Centre for
Building
Performance
Research

A Household Occupants' User Guide.

An instruction tool for the household for buildings designed to minimum code compliance.

Sarah Buet
Nilesh Bakshi
Michael Donn
James Wallace

Research and publication by the
Centre for Building Performance Research,
Victoria University of Wellington.

In partnership with:

Studio of Pacific Architecture.

February 2019

Edition information

ISBN 978-0-475-12431-9

Authors: Sarah Buet, Nilesh Bakshi, Michael Donn, James Wallace
Research Assistants: Sarah Buet.
Partnering Researchers: The Research Group at Studio of Pacific Architecture

Report title. A Household Occupants' User Guide: An instruction tool for the household for buildings designed to minimum code compliance.

Centre for Building Performance Research,
Victoria University of Wellington,
P.O. Box 600, Wellington, New Zealand.

Phone + 64 4 463 6200 Facsimile + 64 4 463 6204

The Document Register is provided at the rear.

Preface

This report presents the findings of the joint research project for identifying key consideration needed for the development of a Household Occupants' User Guide. The project was in response to results from a 2016/17 investigation which found the ratio of timber in modern construction might far exceed that of code estimates and how occupants understanding of behavioural changes were limited and warranted further instruction. The current study aims to identify successful methods of 1) occupant ventilation practices and 2) identify key practices that need to be accounted for when providing any assurance of building performance. The aim for this study is therefore to map key impacts of occupant behaviours, and to compare identoify areas of note that must be cautioned against for the successful performance of the building's thermal and moisture porferomance.

Acknowledgments

This work was funded by the joint investment of Studio of Pacific Architecture and the Victoria University of Wellington through the Victoria Summer Research Scholarship Programme.

This work is made possible by the valued efforts of the partnering researchers from the research group at Studio of Pacific Architecture.

Table of Contents

Abstract

A number of recent research papers argue that a passive approach in the form of household user behaviour is the simplest approach to mitigate poor building performance and optimise environmental conditioning. However, research undertaken into specific New Zealand case studies from BRANZ and the HEEP report have indicated that there is very little evidence of these passive measures currently being adopted. Furthermore, there is currently little one can do in practice to communicate these ideas to a client or future homeowner.

This research identified a range of behavioural changes that occupants are able to implement within their homes in order to improve the internal environmental quality and optimise the buildings performance. These behavioural changes come as a result of identifying and consolidating existing research from a variety of tool and resources to create an occupant user guide that is unique to each dwelling and provides occupant with the tools to make informed decisions within their dwelling.

Introduction

This research investigates passive measures that are able to be adopted by a household in order to mitigate interstitial moisture and poor building performance, and to optimise indoor air quality (IAQ) and environmental conditioning. Whilst a number of recent research papers argue that a passive approach in the form of household user behaviour is the simplest approach, existing New Zealand specific studies from the Building Research Association of New Zealand (BRANZ) and the Housing Energy End-use Project (HEEP) report suggest that there is very little evidence of these passive measures currently being adopted. Furthermore, there is currently little that one can do in practice to communicate this idea to a client or future homeowner. Therefore, through examining various existing tools and resources regarding occupant behaviour and behavioural changes, this report aims to establish a range of methods that users are able to implement in order to achieve comfortable and healthy dwellings. These methods will then be compiled in order to form a master occupant user guide that is able to be customised for a variety of building types and scenarios.

Research question

The primary focus of this particular research can be summarised by the the following research question:

Can a tool be developed that enables architects and building professionals the ability to effectively communicate a range of possible occupant behavioural changes that will improve and optimise the buildings performance and indoor environmental quality?

Background

By nature, occupant behaviour is a complex concept to define due to its stochastic and diverse disposition as well as its interdisciplinary application within the field of building performance research. Whilst the number of studies defining occupant behaviour has drastically increased in recent years, a unified methodology that is able to systematically decipher, identify, and analyse main features of different kinds of occupant behaviour is yet to be established. As a result of this, there is no definitive answer as to how occupants will use a space and what external factors will influence an occupants' decision to act in such a way. Furthermore, different areas of research tend to dictate which of the different behavioural parameters are adopted for analysis. For this reason, it is vital to define the term 'occupant behaviour' in regards to this particular field of research.

In regards to optimising building performance several pieces of literature place reference to occupant behaviour being able to be classified into one of three influencing factor categories; time related behaviour, environment related behaviour, and random behaviour (Peng, et al., 2012). However, these categories are not relevant to this research, as rather this research focuses on how an occupants' behaviour may be altered in order to optimise building performance and improve the indoor environmental quality, regardless of any existing behavioural characteristics. It is therefore redundant to begin to understand external factors that influence the way an occupant acts in the way they do.

The key focus for this research, places emphasis on how the occupant interacts with the building and the passive and active systems within the aforementioned building and how this influences the overall energy consumption and performance of the space. Chen, et al defined the term 'behaviour' as the observable actions or reactions of a person as a result of both internal and external stimuli in order to alter the environmental conditions of a space to some degree (Chen, et al., 2015). This definition places emphasis on the interactions between the occupant and the building and thus is particularly relevant. Subsequently, for this research, 'occupant behaviour' can be defined as the interactions that occur between the occupant and the building in which the environmental conditions are being altered, be that positively or negatively, through the control of active and passive systems with the building e.g. opening windows.

The influence of occupant behaviour on building energy consumption

Within recent years, with the increasing awareness of climate change, the drive for a more sustainable building industry has become an ever-growing global focus. The call for this sustainable development comes due to the increased awareness of the extent of energy consumption of buildings. Of the total primary energy resources, buildings consume approximately a third of that therefore making them an optimal target for the application of energy reduction measures. Numerous studies into building performance, simulation and energy consumption have acknowledged the alarming performance gap between the predicted energy consumption in building simulation and the actual consumption of buildings. It has further been identified that this performance gap comes as a result of occupants' behaviour being largely overlooked during the design of the building and the buildings performance analysis (Delzendeh, Wu, Lee, & Zhou, 2017).

Building performance analysis, or building simulations, are often adopted by building engineers as useful methods to understand and begin to quantify the effect of altering occupants' behaviour on the buildings energy consumption and overall building performance. However, as previously acknowledged occupant behaviour is a complex concept and consequently there is a lack of data in regards to occupants' actual behaviour with a building. As a result of this, when performing building simulations, building engineers are made to assume extreme behavioural patterns such as heating always on or windows always open. These extreme assumed behaviours' therefore often result in an over or underestimation of the predicted energy consumption which therefore significantly reduces the reliability and accuracy of any predicted results (Pan, et al., 2017). These assumed behavioural patterns have widely become recognised as a major source of uncertainty in regards to building performance simulation and thus a barrier when looking to optimise a buildings energy consumption.

Due to the inability to accurately predict the impact of occupant behaviour, within building simulations the technology and systems that are utilised in the space become scrutinized to understand their impact on energy consumption. At present there has been a vast amount of research undertaken to understand the ideal building technologies which should be implemented in order to optimise the buildings performance. However, this level of research does not extend to understand how occupants should use these technologies. The development of buildings that are more energy efficient and perform better requires the perspective of the occupants as it becomes increasingly evident that technology alone is unable to achieve future building energy conservation goals (Zhang, Bai, Mills, & Pezzey, 2018). In a study undertaken in 1983 by van Raaij and Verhallen, it was suggested that the occupants' perception of comfort was one the key influencers on occupant energy use and thus an area that needs to be greatly understood in order to optimise a buildings performance (van Raaij & Verhallen, 1983).

Importance of occupant education

Numerous studies have eluded to various methods of encouraging occupants to changing their behaviours within a space in order to improve building performance and reduce energy consumption. Such methods include means of incentives, goals setting, providing feedback and creating competitions. However, it has been shown that regardless of any incentives that encourage an occupant to behave in a particular way to promote a healthy environment or reduce energy consumption, a lack of knowledge still remains to be the biggest barrier. This lack of knowledge in regards to how their behaviours impact the environment mean that any lasting change in occupant behaviour is often minimal (Gunderson & Day, 2015).

Education and any training efforts regarding building systems and their optimised performance are so often directed towards building professionals such as architects and designers, with building occupants commonly being forgotten. Building occupant education programs are lacking and where they do exist, the information is often complex and indirect. With the unique range of buildings that exist and the numerous design strategies within each, the need for occupants to understand the specific systems and operations within the building they occupy is vital (Gunderson & Day, 2015).

In order to mitigate this barrier that occupants inadvertently create for the reduction of energy consumption, education is the next vital step forward. It is critical that an occupant begins it understand how their actions impact the way the building performs as well as how they can alter their actions to improve the building and create a healthier and more comfortable space for themselves.

Review of existing resources and tools

Currently, there are several tools and resources of which an occupant or architect is able to publicly access in order to gain information on how to incorporate and use passive designs in residential homes to improve and optimize the indoor environmental quality. These two resources come from three primary organizations; the Energy Efficiency Conservation Authority (EECA), BRANZ, and the Ministry of Business, Innovation and Employment (MBIE).

The EECA is a government agency that aims to promote the use of renewable energy sources in both businesses and residential spaces as well as the use of energy efficient systems and energy conservation measures. A website called 'Energywise' is a key resource developed by the EECA and its aim is to provide a consumer with a tool that ensures that they can make informed decisions regarding energy efficient products and energy conserving measures that can be implemented within their homes. There are various subsections which cover the most common areas of poor building performance; heating and cooling, dampness, ventilation and lighting. As mentioned prior, education is a vital aspect of endorsing energy efficient behaviours and the 'Energywise' tool considers this. When providing advice for a consumer, 'Energywise' also gives additional information to educate the consumer as to why an action would, for example, improve the ventilation within their homes. The only downfalls of the 'Energywise' tool are the lack of individual and customisable advice which may lead to confusion for a consumer as well as the inclusion of advice that is more targeted towards design decisions rather than occupant behavioural changes. An example of this would be "When building, design eaves (or roof overhangs) above north facing windows." (EECA, 2018)

'Level' is another website tool that was developed by BRANZ specifically for the construction industry and similarly to 'Energywise' it promotes the idea of sustainable design in order to lower a homes impact on the environment and produce healthier and more comfortable homes. Whilst the website covers a number of categories such as site analysis, site use, material use and health and safety, the focus category for this research was the passive design category. Again similarly to 'Energywise' the passive design category comprised itself of various subsections which covered some of the most common areas of poor building performance; ventilation and lighting, however, was not found to be as comprehensive as 'Energywise'. Whilst 'Level' stresses the importance of passive design as the key to building sustainable homes, a majority of the passive design advice is directed towards to an architect. This direction results in advise that tends to place an emphasis on the design of the space as opposed to how an occupant can alter their behaviours to improve the building performance.

In recent years a collaboration has occurred between BRANZ and the Ministry of Education to produce a number of reports that specify how to design and use learning spaces in order to achieve spaces that are of the highest quality. Whilst these guides are specifically designed with schools in mind, a number of the points touched on are able to be translated into advise for a residential space due to the performance goals remaining consistent between the two. There are a number of different guides which places emphasis on different areas of the internal environment such as indoor air quality and thermal comfort as well as lighting. The key focus of the design guides is to place emphasis on, and educate occupants on how issues within the internal environment occur for example sources of excessive moisture. Once identifying common problem areas, it then goes on the suggest methods of which an occupant, namely a teacher, is able to mitigate these issues. These guides specifically identify the broad methods of improving the space, for example in terms of reducing internal moisture one guide specifies the following steps:

- Eliminate source of moisture
- Manage at source
- Ventilate space

- Temperature control of space
  (BRANZ, 2007)

These key steps mentioned begin to identify the foundations of occupant behavioural changes that can be undertaken within the space rather than identifying specific advise that can be undertaken by an occupant. Additionally, again this form of guide does not provide individual advise for an occupant based upon their specific space instead providing rather generic suggestions.

'Climate consultant' is an interactive design tool which allows for a variety of users from architects and builders to homeowners, to begin to understand the local climate of which the building is situated. An aspect of this 'Climate consultant' tool which relates to this research is the inclusion of a list of customised design strategies which take into consideration the climate of a building site. This tool is one of the first that begins to give specific advise for a building based upon its individual characteristics. The primary goal of this tool is promote a more energy efficient and sustainable building design which is uniquely suited for a specific climate. Whilst 'Climate consultant' is able to produce a customised list of design guidelines from a master list of 68, these guidelines are catered towards to improvement of the design of the space and there is minimal information regarding how an occupant could interpret this information and translate these recommendations into an existing building. The primary focus of this information is directed towards the architect and designer as opposed to the occupant or homeowner.

'Standards New Zealand' is less of a tool than those previously discussed and is more a resources that is used to understand what the minimum requirements in regards to building performance are for a space. 'Standards New Zealand' is a department within the MBIE and dictates minimum requirements for a wide variety of topics including of which is building performance. Building performance standards are spread out amongst various standard documents thus resulting in information that can be hard to gather, compose and digest. Additionally, due to its nature, these standards do not give any specific advise on how to achieve the minimum requirements that have been stipulated and thus must be used in conjunction with another tool to begin to use them in a practical sense.

The 'New Zealand Building Code' (NZBC) is another resource that was composed by MBIE that works in conjunction with the Building Act 2004 and is a resources that all building work in New Zealand must comply with. The NZBC is comprised of predetermined acceptable solution and verification methods of how to achieve the minimum requirements as well as previous alternative solutions that differ from those predetermined. Whilst the NZBC specifies how, for example, the minimum ventilation required can be achieved it does so as instructions towards an architect or designer rather than an occupant. The NZBC is a tool that is better used in the design phase of the building as opposed to the post occupancy phase.

Two common factors arose from this review of existing resources and tools which are;

- No tool or resource provides customised advise for how an occupant can specifically use their space in order to improve building performance and create a healthier and more comfortable indoor environment.
- The information regarding how to improve a space is generally directed towards an architect or designer and places emphasis on how to design a space better as opposed to teaching an occupant how to use the space better.

The focus of this research is to consolidate existing information into a customised guide that is able to advise, as well as educate, an occupant on how to use their space effectively in order to optimise the buildings performance.

Methodology

Identifying and defining housing typologies

At the commencement of this research, it was envisaged that the final output would be several different occupant user guides and each dwelling would be able to fit into a category where there would be a corresponding user guide for that category. This first step in this research therefore was to begin to identify and define these different housing typologies of which a guide would then be made for each. Dwelling size, dwelling shape, number of storeys, and number of bedrooms and bathrooms began to be investigated however two key issues arose from this. Firstly, this method meant that the number of different typologies grew exponentially with every additional question. Just by posing five questions with a range of three to five possible answers for each question, the number of possible outputs was 1200. Due to the wide variety of the New Zealand housing stock and the number of questions that needed to be asked in order to be able to accurately categorize each dwelling into a different typology, it was determined that this method was out of the scope of this particular research project. Secondly, as previously discussed this user guide would be most beneficial if the behavioural changes advice correlated exactly with the systems and types of space that the occupant occupies. Therefore, by aiming to categorize each dwelling into one of five or so different typologies, may result in a user guide which is broad and only offers vague advice for an occupant.

Additionally, it was identified that there was not always a direct correlation between the questions being asked and the impact that they would have on the building performance. For example, regardless of how many bedrooms a dwelling has it is expected that the space performs the same in regards to comfort and indoor environmental quality. This idea was relevant for a number of questions that were being raised such as number of storeys, number of bathrooms and whether the living spaces were open plan or not.

Due to the limitations of the scope and the points discussed above, it was determined that an approach similar to the design strategy outputs of 'Climate consultant' was ideal. The idea became to develop a master guide of all the possible occupant behavioural changes and then ask a series of questions in order to determine which occupant behavioural changes would go into each customised user guide. This method meant that each user guide was able to be specifically customised for each dwelling and thus avoid any occupant confusion of any advice being included in a guide that an occupant was unable to undertake within their particular dwelling.

Identifying occupant behavioural changes

Once understanding that a master occupant user guide was to be created, the next stage was to identify and define the occupant behavioural changes that were to be encompassed within the master guide. The first stage of this was to identify the primary performance goals that ideal will be achieved within the space to create a space that is comfortable and healthy for the occupant nd thus the main objectives of this guide.

Indoor environmental quality (IEQ) is most simply put as the quality and the conditions within a building and includes a variety of different environmental conditions and thus is relevant to the particular research. The Leadership in Energy and Environmental Design (LEED) is one of the most universally utilised green building rating systems and defines IEQ as the thermal quality, lighting and indoor air quality (IAQ) (LEED, 2019). These definitions began to form the basis of the final five focus objectives of this research. Whilst lighting and IAQ are able to stand alone, it was felt that thermal quality should be divided into two separate objectives each focusing on either heating or cooling as looking forward they would require different occupant behavioural changes. As the scope of particular research began with the idea of New Zealand homes being the primary stakeholder of these guides, it was thought to be relevant to consider a common issue in New Zealand homes; moisture. New Zealand homes are infamous for high levels of internal moisture that result in damp spaces that host mold and condensation and thus negatively impact the health of the internal environments. Consequently, it was determined that an objective solely dedicated to reducing internal moisture was produced. From this process the following five objectives have been developed:

- Objective one: Improve indoor air quality
- Objective two: Reduce internal moisture
- Objective three: Indoor lighting
- Objective four: Improve indoor heating
- Objective five: Improve indoor cooling

The second stage of identifying occupant behavioural changes was to begin to broadly identify how each objective would be able to be defined. Whilst undertaking a review of key tools and resource, a number of guides developed by BRANZ and MOE identified broad methods of achieving objectives one, two and three outlined above. Although these existing guides did not specify exactly how an occupant could alter their behaviour to achieve these objectives, these guides provided a foundation of which to work from. From these guides the following sub-objectives were established.

Objective one: Improve indoor air quality	Objective two: Reduce internal moisture	Objective three: Indoor lighting
• Provide good ventilation • Purify air • Extract air at source (BRANZ, 2007)	• Eliminate source of moisture • Manage at source • Ventilate space • Temperature control of space (BRANZ, 2007)	• Optimise daylight • Artificially light spaces effectively • Implement additional artificial lighting (BRANZ, 2007)

In regards to objectives four and five the development of their sub-objectives were somewhat more intuitive however were still developed from a resource identified previously; the 'Energywise' website.

Objective four: Improve indoor heating

- Consider occupants baseline comfort
- Passively heat the space
- Actively heat the space
  (EECA, 2018)

Objective five: Improve indoor cooling

- Consider occupants baseline comfort
- Passively cool the space
- Actively cool the space
  (EECA, 2018)

Once these sub-objectives had been established, the third and final stage was to identify methods and behavioural changes that an occupant could implement. This was done through the accumulating and consolidating of existing advice from a variety of tools and resources such as those identified in the 'Review of existing resources and tools'. It was determined that each sub-objective must contain at minimum, one occupant behavioural change thus ensuring that the master guide is as thorough as possible. Whilst gathering information from the variety of resource, it underwent an information filtering system as to ensure the proposed occupant behavioural changes are reasonably practicable.

Reasonable practicable was defined as a task of which could be reasonable undertaken by an average person. An example of this would be on the 'Energywise' website it is suggested to "Air your house a few times a day with wide open doors and windows to create a cross-draught - even in winter" (EECA, 2019). In contrast 'Climate consultants' recommendation on how to improve and utilises natural ventilation is "Locate door and window openings on opposite sides of building to facilitate cross ventilation, with larger areas facing up-wind if possible" (Milne, Liggett, Benson, & Bhattacharya, 2008). Whilst both are sound advice for methods to incorporate natural ventilation into a dwelling, the latter is not reasonably practicable as an occupant can not be expected to alter the existing locations of their windows and doors. The following is a breakdown of the type of approach that was taken for each of the objectives.

Objective one – Improve indoor air quality

- Provide good ventilation
  - Passively ventilate with openable windows.
  - Passively ventilate with trickle vents.
  - Actively ventilate with extract fans.
  - Actively ventilate with a balanced pressure ventilation system.
  - Actively ventilate with a positive pressure ventilation system.
- Purify the air
  - Eliminate air contaminants as a result of placing rubbish bins in confined indoor spaces.
  - Eliminate air contaminants as a result of storing and using cleaning products in confined spaces.
  - Eliminate air contaminants as a result of placing gardening in confined spaces.
  - Reduce the accumulation of pet dander.
  - Do not leave car(s) running whilst in the garage.
  - Do not smoke tobacco inside.
  - Use solid fuel burners appropriately
  - Appropriately care for solid fuel burners
  - Implement indoor plants
- Extract air at source
  - Extract air through the use of active systems.
  - Extract air through the use of passive systems.

- Extract air through a combination of active and passive systems.

Occupant behavioural changes were identified for each sub-objective and further and more detailed explanations and information regarding how these could be undertaken were also identified. A full break down of all this can be found in the 'Behavioural measures identified' section of this report.

Investigating necessary inputs

Once the potential occupant behavioural changes have been identified and defined the next key stage was to investigate and determine what building characteristics affect whether or not such a behavioural change is plausible within the dwelling. This process involved filtering through each of the 44 identified behavioural changes and listing off the external factors impacting each one. An example of this would be for objective one under sub-objective purify the air the proposed behaviour of 'use solid fuel burner appropriately'. The obvious factor influencing this behaviour is whether there is a solid fuel burner within the dwelling or not. The factor of whether or not the systems had been implemented within the space was a common factor for a majority of the behavioural changes that were identified, being the primary factor for 43% of the behavioural changes.

Additionally, whilst filtering through the proposed behavioural changes it became apparent that a number of them (approximately 47%) had no external building characteristic factor that would influence whether or not they should be included in the occupant user guide. Proposed behavioural changes such as 'Reduce the accumulation of pet dander' fit into this category as the factors influencing this relate to the type of occupancy of the dwelling rather than building characteristic and thus may change if the type of occupancy changes. By determining which behavioural changes fit into this category, the final occupant user guide is allowed some degree of flexibility and consequently longevity.

The remaining 10% of behavioural changes were the core ones that focused on particular building characteristics such as the maximum depth of the dwelling from any window and the availability of outdoor space surrounding the dwelling. Whilst determining a number of these factors, a key assumption was made. This assumption was that these were new buildings that complied with all clauses of the NZBC and several behavioural changes such as 'Passively ventilate with openable windows' were influenced by this assumption. As it was assumed that the building complied with the NZBC and therefore the question 'Do the windows open in the dwelling?' did not need to be asked and this behavioural change could automatically be included in the occupant user guide.

When developing the answers for the corresponding questions, prewritten answers were determined to avoid confusion and the need for excessive matching of a variety of answers. For example, if someone is answering yes to something yes, Yes, YES, Y, y are all plausible answers however, additional coding would be required to match these variety of answers to the corresponding behavioural change.

The list of necessary questions resulted in six simple answer questions and one tick box question asking which systems were in the space. These established question are as follows:

Questions	**Possible answers**
Maximum depth of dwelling from any window?	• > 7 metres • < 7 metres

Are the occupants able to implement permanent systems? E.g. Heat pumps	• Yes • No
Are the occupants able to implement temporary systems? E.g. Portable fans	• Yes • No
Are there internal rooms within the dwelling? E.g. bedrooms or studies (excluded hallways)	• Yes • No
Is there enough external space to dry clothes in the dwelling?	• Yes • No
Is there a garage that is attached internally to the dwelling?	• Yes • No
What mechanical/passive systems are in the space? (tick box question)	• Fitted fans • Trickle vents • Positive pressure ventilation • Balanced pressure • Some form of curtains or blinds on some windows • Dehumidifier either fixed or portable • Some form of heating system e.g. central heating system or heat pump • Some form of cooling system e.g. conditioning unit or heat pump • A solid fuel burner e.g. wood burner or open fireplace • Extraction systems e.g. extract fans

Developing final guide

Once both the required questions and the occupant behavioural changes have been identified, the final stage was to create the final output which is the occupant user guide; this was done through Excel. The use of Excel meant that this tool was able to be interactive and the architect is able to answer the question regarding the building characteristics with ease. The answers of the questions that have been answered by the architect are connected up to the relevant occupant behavioural changes and if a particular answer is 'triggered' then that particular behavioural change appears on a summary sheet.

This summary sheet not only contains the occupant behavioural change but also a description of how this action can be undertaken as well as an educational section in order to from the occupant of why such a behavioural change is being recommend. The format of this on the summary sheet is indicated below.

OBJECTIVE

Sub-objective

Proposed occupant behavioural change

Instructions of how to undertake the indicated behavioural change

Educational segment, explaining why behavioural change is being recommend

Web link for occupant to follow to find further information if desired

Limitations of this methodology

When considering this particular methodology, there are two key limitations that arise. The first of which is that when considering what is reasonably practicable when determining occupant behavioural changes, this system of filtering information is relatively subjective and was based upon my own judgment and previous experiences. However, it is worth noting that a majority of the occupant behavioural changes were relatively clean cut when considering whether they were reasonably practicable. The second limitation is that occupant behavioural changes were only proposed based upon the particular question that were asked and a number of these were based upon which type of environmental systems were in the dwelling. There are countless different types of environmental systems that are able to be incorporated into a dwelling however, the advice for all of these different systems would not fit within the scope of this particular project. Due to this limitation of the scope of the project, the most common environmental systems that are used in New Zealand were considered.

Behavioural measures identified

Through the use of the methodology outlines above, a number of behavioural measures were identified that aimed to positively affect at least one of the following:

- Improve indoor air quality
- Reduce internal moisture
- Improve heating and cooling
- Improve lighting

The identified behavioural measures are categorised firstly into objectives and then into initial strategies of how these objectives can be achieved. The behavioural measures are as follows:

Objective one – Improve indoor air quality

Provide good ventilation

Passively ventilate with openable windows.

By opening windows and doors within a space for 10 minutes a day, the stale indoor air is replaced by fresh air from outdoors and the air quality is improved. Doors and windows should be opened for the specified time even in winter.

Opening the windows and doors improves the indoor air quality by removing pollutants from the air such as moisture, Volatile Organic Compounds (VOCs) and excess carbon dioxide ($C0_2$) which can lead to mould growth and be harmful when inhaled.

(BRANZ, 2017)

Passively ventilate with trickle vents.

By ensuring that trickle vents are constantly left open, the stale indoor air is able to be replaced by fresh air form outdoors and the air quality is improved.

Trickle vents are a passive ventilation option that require minimal occupant involvement and are able to be left open at all times of the day in order to provide ventilation within as space without compromising security. By opening trickle vents indoor air quality is improved by removing pollutants from the air such as moisture, Volatile Organic Compounds (VOCs) and excess carbon dioxide ($C0_2$) which can lead to mould growth and be harmful when inhaled.

(BRANZ, 2017)

Actively ventilate with extract fans.

Extract fans should be used whilst the polluting event (e.g. bathing, cooking or doing laundry) and should be left running for several minutes after the event to remove contaminants from the space.

Ventilation through extract fans commonly takes place in bathrooms, kitchens and laundry rooms and is an effective method of removing moisture and other pollutants which can lead to mould growth.

(McNeil, 2016)

Actively ventilate with a balanced pressure ventilation system.

Not finished – need help

Actively ventilate with a positive pressure ventilation system.

Not finished – need help

Purify the air

Eliminate air contaminants as a result of placing rubbish bins in unventilated indoor spaces.

Whenever possible it is ideal to store rubbish bins in an outdoor space, however if this is not possible for the particular dwelling, appropriate ventilation should be achieved in order to minimise air contaminants. See the 'provide good ventilation' section above for further information on how to ventilate spaces appropriately for this dwelling. Additionally, if rubbish bins are being stored inside, rubbish should be emptied regularly.

By storing rubbish bins as indicated above indoor air quality is improved by removing pollutants from the air which can be harmful when inhaled as well as ensuring that bad odours do not contaminate the air.

(BRANZ, 2007)

Eliminate air contaminants as a result of storing and using cleaning products in unventilated indoor spaces.

Products such as furniture polishes, carpet and upholstery deodorizers, glass cleaners, dishwasher and laundry detergents, and bleach should be sealed properly when not in use and only be used in well ventilated spaces. See the <u>'provide good ventilation'</u> section for further information on how to ventilate spaces appropriately for this dwelling.

Cleaning supplies are one of the most common Volatile Organic Compounds (VOCs) that are found in households and the chemicals that they realise can negatively impact the indoor air quality and be harmful for an occupant is inhaled.

(BRANZ, 2007)

Eliminate air contaminants as a result of placing gardening in unventilated indoor spaces.

Gardening products such as weed killers and fertilisers should never be stored inside the dwelling and instead should be stored in a separate storage space externally e.g. a garden shed.

Gardening supplies are high VOCs that are found in households and the chemicals that they realise can negatively impact the indoor air quality and be harmful for an occupant is inhaled.

(Taptiklis & Phipps, 2017)

Reduce the accumulation of pet dander.

Pet dander is one of the most common indoor air pollutants within a household and in order to reduce excess build-up of pet dander vacuuming between once and twice a week.

Pet dander is the microscopic skin cells and hair that animals such as cats and dogs shed daily and is common cause of allergens for occupants within households.

(Taptiklis & Phipps, 2017)

Do not leave car(s) running whilst in the garage.

Cars should never be left running whilst they are sat in the garage.

Running cars produce chemicals such as carbon monoxide and xylene which are harmful to people and negatively affect the indoor air quality of a space.

(Taptiklis & Phipps, 2017)

Do not smoke tobacco inside.

To eliminate the impact of environmental tobacco smoke on the indoor environment do not smoke inside at any time.

Environmental tobacco smoke (ETS), more commonly known as second hand smoke, is the exposure to numerous harmful chemicals including eight VOCs and is one of the major contributors to indoor air pollution. When smoking in a confined space, these chemicals contaminant the air and affect the indoor air quality and health of the occupants.

(Mueller, et al., 2011)

Use solid fuel burners appropriately

There are several steps that can be taken when using a solid fuel burner to minimise contaminants entering the air within the space:

- Use cleaner fuels such as clean and dry hardwood as these woods burn slower and more evenly and thus produce less smoke
- Do not burn rubbish, treated woods, or any material that can release toxins whilst being burnt

Open wood burners and fireplaces are potential sources of indoor air contaminants and ultra-fine particles which can affect the indoor air quality of the space and be harmful when inhaled by occupants.

(Lincoln-Lancaster County Health Department Air Quality Program, 2012)

Appropriately care for solid fuel burners

There are several steps that can be taken when caring for a solid fuel burner to minimise these contaminants entering the air within the space:

- On an annual basis ensure that a professional inspects and provides any maintenance of the solid burner to ensure that the burner is safe and can burn effectively and efficiently

- On an annual basis ensure that the chimney of the burner is professionally cleaned to remove any creosote (carbonaceous chemicals) build up. This ensures that these chemicals are not contaminating the air
- Regularly clear ashes from the burner in order to reduce the likelihood of these entering the indoor air

Open wood burners and fireplaces are potential sources of indoor air contaminants and ultra-fine particles which can affect the indoor air quality of the space and be harmful when inhaled by occupants.

(Lincoln-Lancaster County Health Department Air Quality Program, 2012)

Use indoor plants

It is recommended that some form of indoor plants are placed into the dwelling in order to improve indoor air quality.

Poor indoor air quality as a result of excessive carbon dioxide within a space means that the space feels 'stuffy' and can leave the occupants feeling tired. Indoor plants are able to greatly improve the indoor air quality of a space by simultaneously taking in carbon dioxide and releasing oxygen.

(Brilli , et al., 2018)

Extract air at source

Extract air through the use of active systems.

Active extraction systems should be used when the 'polluting active' e.g. showering or cooking, is occurring and should be left running for several minutes after to ensure all excess moisture is removed from the air. If possible, the room should also be closed off e.g. closing the bathroom door, as this will prevent the spread of moisture to other rooms.

Appropriate extraction ensures that excess moisture which can lead to mould is being removed from the space and any air containments that are harmful to occupants are being removed. Different rates of extraction are required for different spaces of a dwelling and thus it is recommended that a specialist is consulted to ensure that the appropriate system is being used to meet the required extraction rate as specified in NZS 4303.

(EECA, 2019)

Extract air through the use of passive measures.

Windows and external doors should be opened when the ‘polluting active’ e.g. showering or cooking, is occurring and should be left open for several minutes after to ensure all excess moisture is removed from the air. If possible, the room should also be closed off e.g. closing the bathroom door, as this will prevent the spread of moisture to other rooms.

Appropriate extraction ensures that excess moisture which can lead to mould is being removed from the space and any air containments that are harmful to occupants are being removed. Different rates of extraction are required for different spaces of a dwelling and thus it is recommended that a specialist is consulted to ensure that the appropriate system is being used to meet the required extraction rate as specified in NZS 4303.

(EECA, 2019)

Extract air through both active and passive systems.

When using an extraction fan and utilising openable external windows or doors, the overall effectiveness of the extractor fan is improved. Aim to open the windows and doors and turn on the extraction fan when the ‘polluting activity’ is occurring and continue doing this for several minutes afterwards to ensure all excess moisture has been removed from the air. Wherever possible, close off the room e.g. close the bathroom door, when the ‘polluting activity’ is occurring to minimise the spread of excess moisture to other rooms

Appropriate extraction ensures that excess moisture which can lead to mould is being removed from the space and any air containments that are harmful to occupants are being removed. Different rates of extraction are required for different spaces of a dwelling and thus it is recommended that a specialist is consulted to ensure that the appropriate system is being used to meet the required extraction rate as specified in NZS 4303.

(EECA, 2019)

Objective two – Reduce internal moisture

Eliminate source of moisture

Do not dry clothes inside, instead dry them outside.

In order to reduce this excess moisture, build up, ensure that clothes are being dried outside whenever possible.

Drying clothes inside in an unvented space can result in 12kg of moisture being expelled into the air which can then lead to mould growth inside the dwelling. This mould growth can be harmful for occupant's health.

(BRANZ, 1987)

Ensure that open tanks, such as fish tanks, are covered.

Open fish tanks, and any other form of water tanks that house animals, should be covered whenever they are filled with water.

Open tanks increase the amount of moisture in the air within a building due to evaporation over time. This excess moisture in the air can then lead to mould growth inside the dwelling. This mould growth can be harmful for occupant's health.

(BRANZ, 2007)

Manage at source

Drying clothes inside.

If the dwelling or weather conditions do not allow for clothes to be dried outside, ensure that the space is ventilated appropriately when drying clothes inside. See the 'provide good ventilation' section above for further information on how to ventilate spaces appropriately for this dwelling.

Drying clothes inside in an unvented space can result in 12kg of moisture being expelled into the air which can then lead to mould growth inside the dwelling and this mould growth can be harmful for occupant's health. However, by ventilating the space properly this excess expulsion of moisture can be minimised.

(BRANZ, 1987)

Extract air at source.

Utilising extract systems to extract air at the source of the moisture such as in bathrooms, laundry rooms and kitchens.

See the 'extract air at source' section above for further information on how to extract air at the source appropriately for this dwelling. By extracting the air at the source, excess moisture within the dwelling is reduce which if left could have led to mould growth inside the dwelling and this mould growth can be harmful for occupant's health.

(BRANZ, 2007)

Ventilate space

Ventilate spaces appropriately to reduce moisture build up.

In order to reduce internal moisture ventilation of the space is vital to reduce excess moisture build up. See the <u>'provide good ventilation'</u> section above for further information on how to ventilate spaces appropriately for this dwelling.

(BRANZ, 2007)

Temperature control of space

Heat the space appropriately to reduce relative humidity.

Temperatures within the dwelling should be kept at a minimum of 18 °C.

A high relative humidity within a space is uncomfortable for the occupants and makes the space feel 'Stuffy'. See sections 'passively heat the space' and 'actively heat the space' below for further information on how to heat spaces appropriately for this dwelling.

(BRANZ, 2007)

<u>Objective three – Optimise indoor lighting</u>

Optimise daylight

Open blinds during the day to allow for increased penetration of natural daylight into the space.

In order to optimise daylight as much as possible, open blinds or curtains during the day to allow for daylight to enter the space and adequately light the space.

Appropriate lighting ensures that an occupant is not straining their eyes whilst undertaking daily activities and the use of natural light reduces energy consumption within the dwelling.

(BRANZ, 2017)

Manage furniture heights and layouts.

When laying out rooms and organising furniture, ensure that tall furniture is not placed in front of windows.

By arranging furniture properly this will allow for more daylight penetrate the space and light the space sufficiently and appropriate lighting ensures that an occupant is *not straining their eyes whilst undertaking daily activities and the use of natural light reduces energy consumption within the dwelling.*

(BRANZ, 2017)

Artificially light spaces effectively

Use efficient lighting systems such as LEDs.

Implement efficient lighting within the dwelling such as LEDs.

Such systems as LEDs provide better quality light for the space as well as being more energy efficient, using up to 85% less energy than incandescent lights.

(EECA, 2019)

Turn off lights when spaces are not in use.

When people are not occupying the space, ensure that any artificial lighting is turned off.

This ensures that energy is not being wasted to light a space when it is not necessary.

(EECA, 2019)

Implement further artificial lighting

Add in additional lighting where daylight is inadequate.

Utilise artificial lighting in an efficient and effective manner.

The use of solely daylight may not be able to adequately illuminate a room, such a scenario may occur in an internal room, in a space that is exceptionally large, or at night. See section 'utilise artificial lighting effectively' above for further information on how to affectively artificially light for this dwelling.

<u>Objective Four – Improve indoor heating</u>

Change occupant's behaviour

Consider occupant comfort.

If an occupant is cold, it is suggested that an occupant puts on additional clothing before using mechanical heating systems.

The most energy efficient method for improving the thermal comfort of the occupant with in a space is to ensure that the occupant is clothed appropriately for the climate and the desired temperature.

Passively heat the space

During the winter months, open blinds/curtains during the day in order to utilise the solar gains.

Open curtains and blinds at sunrise in order to allow for the dwelling to gain heat from the sun. This is particularly relevant during the colder months of June, July and August in order to maximise solar heat gain.

By passively heating a space through solar gains the amount of energy a household consumes is reduced greatly which may result in a financial saving for households.

(EECA, 2018)

During the winter months, close blinds/curtains after sunset in order to contain heat.

In order to contain any internal heat that has been gained throughout the day, draw the curtains within the dwelling at sunset. This is particularly relevant during the colder months of June, July and August in order to preserve maximum heat.

By passively heating a space and insulating it effectively the amount of energy a household consumes is reduced greatly because of less heat being lost. This may result in a financial saving for households as heat is not needing to be constantly pumped into the home.

(EECA, 2019)

Use curtains effectively to insulate and contain heat.

In order to appropriately insulate and contain internal heat with the use of curtains, aim to create a seal between the window and the curtain. In order to provide appropriate insulation with curtains, consider the following:

- Utilise curtains that are winder than the window frame and fit tightly around the frame
- Thicker, double layered curtains will provide better insulation
- Utilise floor length curtains as sill length curtains are often ineffective

By insulating effectively, the amount of energy a household consumes is reduced greatly because of less heat being lost. This may result in a financial saving for households as heat is not needing to be constantly pumped into the home.

(EECA, 2018)

Block put draughts and minimise air leaks by implementing curtains around windows or draughts stops underneath doors.

Minimise the amount of heat that is lost through infiltration by stopping draughts around windows and doors. For windows, utilise curtains and see 'use curtains effectively' section above for further information. For doors, use draughts stoppers such as draught excluders or door snakes or install draught stopping tape.

By insulating effectively, the amount of energy a household consumes is reduced greatly because of less heat being lost. This may result in a financial saving for households as heat is not needing to be constantly pumped into the home.

(EECA, 2018)

Close off any rooms that are not occupied or do not wish to be heated in order to minimise the spread of warmth to unnecessary rooms.

Close off any unoccupied rooms whilst heating a space.

This will contain the spread of heat to only the occupied rooms and conserve both heat and energy within the household. This may result in a financial saving for households as heat is not needing to be constantly pumped into the home.

(EECA, 2019)

Allow heated air to flow between occupied rooms if there is no central heating system.

When one room is being heated, and there is no central heating systems, open up adjoining rooms if they require heating.

This will allow for the heated air to transfer into the room(s) which are not being heated but are still occupied. Additionally, this will also ensure that the room with the heating systems does not over heat due to lack of air flow. In turn this will ensure that the space is more comfortable for the occupants and may result in a financial saving for households as heat is not needing to be constantly pumped into the home.

(EECA, 2019)

Use the appropriate fuel for a solid fuel burner.

To get a fire started, lighter wood or softwoods such as Pine are ideal for kindling. However, once an acceptable fire has been established it is important to use denser wood or hardwood such as Oak as optimal.

It is important to use the appropriate fuel for a solid fuel burner so ensure is runs as efficiently as possible. Hardwoods burner slower and therefore longer as well as give off more heat when they are burnt.

(EECA, 2018)

Actively heat the space

Use efficient active heating systems for the desired space.

It is recommended to seek professional advice from a supplier when using active heating systems such as heat pumps within a space.

It is vital that the correct system is being used for the space as a heating system that is too small for the room that is being heated will result in a space that is inadequately heated and a large amount of energy being expended which may result in a greater cost to the occupant.

(EECA, 2018)

Use ceiling fans in conjunction with heating systems.

When a space is being heated, a ceiling fan on a slow setting can be utilised to aid in circulating heat air around a space.

This is particularly relevant in dwellings with high ceilings as hot air rises and the circulating of the air will aid in bring the hot air back down to the occupants' level. By implementing this technique, the heat produced is optimised and less heat is needed to ensure that the space is comfortable. This may result in a financial saving for households as heat is not needing to be constantly pumped into the home.

(EECA, 2018)

Objective five – Improve indoor cooling

Change the occupant's behaviour

Consider occupant comfort.

If an occupant is hot it is suggested that occupant takes off any excessive clothing before using mechanical cooling systems.

The most energy efficient method for improving the thermal comfort of the occupant with in a space is to ensure that the occupant is clothed appropriately for the climate and the desired temperature.

Passively cool the space

During the summer months, close blinds/curtains during the day in order to minimise the amount of solar gains penetrating the space.

Close blinds and curtains that are subject to direct sunlight. This will be particularly effective during the summer months (December, January, and February).

Closing the blinds will minimise the level of solar gains penetrating the space and this will reduce the amount of energy needed to cool the space. This may result in a financial saving for households.

(EECA, 2018)

Open windows strategically to utilise the cool air.

Create a cross draught within the space by opening windows and doors.

A cross- draught in the space will cool down the dwelling as the cooler outdoor air moves through the space and this will reduce the amount of energy needed to cool the space. This may result in a financial saving for households.

(EECA, 2018)

Actively cool the space

Utilise ceiling fans.

Ceiling fans are able to be used in order to effectively actively cool dwellings as they create a breeze within the space.

A breeze within the space will cool down the dwelling as the air moves through the space and this will reduce the amount of energy needed to cool the space. This may result in a financial saving for households.

(EECA, 2018)

Use efficient active cooling systems for the desired space.

It is recommended to seek professional advice from a supplier when using active cooling systems.

It is vital that the correct system is being used for the space as a cooling system that is too small for the room that is being cooled will result in a space that is inadequately cooled and a large amount of energy being expended which may result in a greater cost to the occupant.

(EECA, 2018)

Use energy efficient products in order to reduce internal heat gains from products.

In order to minimise these internal heat gains, energy efficient products should be used such as LEDs.

Lights and equipment create heat gains within the space which can increase the need to cool a space which may result in a greater cost to the occupant. For example, LEDs emit minimal light in contrast to incandescent lights which emit 90% of their energy as heat.

(EECA, 2018)

Discussion

Limitations

Often research encounters limitations to the scope the project and subsequently the outputs and results are limited. For this particular research the New Zealand housing stock was the focus of the guide and thus any questions were directed towards those houses built in New Zealand and to New Zealand standards. Housing codes and building compliance vary greatly from country to county and thus the suggested occupant behavioural changes may not apply to various other countries and only apply to New Zealand homes. Additionally, the surrounding climate of the house has been considered when suggesting occupant behavioural changes and again this has been catered to the New Zealand climate. As a result, until further research is undertake, this occupant user guide is limited to only being applied and given to occupant which reside in New Zealand homes.

The longevity of an occupant user guide is questionable due to the possibility of an occupant adding in further environmental systems to their dwelling once the guide has been developed. For example, if an occupant was to add in a solid fuel burner, their occupant user guide would not include any advice regarding how to appropriately use this. Whilst this would not discredit the existing proposed behavioural changes that are in the guide, it would limit its effectiveness.

Further research

There are several areas that this research could expand on in order to further develop this guide. Firstly, it has been previously established that the impact of occupants behaviour on energy consumption within a building is grossly over or underestimated within the design phase. Further research may be able to suggest how this occupant user guide could be used in the design phase of the building in order to dictate design decisions such as which systems should be implemented similar to that of 'Climate consultant'. Essentially this would at as a secondary guide that relates to the design of building and is for the use of the architect.

Another area of further research which was not considered in this particular research was the occupant's ability or willingness to undertake behavioural changes. When establishing which questions were being asked in regards to the existing building, the ability of those living within the space was not considered. For example, if an elderly or disabled person were to be living in the space, although the dwelling may have the capabilities to hang washing outside the occupant may be unable to do so and thus such a recommendation becomes redundant. Further research may be able to indicate that whether asking question about the occupants' capabilities and willingness to undertake behavioural changes would be able to improve the guides effectiveness due to its increased customization. However, with the addition of this area of research and this increase in customization for the occupant other limitations may arise and the question of "what happens when a new occupant occupies the space?" is posed.

Lastly, a previously specified limitation was that of this guide only being able to be used when considering New Zealand houses. Further research could investigate how this guide could be adapted to be utilised in various other countries. This further research would require an understanding of the counties code and building complies regulations as well as the countries climate and typical building systems and characteristics.

Implications

When establishing this occupant user guide, as has been previously mentioned the New Zealand housing stock was the subject of the research and thus it has been assumed that this research takes into consideration these a new house that are being built to comply with the NZBC and are aiming to achieve minimum requirements as specified in New Zealand standards.

Summary and conclusion

At the commencement of this research the following research question was established: can a tool be developed that enables architects and building professionals to be able to effectively communicate a range of occupant behavioural changes that will improve and optimise the buildings performance and indoor environmental quality? Having undertaken a process of identifying and consolidating existing research from a variety of tool and resources, the short answer to the research question is yes. This research has been able to identify a range of behavioural changes that occupants are able to implement within their homes in order to optimise the buildings performance and improve the internal environmental quality. Furthermore, information gathered in this research has been able to be used to create tool that develops an occupant user guide that is unique to each dwelling and provides occupant with the resources to make informed decisions within their dwelling.

As previously discussed, there are several areas of future research that would further improve this tool by ensuring that this tool is customised further to become more accurate and thus efficient for each individual dwelling. However, currently this research and the subsequent development of this user occupant guide tool serves as a basis for the foundations for this future research.

References

BRANZ. (1987). *Ventilation to reduce indoor condensation* . BRANZ.

BRANZ. (2007). *Designing Quality Learning Spaces: Lighting* . Ministry of Education .

BRANZ. (2007). *Designing Quality Learning Spaces: Ventilation & Indoor Air Quality.* Ministry of Education .

BRANZ. (2007). *Designing Quality Learning Spaces: Ventilation & Indoor Air Quality.* Ministry of Education.

BRANZ. (2017, August 29). *Daylighting*. Retrieved from Level: http://www.level.org.nz/passive-design/daylighting/

BRANZ. (2017). *Designing quality learning spaces - Indoor air quality and thermal comfort .* Ministry of education . Retrieved from Level.

BRANZ. (2017, August 29). *Passive ventilation fixtures* . Retrieved from Level: http://www.level.org.nz/passive-design/ventilation/passive-ventilation-fixtures/

Brilli , F., Fares, S., Ghirardo, A., de Visser, P., Calatayud, V., Munoz, A., . . . Menghini, F. (2018). Plants for Sustainable Improvement of Indoor Air Quality. *Trends in Plant Science, 23*(6), 507-512.

Chen, S., Yang, W., Yoshino, H., Levine, M. D., Newhouse, K., & Hinge, A. (2015, October 1). Definition of occupant behavior in residential buildings and its application to behavior analysis in case studies. *Energy and Buildings, 104*, 1-13.

Delzendeh, E., Wu, S., Lee, A., & Zhou, Y. (2017, December). The impact of occupants' behaviours on building energy analysis: A research review . *Renewable and Sustainable Energy Reviews , 80*, 1061-1071.

EECA. (2018, December 4). *Cooling your home*. Retrieved from EECA Energywise: https://www.energywise.govt.nz/at-home/heating-and-cooling/cooling-your-home/

EECA. (2018, December 4). *Cooling your home* . Retrieved from Energywise: https://www.energywise.govt.nz/at-home/heating-and-cooling/cooling-your-home/

EECA. (2018, December 19). *Curtains and blinds* . Retrieved from EECA Energywise: https://www.energywise.govt.nz/at-home/windows/curtains-and-blinds/

EECA. (2018, December 20). *Energy efficient bulbs*. Retrieved from Energywise: https://www.energywise.govt.nz/at-home/lighting/choosing-the-right-energy-efficient-bulb/

EECA. (2018, December 20). *Heat pumps*. Retrieved from EECA Energywise: https://www.energywise.govt.nz/at-home/heating-and-cooling/types-of-heater/heat-pumps/

EECA. (2018, December 4). *Heating your home*. Retrieved from Energywise: https://www.energywise.govt.nz/at-home/heating-and-cooling/heating-your-home/

EECA. (2018, June 27). *Wood burners*. Retrieved from EECA Energywise: https://www.energywise.govt.nz/at-home/heating-and-cooling/types-of-heater/wood-burners/

EECA. (2019, January 30). *Energywise*. Retrieved from Ventilation checklist: https://www.energywise.govt.nz/at-home/ventilation/ventilation-checklist/

EECA. (2019, January 8). *Simple ways to lower energy bills*. Retrieved from EECA Energywise: https://www.energywise.govt.nz/at-home/simple-ways-to-lower-energy-bills/

EECA. (2019, January 30). *Ventilation checklist*. Retrieved from Energywise: https://www.energywise.govt.nz/at-home/ventilation/ventilation-checklist/

Gunderson, D. E., & Day, J. K. (2015, January). Understanding high performance buildings: The link between occupant knowledge of passive design systems, corresponding behaviors, occupant comfort and environmental satisfaction. *Building and Environment, 84*, 114-124.

LEED. (2019). *Better buildings are our legacy*. Retrieved from U.S Green Building Council : https://new.usgbc.org/leed

Lincoln-Lancaster County Health Department Air Quality Program. (2012). *Reduce air pollution from your wood burning stove or fireplace .* Lincoln .

McNeil, S. (2016, February/March). Ventilation options. *Build Magazine*, pp. 44-45.

Milne, M., Liggett, R., Benson, A., & Bhattacharya, Y. (2008). *Additions to a Design Tool for Visualizing the Energy Implications of California's Climates.* UCLA, Department of Architecture and Urban Design. University of California Energy Institute.

Mueller, D., Uibel, S., Braun, M., Klingelhoefer, D., Takemura, M., & Groneberg, D. (2011). Tobacco smoke particles and indoor air quality (ToPIQ) - the protocol of a new study . *Journal of occupantional medicine and toxicology* .

Pan, S., Wang, X., Wei, S., Xu, C., Zhang, X., Xie, J., . . . de Wilde, P. (2017, May). Energy waste in buildings due to occupant behaviour. *Energy Procedia, 105*, 2233-2238.

Peng, C., Yan, D., Wu, R., Wang, C., Zhou, X., & Jiang, Y. (2012, June). Quantitative description and simulation of human behavior in residential buildings . *Building Simulation , 5*(2), 85-94.

Taptiklis, P., & Phipps, R. (2017). *Indoor air quality in New Zealand homes and schools.* Wellington : BRANZ.

van Raaij, W. F., & Verhallen, T. M. (1983). A behavioural model of residential energy use. *Journal of Economic Psychology* , 39-63.

Zhang, Y., Bai, X., Mills, F. P., & Pezzey, J. C. (2018, August). Rethinking the role of occupant behavior in building energy performance: A review . *Energy and Buildings , 172*, 279-294.