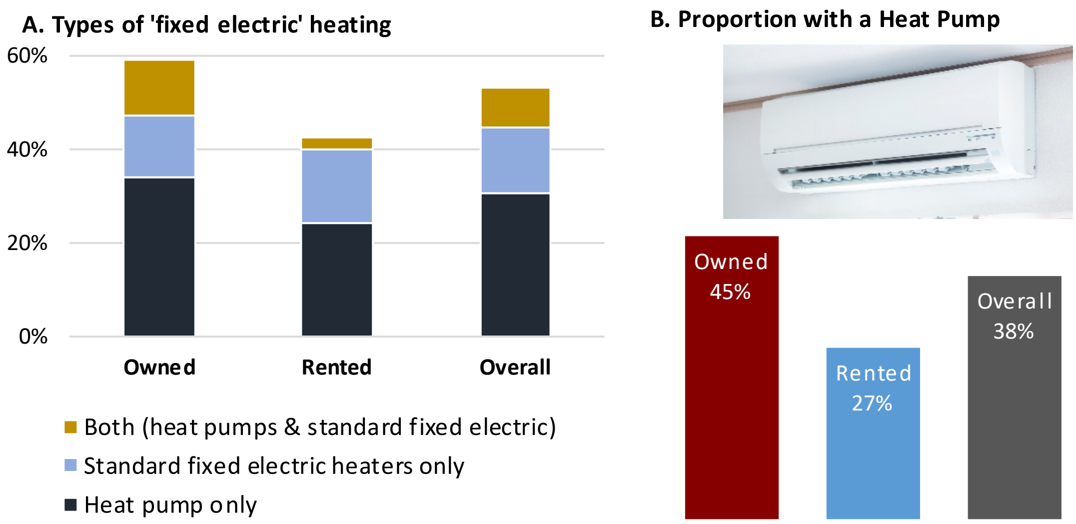


Figure 30. Proportion of houses with 'fixed electric' heating and total with heat pumps. (Source: HCS 2015 physical house assessment; image: istock)

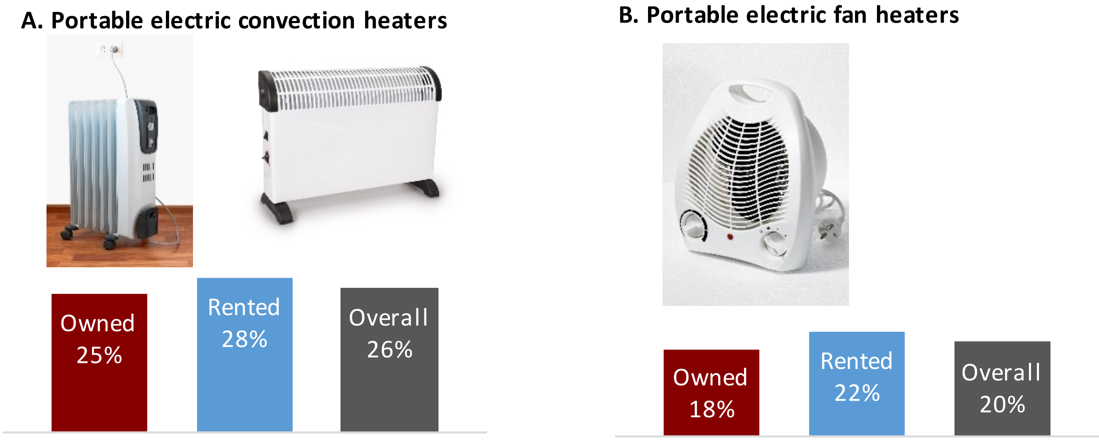


Figure 31. Presence of portable electric convection heaters and portable electric fan heaters. (Source: HCS 2015 physical house assessment; images: istock)

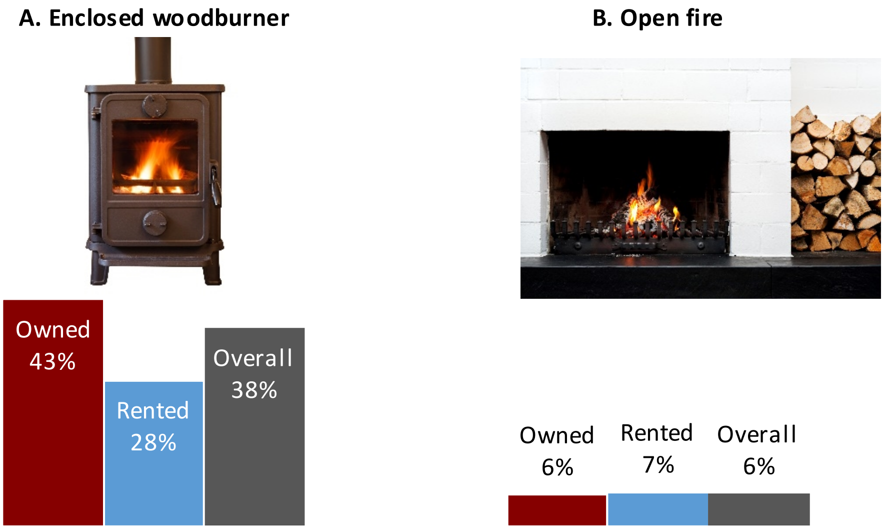


Figure 32. Proportion of houses with wood burners and open fires. (Source: HCS 2015 physical house assessment; images: istock)

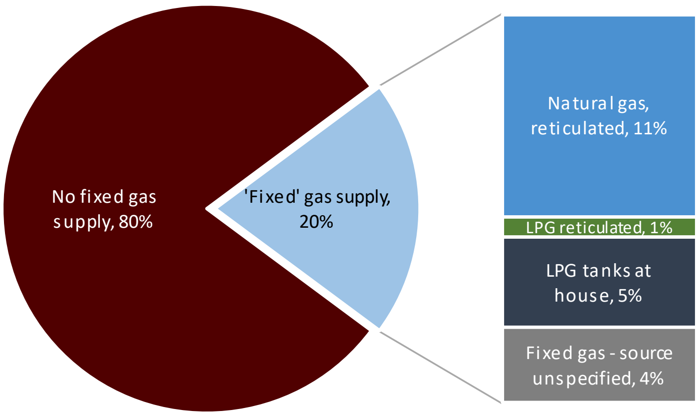


Figure 33. Proportion of houses with a 'fixed' gas supply and type of gas supplied. (Source: HCS 2015 physical house inspection)

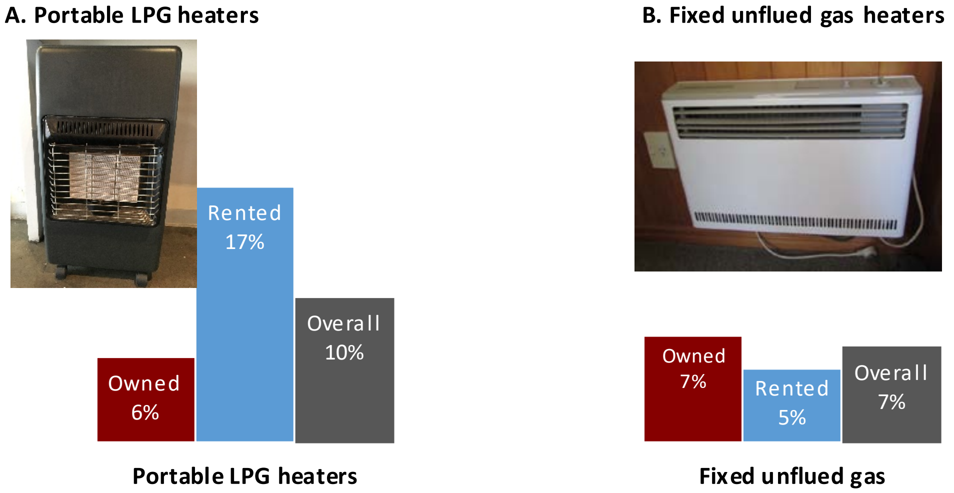


Figure 34. Proportion of houses with portable LPG cabinet heaters. (Source: HCS 2015 physical house inspection)

Heating habits

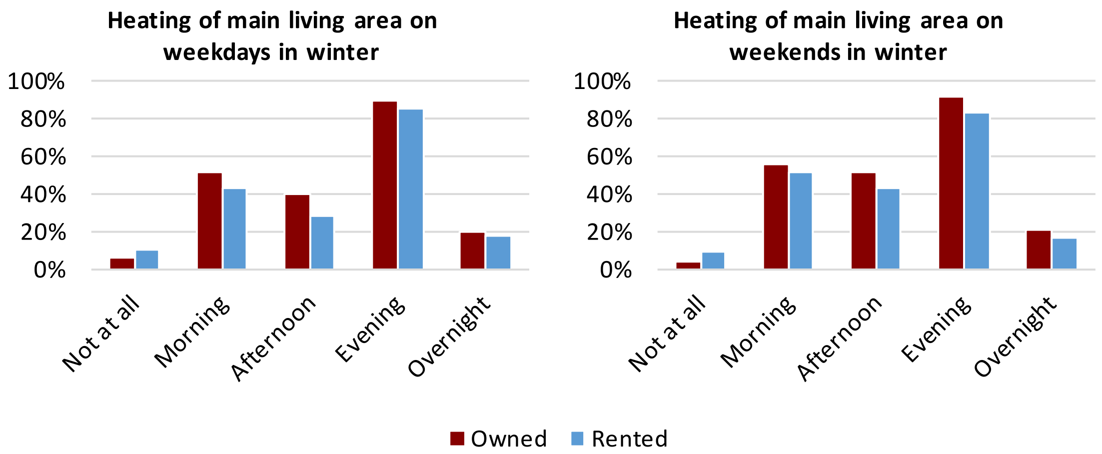


Figure 35. Heating of main living area on weekdays and weekends in winter. (Source: HCS 2015 householder appliance-use survey)

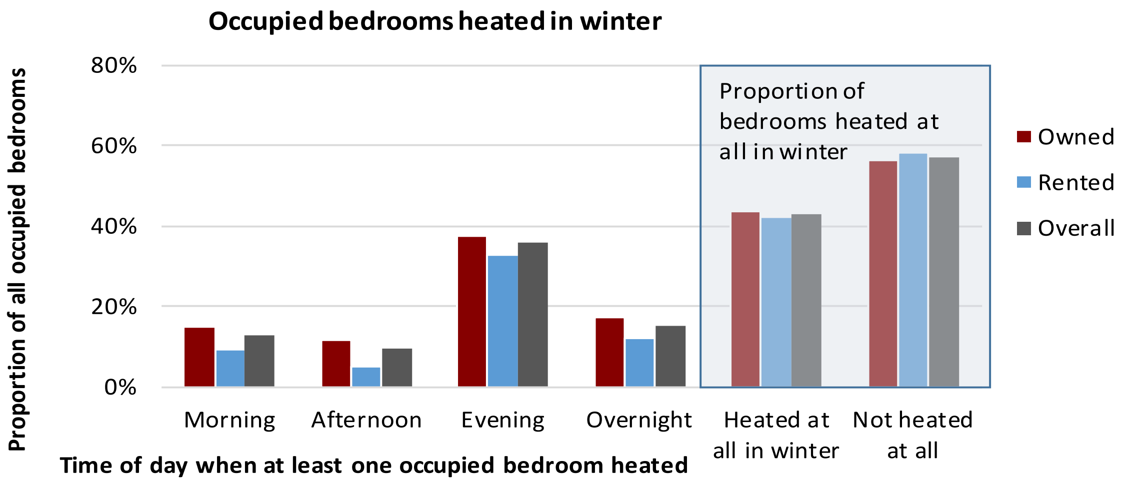


Figure 36. Heating of occupied bedrooms in winter (figures as a proportion of all occupied bedrooms). (Source: HCS 2015 householder appliance-use survey)

Heating, ventilation and mould in the bathroom

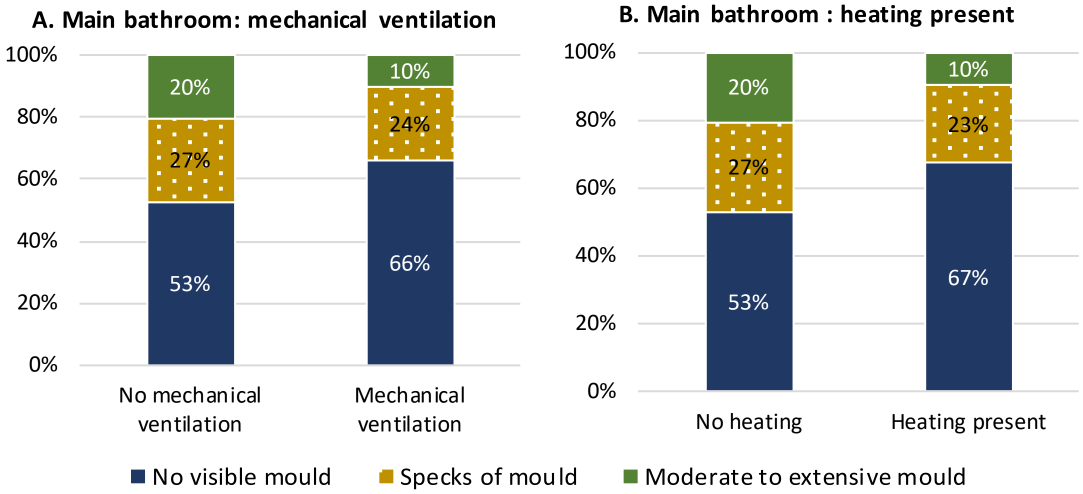


Figure 37. Extent of visible mould in the main bathroom by presence of (A) mechanical ventilation and (B) heating. (Source: HCS physical house assessment)

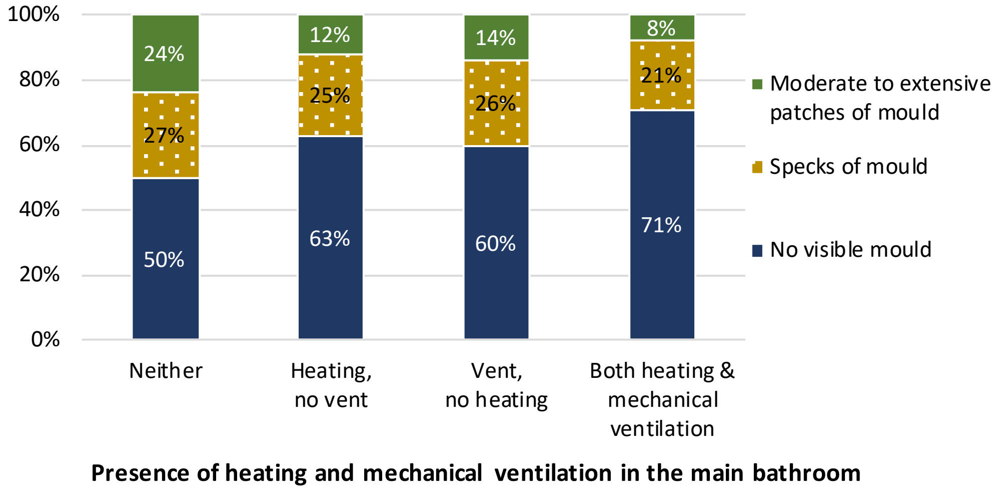


Figure 38. Presence of mould in main bathrooms with and without mechanical ventilation and heating. (Source: HCS 2015 physical house assessment)