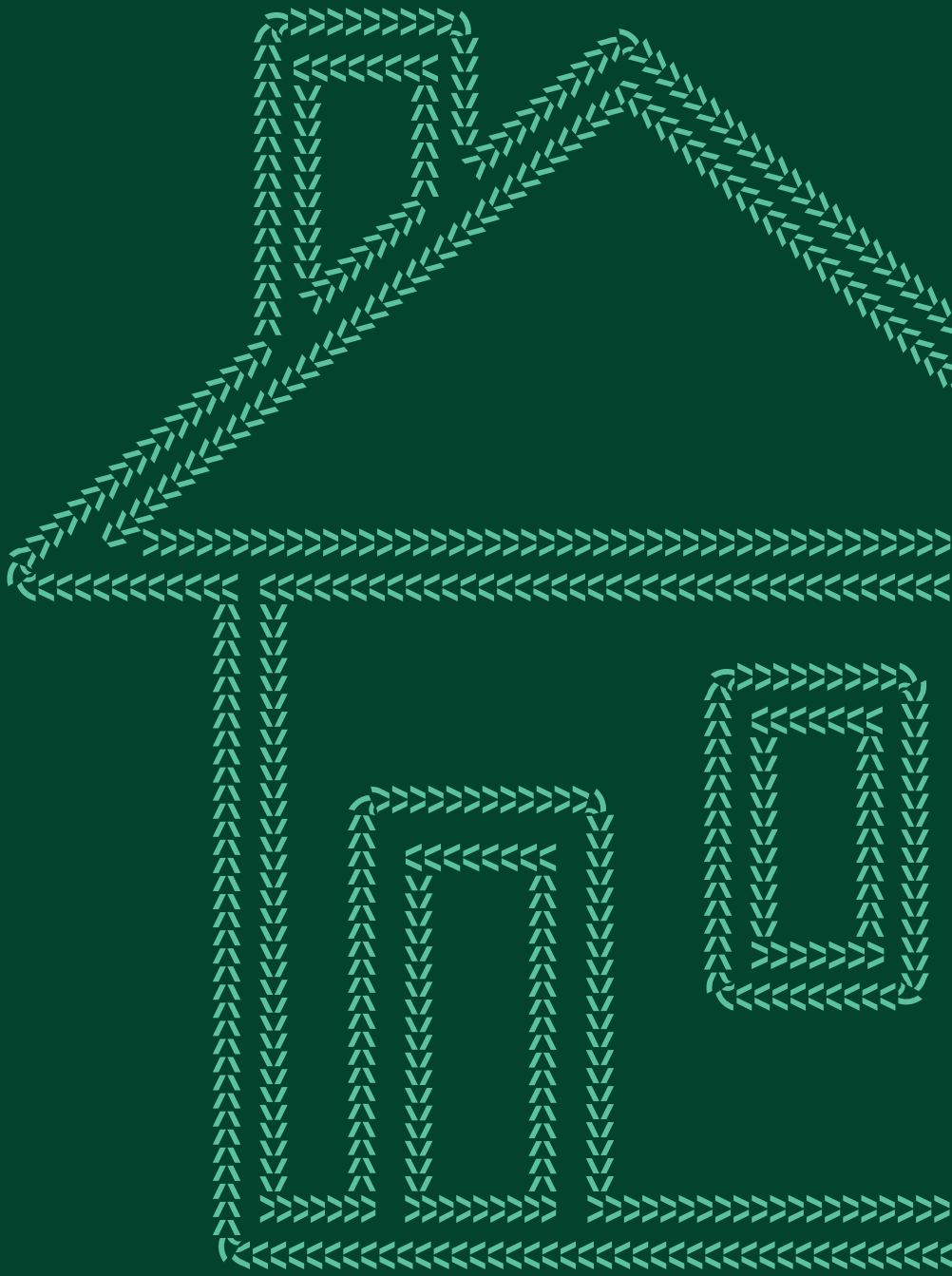
Deep Energy Retrofit for New Zealand

Residential



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About the author

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Jason is a certified Passive House designer and certifier and the Australasian instructor for the PHI Retrofit Expert class. He well understands the profound health and structural risks of inappropriate retrofitting practices. He has authored several technical publications, including the *High-Performance Construction Details Handbook*.

In this new publication, Jason translates complex moisture, air and thermal dynamics into practical, step-by-step guidance, empowering both construction professionals and homeowners to more confidently navigate deep energy retrofits in New Zealand.

Disclaimer

This publication is provided to inform professionals of the rationale and benefits of deep retrofits along with detailed guidance about best practice that is relevant to New Zealand's climates, regulatory environment and standard construction methods. The authors of this publication have used their best efforts to provide accurate and authoritative information regarding the subject matter covered. The authors, Sustainable Engineering Ltd and New Zealand Green Building Council (NZGBC) make no warranty of any kind, expressed or implied, with regard to the information contained in this work. The information presented must be used with care by professionals who understand the implications of what they are doing. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

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Acknowledgements

This book is the result of years of professional practice in New Zealand as a building scientist, Passive House designer and certifier and educator. I thank my clients for all the opportunities they bring to my small team of experts at Sustainable Engineering Ltd, plus the students who attend our in-person and online training. Your problems are interesting to solve and your questions are (mostly) excellent. This handbook is testament to the generous and encouraging nature of the Passive House community in Aotearoa, which is bound together by shared and deeply held values. All New Zealanders deserves to live in decent homes: comfortable, healthy and not costing the earth.

A number of respected colleagues helped inform this handbook and to them I offer sincere thanks. Experienced architects, Passive House designers, engineers, project managers, suppliers and manufacturers of high-performance building materials all generously reviewed this text and provided useful feedback. The handbook is better for it—but of course all errors or omissions are solely my responsibility.

A special mention is owed to my staff— Sara Wareing, Toby Brooke, Ike Saniel, Jessica Winter, and Alvin Abon—whose project experience and insights formed much of the foundation for this book. Thanks also go to my long-time editor Rachel Rose.

—Jason Quinn, Wellington 2 June 2026

Editor: Rachel Rose
Designer: Jemma Cheer

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About the New Zealand Green Building Council

The New Zealand Green Building Council (NZGBC) is a not-for-profit membership organisation working to accelerate the development of healthy, low carbon and sustainable buildings across Aotearoa New Zealand.

We work with more than 600 members from the property and construction sector, government, homeowners and communities to improve the quality and performance of the places where New Zealanders live, work and learn. Through industry leadership, advocacy, education, research and trusted certification tools, we support a built environment that is better for people, businesses and the planet.

NZGBC also works to improve the quality, comfort, health, energy efficiency and climate resilience of existing and new housing through research, guidance, industry engagement and programmes such as Homestar and Homefit. By supporting homeowners, designers, builders and assessors to upgrade existing homes, we aim to reduce emissions, lower energy costs and create healthier places for people to live. This Deep Retrofit Guide forms part of that commitment to supporting healthier, warmer and more energy-efficient homes across Aotearoa New Zealand.

About EECA

EECA (the Energy Efficiency and Conservation Authority) is a delivery agency, a regulator, and an authority for energy use. Its purpose is to mobilise New Zealanders to be world leaders in clean and clever energy use.

EECA's work encourages, promotes, and supports energy efficiency, energy conservation, and the use of renewable sources of energy. EECA works across emerging and innovative technology, smart systems and future fuels to support households, industry and Aotearoa New Zealand.

New Zealand Institute of Architects (NZIA)

Te Kāhui Whaihanga New Zealand Institute of Architects welcomes this guidance as a valuable and timely contribution to deep retrofit practice in Aotearoa New Zealand. It helps to fill an important gap in industry knowledge and practice by providing New Zealand-specific advice for substantially improving the health, comfort, and performance of existing homes.

Retrofit, and particularly deep energy retrofit, is an often-overlooked opportunity to improve our existing housing stock. There is significant potential to lift building performance, improve energy efficiency, reduce emissions, and enhance resilience in the face of climate change and more frequent extreme weather events.

Architectural Designers NZ (ADNZ)

ADNZ supports the publication of Deep Energy Retrofit Handbook for New Zealand as a contribution to lifting retrofit capability across the profession — and as a useful complement to the moisture and building-physics education ADNZ has been running with Sustainable Engineering.

The guide addresses many of the questions our members raise in practice, from moisture physics and the four control layers through to the H1 standards and risk-recognition frameworks that drive successful deep energy retrofits in New Zealand conditions.

A note about support and endorsement

Both NZIA and ADNZ support the guide's overall contribution to building deep retrofit capability and improving understanding of building performance and resilience. However, this does not constitute endorsement of any specific methodology, certification system or tool referenced within the guide.

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How to use this book

This resource has been created to support architects, designers, builders and project managers as they tackle the challenge of substantially improving the health and performance of New Zealand's housing. Suppliers and manufacturers of components and retrofit systems will also find it useful.

It aims to fill what is, at time of writing in 2026, a yawning gap in information available in this country. While there are some excellent deep retrofit guides published in Europe, their housing design, construction materials and climates are different. We need solutions and guidance created for New Zealand conditions.

Deep energy retrofits go well beyond the low-hanging fruit. Definitions and goals follow but it is vital to approach these retrofits systematically and carefully. Best outcomes for people's comfort and health, the structural durability of an individual house and the environment as a whole will come from upgrading the entire building envelope in a planned way. This may happen all at once or in a step-by-step fashion over time, when existing components reach the end of their life.

Readers may wish to skip ahead to consult the detailed guidance provided for individual elements: for instance, how to convert to a warm roof or safely install insulation into a timber-framed cavity. But readers are urged to come back to review the whole text. Retrofitting must be approached holistically and on the basis of a sound understanding of fundamental building principles.

A deep energy retrofit is complex by definition. Known good constructions are only useful in the context of blank slate new builds. Accordingly, this handbook is not the equivalent of a cookbook full of recipes. It's more like a 'choose your own adventure' story, because every existing house is a unique puzzle. It seeks to significantly improve building and design professionals' expertise and confidence in tackling deep-energy retrofits.

Understanding some building physics is required. This is the basis on which designers and builders can distinguish between low and high-risk solutions, avoid common traps and pitfalls, capably think through a construction and select the approach that is best suited to a specific project.

Currently, the risks involved in retrofitting are not widely understood. Throughout the book, low-risk actions are indicated. If the guidelines are followed, the risks of unintended consequences are low. Other interventions are higher risk and these are clearly labelled as such. Do not dismiss these cautions. Many New Zealand houses remain structurally sound only because they leak heat, which dries out the building structure. Once this balance is altered—for instance by increasing insulation performance—counterbalancing measures like reducing air leakage are absolutely necessary to ensure ongoing structural durability.

This technical document is accompanied by a separate resource aimed at homeowners, the *Homeowners guide to a deep energy retrofit*. This aims to empowers homeowners with the knowledge to understand the deep retrofit process, ask the right questions of their design and build team and make sound decisions.

1 Introduction

Deep energy retrofits at scale are how New Zealand's unhealthy, poorly performing, existing housing stock can be transformed into decent homes that are comfortable year-round, promote good health and slash the energy and associated carbon emission required to operate them. The problem of cold, damp, mouldy, under-ventilated and hard to heat homes is entrenched in this country. Solving the problem requires a systematic approach and careful planning and detailing, all rooted in an understanding of building physics.

A comprehensive definition of a deep energy retrofit is still to be developed for Aotearoa. 'Upgrading everything that is possible to improve' is put forward as a working definition. This handbook brings together principles and approaches that are designed for the New Zealand climate and the building materials and construction details typically used here; international resources are of limited applicability.

Retrofitting is harder than improving the performance of new buildings. Every project will be different because it must respond to the individual challenges presented by a specific building and the aspirations of its owners. Generalisations cannot be made on the basis of building typology or era.

The following guidance follows a whole-of-building approach as upgrading both the building envelope and systems is the only way to bring about substantive improvement across a range of measures. System upgrades are covered more briefly in Chapter 6 Building systems, as there is no need to duplicate local resources that are already available.



A deep energy retrofit may proceed along either of two pathways: a heroic all at once effort that upgrades everything in a single stage or a step-by-step approach that upgrades elements over time as building components reach end of life. Both are most effective if decisions are made on the basis of predictive energy modelling at design stage, which ensures that homeowners get the most value for the least cost over the life of the building. Either pathway must proceed on the basis of a masterplan that details how components interact. This is especially important for step-by-step retrofits where, at each stage, preparation must be made for future upgrades.

The risks associated with even ad hoc shallow improvements (eg retrofitting wall insulation into certain assemblies) are not widely understood in the design and construction industry at present. For this reason, Chapter 3 Foundational building science takes the reader through fundamental building physics, explaining the mechanics of building failure and how to prevent it. Understanding the four building control layers that manage the movement of water, air, vapour and thermal (energy) establishes the foundational principles that should underpin every professional's approach to a deep energy retrofit. Upgrading ventilation to provide for continuous, adequate air exchange is emphasised, in part because it is overlooked by the New Zealand Building Code.

A systematic four stage workflow is described in Chapter 4 The deep retrofit workflow. Deep energy retrofits should proceed on the basis of thorough research and planning with decisions guided by robust data.

The bulk of this handbook details a range of solutions for improving key building assemblies. Some readers will want to skip ahead to pore over the details and construction drawings that provide detailed instructions, along with cautions and recommendations.

Three case studies are extensively outlined in Chapter 7 Case studies: Retrofit in practice. The homes chosen are trailblazers in New Zealand, constructed in different eras and from different materials but are alike in achieving outstanding improvements in human health and comfort and building durability and efficiency. The case studies include mid-construction photos, floor plans, schematics, construction details, building performance data and descriptions of the challenges they faced, and solutions chosen.

The handbook concludes with a short description of further resources in Chapter 8 Further Resources.

2 A roadmap to a better home

A deep energy retrofit is a whole-building renovation that dramatically improves the health and comfort of the home's occupants. The goal is to find the sweet spot: the most benefits for the least cost. *Comfort* means indoor temperatures are stable and comfortable year-round throughout the whole house, with minimal active heating or cooling. Draughts, cold surfaces, condensation and mould are banished. *Health* means the indoor air quality is excellent: sufficient ventilation to prevent mould and remove pollutants, including CO_2, particulate matter and VOCs and to keep relative humidity in the 40-60% range.

These outcomes are achieved by upgrading both the building's *fabric* to improve thermal performance and its *systems*, such as introducing continuous ventilation. These changes bring about significant reductions in a home's overall utility energy demand and therefore energy bills. Adopted at scale, this would significantly assist New Zealand achieve its greenhouse gas emission reduction targets.

A deep energy retrofit is a holistic approach that treats the building as a single integrated whole. It brings about improvements to both the building's fabric (insulation levels and degree of airtightness) and its systems (heating, hot water, ventilation and lighting). Deep energy retrofits are notable for delivering important benefits at multiple levels: for individuals and families, communities, nations and planetary systems.

2.1 The benefits of deep energy retrofits

A deep energy retrofit is an investment that pays a triple dividend: it benefits people, the planet and New Zealand as a whole. A deep retrofit improves the health and comfort of both current occupants and multiple generations to come. It's an investment that pays back now and in the future.

For people: health and comfort
Deep energy retrofits create homes that keep families well. A warm, dry and healthy indoor environment with a constant supply of fresh, filtered air directly addresses the health burden imposed by poor quality housing.[1] It also reduces energy hardship. Summer overheating is minimised by careful planning and product selection. Removing gas to become an all-electric household improves indoor air quality. Together, these improvements provide a level of quiet, indoor air quality and thermal comfort that supports better sleep and wellbeing.

For the planet: climate change mitigation
Deep energy retrofits are a powerful and practical pathway for contributing to climate change mitigation targets because they radically reduce operational carbon (those emissions emitted by operating the building over time). It is a tangible way by which homeowners and institutional landlords can contribute to a low-carbon future, creating benefits now and a legacy for the future.

Upgrading existing structures rather than tearing them down and building new also reduces the carbon emissions that come from the manufacture of materials and construction (embodied carbon).

1 Quinn, J. (2025, Sep 12). How much is healthy indoor air worth? This study has an answer. *Sustainable Engineering Ltd*.

For the country: strengthening the economy and the national grid

A nationwide deep retrofit programme creates skilled, local jobs and increases the value and durability of New Zealand homes. By radically reducing winter heating demand peaks, energy-efficient homes reduce the strain on the national electricity grid. Energy spikes during heatwaves are also reduced. This makes for a more resilient power supply, with widespread benefits for commercial users as well as the economy as a whole.

Rapid uptake of currently achievable best-practice standards in housing efficiency could reduce the winter-summer demand variation by three quarters compared to business as usual by 2050, say experts.[2] It could reduce the need for extremely expensive new electricity generation projects needed to meet demand peaks that are only seasonal in nature. It also negates the need for expensive legacy investment designed to prolong use of gas.

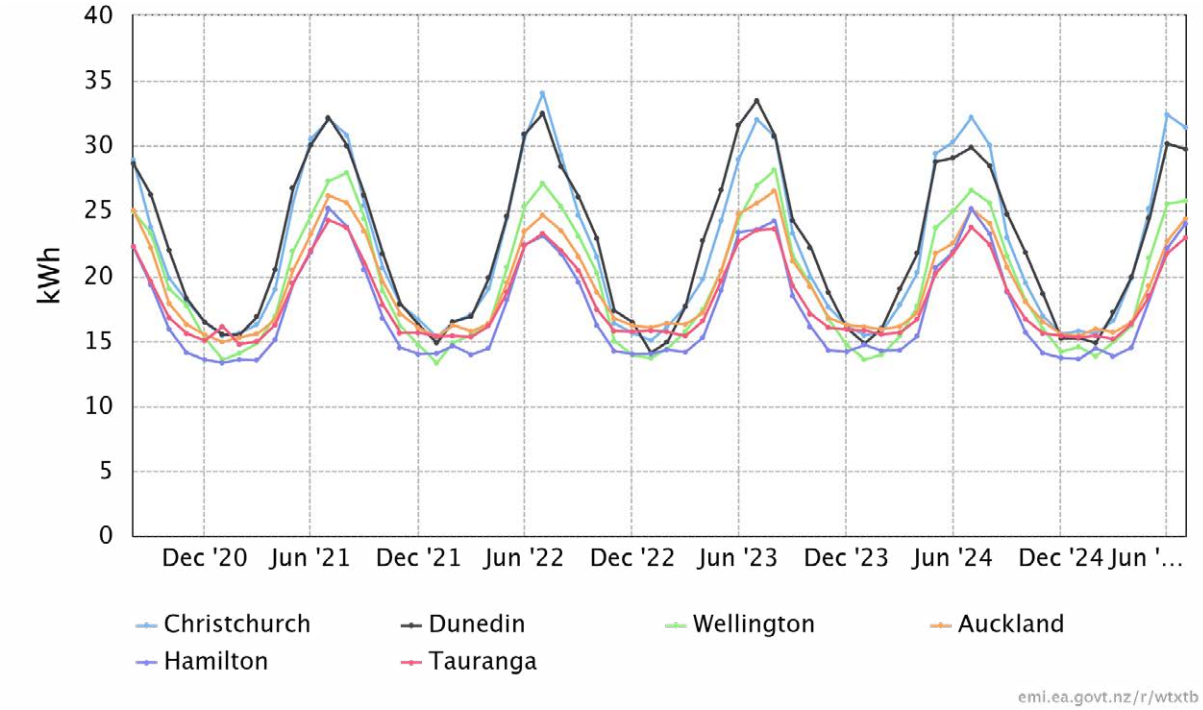


Figure 1: Seasonal residential electricity consumption trends (August 2020 to July 2025) in kWh/day. Notice that demand nearly doubles in winter; the colder the climate, the higher the winter peak demand. This seasonal spike in demand can be reduced significantly by deep energy retrofits. Chart from NZ Electricity Authority www.emi.ea.govt.nz/r/wtxtb

2 Jack, M.W., A. Mirfin, and B. Anderson. 2021. "The Role of Highly Energy-Efficient Dwellings in Enabling 100% Renewable Electricity." Energy Policy 158 (November): 112565. https://doi.org/10.1016/j.enpol.2021.112565.

2.1.1 New Zealand homes need fixing

Home should be a sanctuary, a place where people are healthy, comfortable and secure. Sadly, this is not the reality for a great many New Zealanders. An inadequate minimum standard established for decades by the New Zealand Building Code has resulted in housing stock that is, in general, unfit for purpose. For instance, around 800,000 existing homes were built before insulation became a requirement in 1978, a large portion of New Zealand's two million private dwellings.[3]

Nearly half of New Zealanders report living in a cold or damp home,[4] a key factor in the disturbing excess winter mortality rates of about 1450 deaths per year.[5] Conversely, as the climate warms, overheating risk climbs. From a climate perspective, the energy used to heat inefficient homes is also a major problem, responsible for a significant portion of Aotearoa's carbon emissions[6].

The only good news is that there's a proven pathway to change this.

A significant portion of New Zealand homes are urgently in need of improvement, with key indicators suggesting 40-50% of houses are ideal candidates for deep retrofitting. The HEEP2 report reveals nearly half of homes (48%) are colder than occupants desire, over half (51%) are entirely single-glazed, and significant portions suffer from frequently reported damp (33%), condensation (75%), and mould (48%)[7]. Such widespread issues with thermal comfort and moisture control point to poorly performing building envelopes, underscoring the need for comprehensive upgrades.

2.2 A working definition

A deep energy retrofit is a new concept for New Zealand and a clear definition to suit our conditions will hopefully quickly emerge as more projects are completed. Europe is far ahead of New Zealand when it comes to improving residential energy efficiency and its experience points to several ways of describing the distinct characteristics of a deep energy retrofit.

One option is to rely on a verifiable standard developed for retrofits by the Passive House Institute. Called EnerPHit, it is a modified version of the Passive House (aka Passivhaus) performance standard. This is a gold standard approach that uses design-stage energy modelling, careful quality control and independent verification of performance.

However, EnerPHit was developed in Europe in different cultural contexts. Most Europeans live in apartment blocks, which are much cheaper and easier to upgrade than single-family homes. Their construction details are markedly different as masonry is a very common building material. The airtightness requirement may be more stringent than needed to control interstitial condensation and energy loss in New Zealand's warmer climates. Similarly, the EnerPHit component method

3 NZGBC Existing Homes Roadmap; see also NZ Stats 2023 2023 Census population, dwelling, and housing highlights | Stats NZ

4 Anderson B, White V, Jones S. Household Energy End-use Project 2: Report on winter comfort, heating and indoor temperatures (preliminary analysis). BRANZ; 2024. Study Report SR495.

5 Telfar-Barnard, L., Baker, M., Howden-Chapman, P., & Wilson, N. (May 9, 2024). Surviving winter: NZ's journey through 145 years of seasonal survival – New study. Public Health Expert Briefing.

6 J. Vickers and B. Fisher, *The carbon footprint of New Zealand's built environment: Hotspot or not?* (v1.0), Wellington, NZ: thinkstep Ltd, May 14, 2018. [Online]. Available: www.thinkstep-anz.com

7 Anderson B, White V, Jones S. Household Energy End-use Project 2: Report on winter comfort, heating and indoor temperatures (preliminary analysis). BRANZ; 2024. Study Report SR495.

requirements for installed window R-values and overall mechanical ventilation heat recovery efficiency may not be economic given the current dynamics of New Zealand's building supply market. This will change as sales of higher-performing components increase: more scale will reduce cost and domestic manufacturing is already increasing. Nevertheless, EnerPHit provides an excellent framework for planning and decision making even if certification is not ultimately sought.

Deep energy retrofits are also sometimes defined in Europe as those which result in a 50% reduction in total household energy use at the utility meter considering pre-bound and rebound effects (more details in section 4.1.2). But this number is an average of the results for a particular building typology in a specific country or climatic region. It's a blunt tool that is not suited for use at an individual project level. Retrofitting doesn't suit generalisation as every project has its own constraints and opportunities.

Consensus has yet to be developed regarding the definition of a deep energy retrofit in New Zealand. As a working definition at this stage of uptake, this handbook proposes the following. *A deep energy retrofit is a systematic, whole-house upgrade to an existing home that achieves decent-health, comfort, energy and carbon efficiency by way of upgrading insulation, ventilation and energy systems*. These improvements are verified through energy modelling and ideally benchmarked against an internationally recognised standard such as EnerPHit, AECB CarbonLite or LETI Retrofit.

A performance target helps distinguish a deep energy retrofit from shallow retrofits, which rely on ad-hoc changes and generic, single-intervention responses like upgrading insulation. Deep energy retrofits are not a tick-box exercise focused on individual products. They focus on outcomes not inputs and the retrofit is concerned with both the building fabric and the building systems.

2.3 Balancing improvements to fabric and systems

This handbook primarily focuses on providing detailed, practical advice on how to do fabric retrofits well and safely. This focuses on the building envelope (aka building enclosure) and how it can be improved. Sometimes fabric and systems upgrades are presented as binary alternatives. This isn't helpful; a deep energy retrofit requires a whole-of-system approach that tackles both the building fabric and its systems. While this handbook primarily focuses on safely and effectively upgrading the building fabric to mitigate structural and moisture risks, achieving a high-performance standard requires both elements to work in tandem. This handbook does not attempt to duplicate excellent resources already available that offer in-depth technical content on system upgrades, such as heat pumps.

Reducing energy demand through fabric improvements is a sound engineering principle. Those improvements must then be paired with right-sized, efficient systems. Individual context and circumstances (including budget) will often dictate how these upgrades are staged over time. In a step-by-step retrofit, initial system upgrades—such as heat pumps for space and water heating or the introduction of continuous mechanical ventilation—can be a sensible first step. These systems deliver immediate health and comfort benefits while planning and saving for the fabric upgrades gets underway. A successful deep energy retrofit ensures both the fabric and the systems are fully upgraded and integrated.

2.4 Doing it right

2.4.1 Avoid the shallow retrofit trap

The common approach of ad-hoc, minor upgrades often leads to the lock-in effect. This is where small, isolated improvements make a proper, comprehensive retrofit more difficult and expensive in the future.

For instance, installing standard aluminium double-glazed window inserts is a substantial improvement on the single-glazed windows they replace but it falls far short of the superior performance offered by thermally-broken uPVC inserts with best available double-glazing specs. The cheaper option is still an improvement but it locks-in still mediocre performance and makes it difficult to justify replacing glazing in future with superior products that are installed in a more efficient way. The difference in initial purchase cost may not be large and is paid back in energy savings.

2.4.2 Energy modelling at design stage

Carrying out energy modelling from the earliest design stages is the most effective and efficient way to approach a deep energy retrofit. This provides a comprehensive simulation of how the retrofitted building will actually perform. Different strategies and building materials can be readily and quickly explored, with real-time feedback about how these interact to impact energy performance and human comfort. Energy modelling is covered in more detail in section 4.1.4.1.

2.5 Two pathways to a better home

There are two ways to approach a deep energy retrofit: all at once, or in stages over time. Either should start with a comprehensive retrofit roadmap or masterplan. This document clearly describes the desired final outcome and lays out a step-by-step plan to guide all decisions.

The all-at-once retrofit

This involves carrying out all energy efficiency measures during a single, extensive renovation period. It is often the most straightforward approach but it can be disruptive and have a high upfront cost. It is likely not all of the components being replaced will be at the end of their life.

The following example is well suited to an all-at-once retrofit. The homeowners are planning to gut their 1960s home, move internal walls and add a small extension. The house will be a full construction site and their family will be living elsewhere. The roadmap allows the design and construction teams to integrate new high-performance windows, a continuous external insulation system and the MVHR ventilation ductwork, make the building envelope more airtight and add solar control as needed. This results in a completely transformed, high-performance home in one round of construction.

The step-by-step retrofit

A phased approach guided by the master plan is a pragmatic and affordable pathway and the likely choice for most deep energy retrofits. Generally, each phase of work would be triggered when a key building element is approaching the end of its life. Each stage is designed to integrate seamlessly with the next.

For instance, when a new roof is required, high-performance roof insulation is also installed and the ceiling is air sealed. When windows have reached the end of their life, high-performance replacements can be installed in a way that will seamlessly integrate with future upgrades to the thermal envelope and wall insulation. The roadmap is the critical element that turns a series of separate jobs into a coherent deep energy retrofit.

In this example, a roadmap for a family's 1910s-built home identifies that the roof, windows and cladding will all need replacing within the next 15 years and lays out the following sequence of work.

- Year 1: Upgrade windows. Old, single-glazed windows are replaced with high-performance triple-glazed units (low-e coatings, argon-filled, effective thermally broken frames). The windows are installed in-line with the insulation layer planned for the future and the flashings and air sealing are detailed to integrate with the future wall system.
- Year 5: Upgrade floor. The drafty uninsulated floor is retrofitted with insulation and an air control layer.
- Year 6: Upgrade ventilation. An MVHR with heat recovery is added. It saves a small amount of heat but more importantly adds fresh, controlled ventilation all the time, regardless of the weather outside.
- Year 9: Upgrade walls and roof. The iron roof is failing and the original cladding is rotten. Following the roadmap, contractors re-roof but also air seal the entire ceiling plane from the attic, replace all old downlights and install a thick layer of insulation. Recladding allows for installation of the final piece of the puzzle: a continuous layer of external wall insulation that connects perfectly to the details already prepared at the windows years earlier. The windows are reinstalled and new flashings fitted, completing a high performing and substantially more airtight building enclosure.
- Year 10: Add PV system. With the new roof installed, a rooftop PV solar system is installed to provide more electricity than is used annually by the home.

It would be excellent practice to include the retrofit roadmap in the building consent submission. Having the document in the official property file ensures easy reference by future owners.

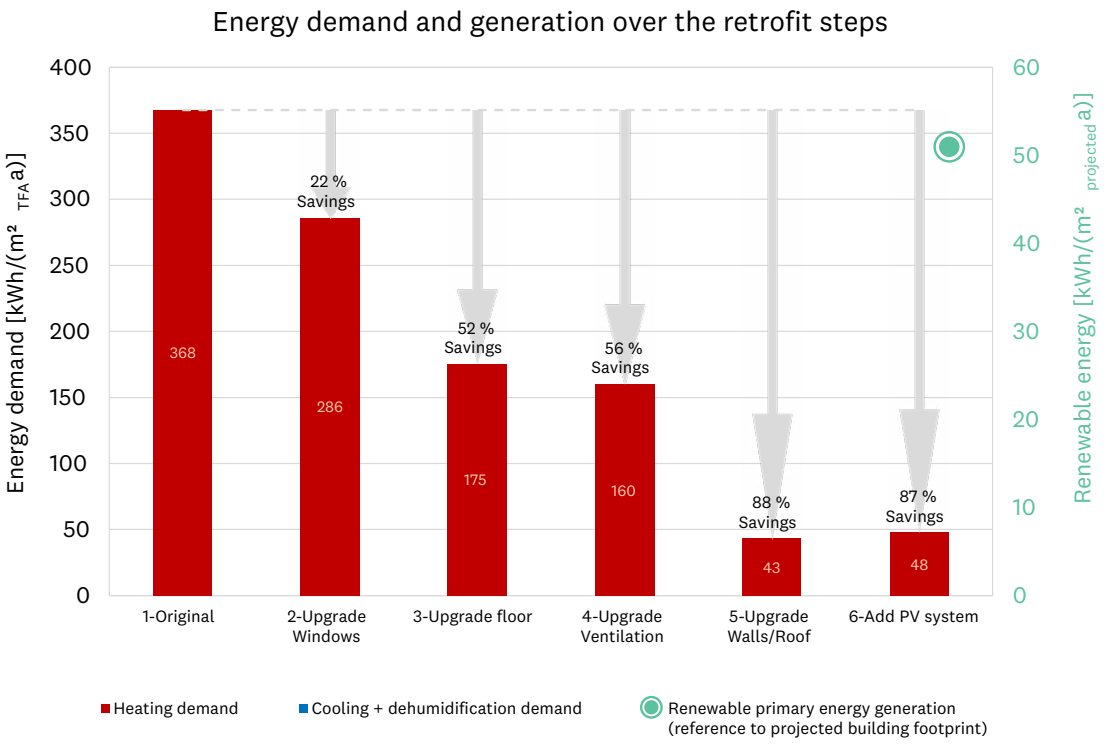


Figure 2: This chart shows a step-by-step deep energy retrofit plan for a timber-framed home in the North Island, which is burdened by both poor form factor and site orientation. This project would meet the EnerPHit component method for PHI certification, even though the reduced heating demand of 58 kWh/(m² year at the final step is still far in excess of the 15 kWh/(m² year) requirement for EnerPHit[8]. This number is dependent on the climate zone.

8 The component method is explained in full in Section 4.1.4.2

3 Foundational building science

This chapter introduces core building science concepts. It explains how and why buildings fail and the types of moisture risk that must be controlled in order for homes to be long lasting and healthy places to live. It also explains why this knowledge is even more crucial when approaching a retrofit compared to a new build. Key takeaways are presented in italics: whether a designer, contractor or consultant, these are crucial things to understand when engaged in retrofit work.

3.1 How to avoid whole-of-building issues

3.1.1 Ensure ventilation

Buildings need regular, continuous air exchange: a means of bringing in fresh outdoor air and removing stale, damp indoor air. This can be achieved in theory by diligent opening of windows but in practice this is highly unlikely as the cost is high on multiple fronts. Modern patterns of living mean relying on occupants to open windows enough to provide sufficient air exchange is unrealistic.

It is not the case that only modern or high-performance homes need mechanical ventilation. There is no New Zealand home so draughty that uncontrolled air leakage provides enough year-round air changes that continuous ventilation is unnecessary. See Section 3.4 for more detail.

Every New Zealand home needs continuous mechanical ventilation in order to ensure a healthy indoor environment.

3.1.2 Reduce overheating risks

Overheating is a relative concept. There are some hard biological parameters but it is largely culturally defined. In New Zealand, an indoor temperature above 25C is a reasonable definition of overheating. Historically it's not been a big problem in this country because of a temperate climate and patterns of construction. However, a combination of factors has led to growing awareness of the need to design housing (and other buildings) to reduce the risk of overheating.

Increased frequency of overheating of New Zealand homes is being driven by increasing temperatures and extreme weather events due to climate change, a growing number of higher-density residential complexes, higher glazing ratios, inadequate ventilation and poorly planned building orientation. Air-conditioning is becoming more common in newer homes and those retrofitted with heat pumps but operating it can be a burden on household budgets and the electrical grid. Some high-profile cases cited in mass media in recent years illustrate how even high levels of air-conditioning cannot always overcome poor design choices[9].

Preventing overheating requires thorough analysis of solar gain throughout the year. New builds have more options, such as changing glazing ratios and orientation and specifying external shading to prevent overheating. Problematic orientation is one of the biggest challenges to overcome on deep energy retrofits. Solar gain can be managed—and overheating reduced—by specifying low solar heat gain glass in new windows or retrofitting external shading elements.

9 Tracy Neal. (2025). Tenant quits lease after apartment hits almost 44C, bond refunded. *NZ Herald*, accessed 02 June 2026.

Keeping curtains drawn throughout the day, a common New Zealand response to overheating, is considerably less effective than external shading and is less effective as glazing performance increases. It's better to keep the sunlight and heat outside the thermal envelope, not inside, trapped between glazing and curtains.

3.2 How to avoid building assembly failures

The most common building durability failures are driven by high moisture levels within the building assemblies leading to mould, rot and decay. This is bad for building durability and the health of the people living in them. These failures occur when moisture finds its way into a building assembly and does not dry out sufficiently quickly. Mismanaging air flow and moisture during a retrofit can produce building failures. *Without a clear understanding of building science basics, especially the four building control layers, retrofitting actions risk amplifying existing problems or creating entirely new ones.*

The four control layers are building materials that control the movement through building assemblies of

- water
- air
- vapour
- thermal (energy eg heat or coolth).

They are explained in more detail in Section 3.6.

3.3 What goes wrong and why

Problems can be divided into two basic issues: problems for the integrity of the building structure and health problems for the people who live in them. The root cause of both however is the same: *moisture building up in and on building assemblies that can't dry out.*

3.3.1 Building failures

Because a deep energy retrofit strives to improve occupants' thermal comfort and health and reduce energy consumption, it's common to start with increasing insulation. Retrofitting insulation by definition reduces the heat flow through assemblies—but also the degree of ventilation inside those assemblies, as air is replaced with insulating material. Accordingly, it becomes much harder for the building assembly to dry out if it gets wet. Over time this can lead to rot and decay.

To prevent building failures, the drying potential of the building assemblies must be improved at the same time as insulation values are increased.

Moisture build-up doesn't only happen when rain gets inside the building structure. Thermal bridges also contribute to moisture problems. These are materials or construction details that create pathways for heat to quickly pass from one side of the building envelope to another. Aluminium window and door frames that are not thermally broken are an example every New Zealander is familiar with. When it's cold outside, the window frames become much colder than the internal air temperature and condensation forms. This also happens *inside* building assemblies, where it is not visible.



Figure 3: Moisture from inside the home is carried by air leaking through the ceiling assemblies into the roof space. The warm moist air hits the cold underside of the roof underlay and condenses. Without sufficient ventilation, the accumulation of moisture can lead to mould and structural damage in the roof.

3.3.2 Health failures

Poor quality housing causes serious health problems for New Zealanders. Living in damp, mouldy homes is directly linked to this country's high rates of respiratory illness, New Zealand's third-highest cause of death.[10]

Dampness can be caused by building failures or because interior environments are too cold and not adequately ventilated. It is a problem in many modern homes, not just aged housing stock. It is made worse in situations of fuel poverty and overcrowding or buildings that are so thermally inefficient they are actually impossible to adequately heat.

Deep energy retrofits should solve these problems. By improving thermal performance and upgrading thermal envelopes, heating and cooling become cheaper and easier and homes can be affordably maintained at a comfortable and healthy temperature: a minimum of 18 ˚C, 20 ˚C where residents include children, elderly people or those who are medically vulnerable[11].

10 Ahmad Mahmoodjanlou. 2025. Living in damp dwellings, Environmental Health Intelligence NZ, accessed 02 June 2026

11 World Health Organization. 2018. WHO Housing and Health Guidelines

3.4 Plan for mechanical ventilation

New Zealand has an indoor air quality (IAQ) problem. The lack of ventilation in New Zealand homes is a significant issue that is not acknowledged at a regulatory level. Ventilation is the exchange of stale indoor air with fresh outdoor air at an appropriate rate. The Building Code requirements are manifestly inadequate; it requires only that each room has a window *capable* of being opened. This ignores the reality of how people live in their homes and the impracticality and undesirability of opening windows for much of the year given temperature differences between indoors and outdoors, rain or wind, security and air or noise pollution.

Ventilation is needed to:

- keep relative humidity (RH) levels within an acceptable band of 40-60%,
- flush the CO_2 that people and pets breathe out, and
- dilute volatile organic compounds (VOC) and particulate matter (PM) off-gassing from materials and processes inside the home.

Moisture builds up indoors because of normal everyday processes like cooking, showering and breathing. It is made worse if, for instance, laundry is dried inside or sodden towels or coats left to air dry inside. The number of occupants and the amount of each day they spend inside all directly impact moisture accumulation. New Zealand homes are notoriously damp.

RH is expressed as a percentage, which indicates how much moisture is in the air relative to the maximum amount of moisture that air can hold at a given temperature. It changes a lot depending on the temperature of the air: the warmer it becomes, the more moisture air can hold. This is why ventilation alone can't maintain good IAQ in winter.

Some form of continuous extract mechanical ventilation is required in every indoor environment, including homes. It is a mistake to think that ventilation systems are only needed in homes specifically built to be airtight. Not even the draughtiest home delivers adequate air exchange over the course of every single day, season and year.

Ventilation and maintaining healthy indoor temperatures work together to keep relative humidity at healthy levels. Both are essential.

New Zealand's long latitude span means diverse climates; Queenstown (south, elevated, inland) has much lower humidity compared to Auckland (north, low-lying, coastally influenced). Accordingly, different strategies are needed in different locations. A well-performing building in Northland will in some circumstances need active dehumidification.

3.5 Avoid thermal bridges

Even in homes where RH is generally well managed, mould can still be a problem if there are thermal bridges. This is a consequence of thermal bridges creating cold spots on interior surfaces. At an uninsulated wall-to-floor junction, this might cause mould in carpet laid atop a concrete foundation. Other risky locations are aluminium window frames without proper thermal breaks, at corners or any uninsulated junction between concrete or steel and timber.

The thermal bridge creates a cold spot on the surface of materials that cools the air immediately around it and leads to a corresponding rise in local RH. For example, even in a room heated to 20 ˚C, a cold aluminium window frame at 15 ˚C will cause the surface RH to rise above 80%, the threshold for mould growth on materials like timber and paper-based products that readily grow mould. Building scientists predict this risk based on a specific building, climate and building assembly.

3.6 The solution: four essential building control layers

Building durability failures and unhealthy living environments are the predictable outcomes of the uncontrolled movement of heat, air and moisture within a building assembly.

A successful retrofit will control these forces through excellent design and careful construction. The four essential control layers together create a robust framework for the design of a healthy and durable house.

The control layers lie within the building's enclosure—the system that separates the conditioned inside environment from the outside environment. The enclosure (or building envelope) includes everything from the paint on the cladding to the interior finish surface.

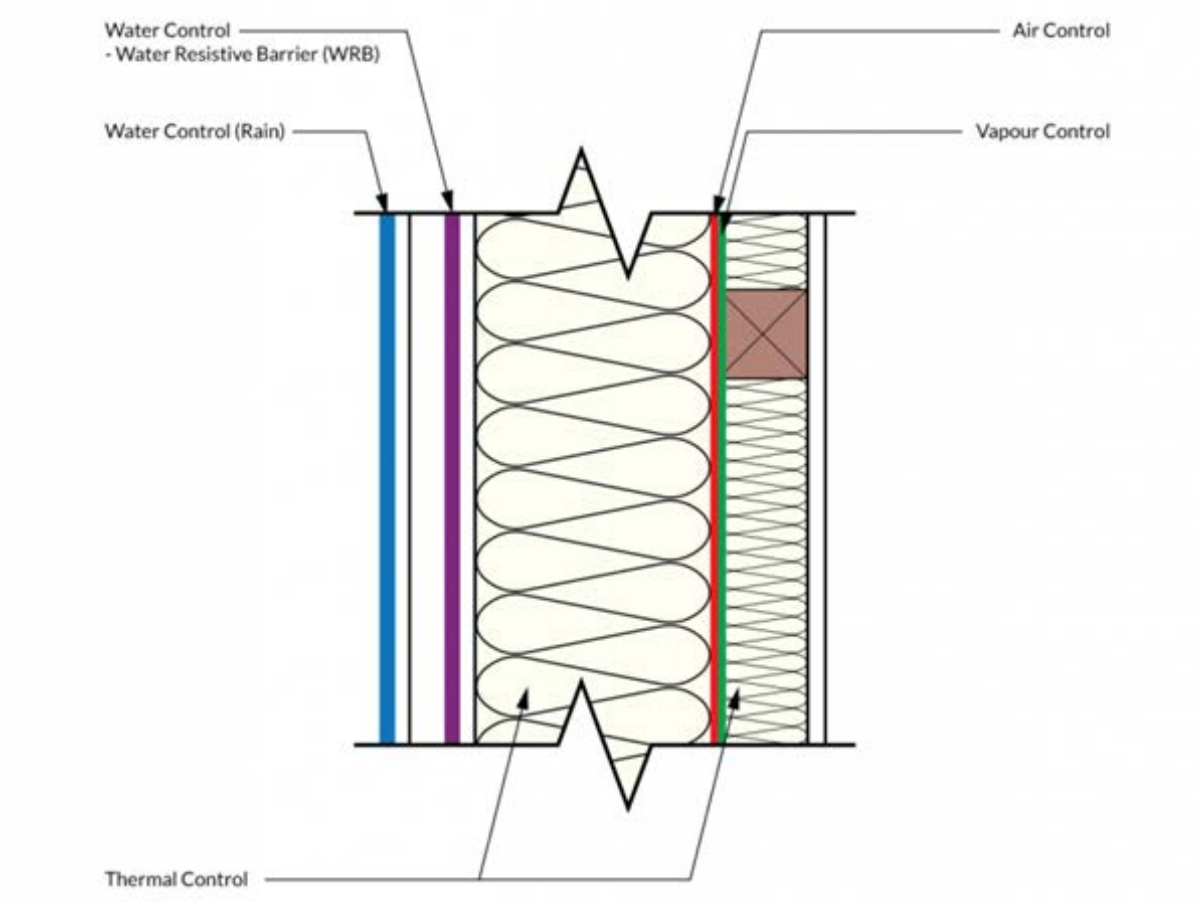


Figure 4: The four main control layers in a building's enclosure. In some assemblies, air and vapour control is provided by a single product.[12]

12 In this example a specialist smart vapour retarder membrane serves as the control layer for both air and vapour. However, air and vapour are not *necessarily* controlled by a single product in all assemblies.

The four control layers are introduced here in order of priority.

- **Water control layer**
  The external water control layer has the fundamentally important job of keeping the rain out. New buildings specify flashings and ventilated cavity cladding systems to prevent moisture problems. *A retrofit should bring the water control function up to modern standards or best practice.* This is explained in more detail in 3.7.1.
- **Air control layer**
  The air control layer prevents air from leaking through the building enclosure. Air leakage is a problem in two ways: it wastes energy (eg warm indoor air in winter is lost to outside) and it carries moisture into wall and roof structures. The moisture condenses as it cools, which can cause damage.[13] Air transport is the primary way interior moisture causes damage; vapour diffusion is secondary.
- **Vapour control layer**
  Vapour control layers moderate how moisture transfers *directly* through materials, a process called diffusion. Vapour refers to individual water molecules. Many modern vapour control layers also increase an assembly's drying potential by becoming more permeable to vapour when the local relative humidity is high: that is, the wetter the product, the quicker it can diffuse that moisture.
- **Thermal control layer**
  The thermal control layer is the least critical of the four with regard to building durability. (Ironically, it gets the most attention due to shallow retrofits' focus on saving money on heating and improving thermal comfort.) First, the water, air and vapour control layers must be defined and implemented correctly. Only then is it suitable to focus on the thermal layer.

Gaps or compression in the insulation material leads to thermal bypass, which can reduce performance by 30% or more (3.6.2 has more detail).

The thermal performance of a wall is highly dependent on the quality of the installation of insulation.

3.6.1 Understand how the four control layers work

The four control layers must completely and continuously wrap around the building enclosure. At every junction in the building, the designer must understand how the control layers are continuous across the detail. It is both risky and potentially negligent to leave this for contractors to figure out on site.

13 In New Zealand, the failure of the air control layer is the cause of the much-publicised problem of school roofs leaking when it is sunny. Residential and office building roofs have failed for the same reason in climates as diverse as Wellington, Auckland, and Queenstown. See more.

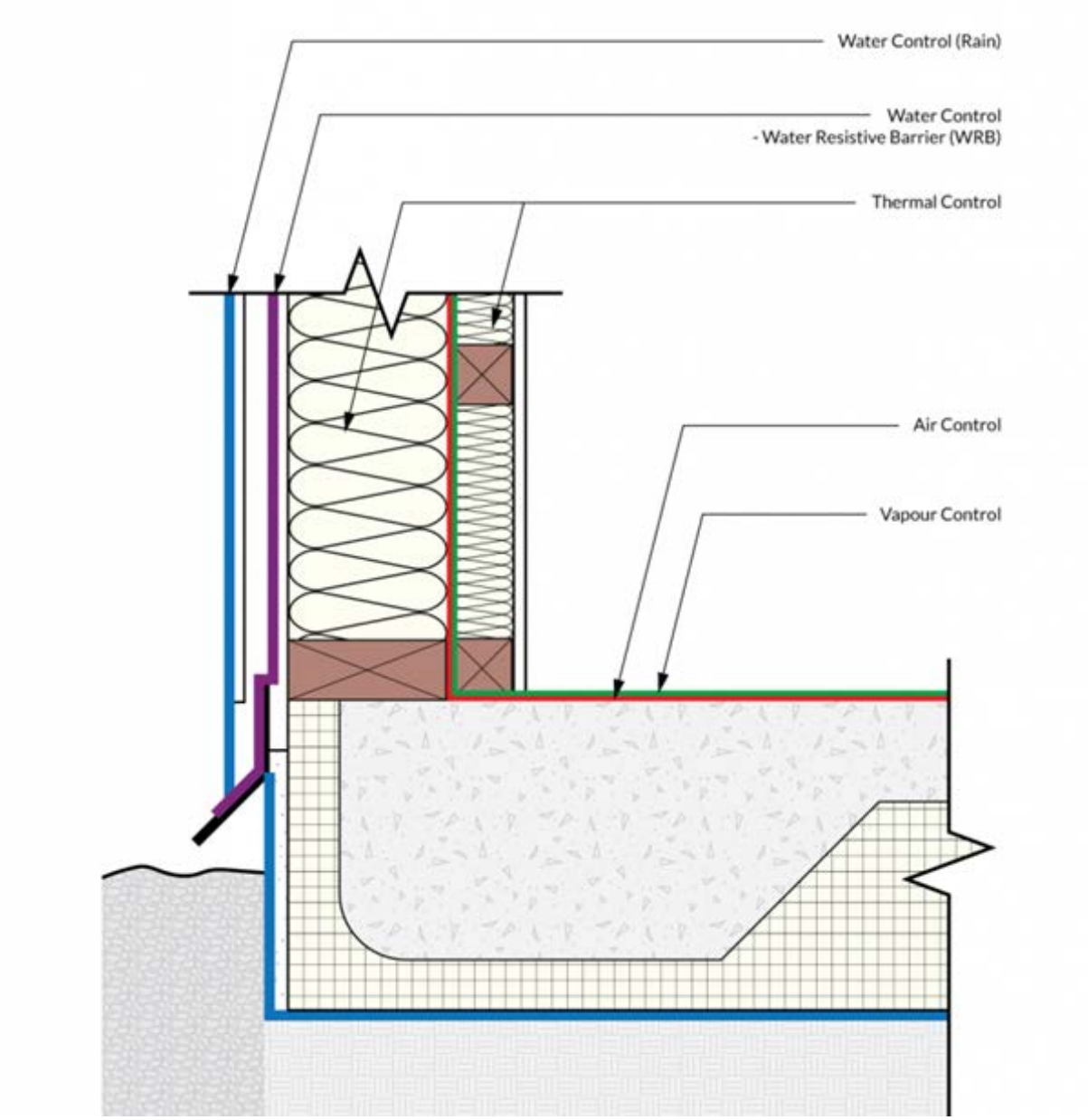


Figure 5: The four control layers where a wall joins a floor junction.

1. The **water control layer** on the wall (its cladding) runs down to join the water control layer on the slab. As water control is absolutely vital for durability, a second water control layer, the **weather resistive barrier** (WRB or building wrap), is installed behind the primary layer.

2. The **air control layer** joins the top surface of the concrete slab to the inside surface of the airtight membrane in this wall.

3. The **vapour control layer** is, in this case, the same material (concrete slab surface) as the air control layer.

4. The **thermal control layer** is contiguous, except for the point at the timber bottom plate.

3.6.2 Prevent thermal bypass

Thermal bypassing is the air movement through and around insulation and it has a very big impact. It can reduce the thermal performance of wall assemblies by 30% or more.[14] Prevent thermal bypass by ensuring:

- the thermal control layer is contiguous and lines up at all junctions (eg roof-to-wall), and
- there is no windwashing through the insulation (in practice this is done by requiring the insulation to be fitted against an air control layer or with a building wrap or membrane to the outside) and the insulation is fitted snugly without gaps.

3.6.3 Ensure insulation install quality

The quality of the insulation installation is critically important and often neglected. The New Zealand Building Code doesn't have a formal insulation installation quality grading scheme and installation is often subcontracted to the lowest bidder. *In practice, focusing on how well the insulation fits the cavity can be more impactful than simply choosing higher R-value products.*



Figure 6: Well-fitted insulation has no gaps and fits directly against an airtight layer (sheet product or a membrane). This prevents thermal bypass and achieves the design level of insulation performance.

Retrofitting insulation is fundamentally more labour-intensive than new construction. In a new build, the wall framing is typically set at a standard 600mm on centre making it simple to slide pre-cut insulation batts slide into place quickly and snugly. Older houses rarely have consistently spaced framing and as a result, every single piece of insulation may need to be custom-cut and carefully fitted. This is more time-consuming and requires a lot more skill and attention to detail.[15]

14 Designers can refer to Siddall, M., Thermal Bypass Risks 2022. This article discusses a US checklist developed for builders. This article by the author goes into more detail in the New Zealand context.

15 Many practical examples are cited in this article by the author.

Homeowners should get the thermal performance they're paying for.[16] Batt insulation in particular is not forgiving of sloppy installation. *In the case of an R3.0 roof, its effective R-value is halved if just 10% of the ceiling area is left exposed by gaps.*



Figure 7: Gaps and poor fit can easily halve the intended R-value of an insulated assembly. Existing insulation may also be contaminated post-installation (eg rodent activity) and potentially moisture damaged.

3.7 The forces to manage: how moisture and heat move

Heat and moisture are the interconnected and primary forces at play in a building assembly. Managing moisture, especially in its liquid form, is the foremost priority when creating a durable and healthy building. Moisture moves through an assembly in three main ways, which are addressed below in order of importance: bulk water, air leakage and vapour diffusion.

3.7.1 Bulk water

The most destructive force is bulk water from rain. A building must be designed to manage this first. A common design methodology is 'the 4Ds'.

- Deflection: keep water off the building with features like roof overhangs.
- Drainage: provide a clear path for any water that does get on the building to drain away, such as a ventilated cladding cavity.
- Drying: ensure the assembly has the potential to dry out if it gets wet.
- Decay resistance: use materials that are not easily damaged by moisture.

16 NZS 4246:2016 – "Energy efficiency: Installing bulk thermal insulation in residential buildings", is due for an update and there has been discussion about adding a comprehensive section on retrofitting. Currently it is mentioned only very briefly in the standard. Adding in an insulation installation grading scheme, even if it was advisory and not normative, would be very helpful to industry and clients.

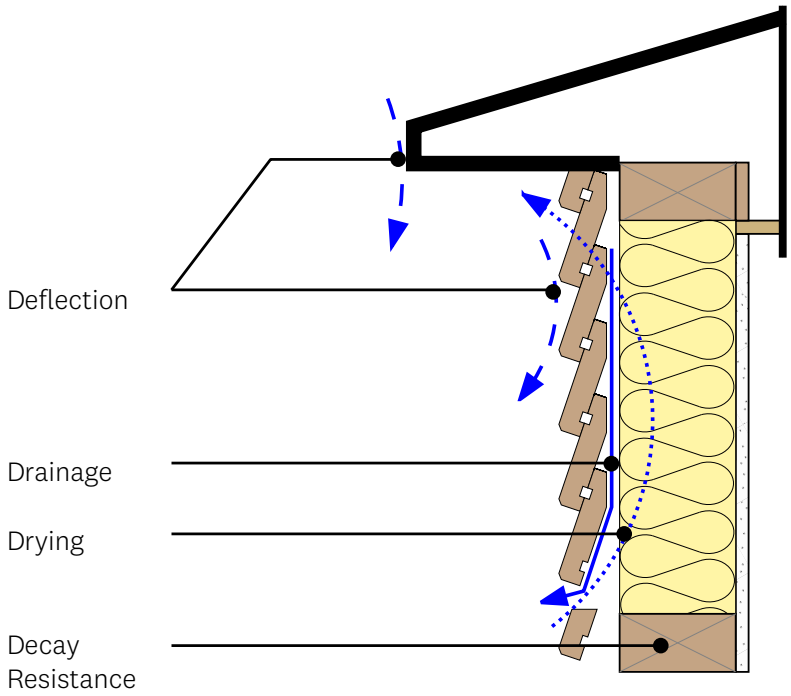


Figure 8: The 4Ds of water management[17]

Modern cladding systems often incorporate a pressure-equalised cavity where an airtight inner layer and a leaky outer rainscreen prevent wind pressure from driving water into the wall. *Sealing intentional drainage gaps in these systems can cause leaks into the building assembly or even the building interior.*

3.7.2 Air leakage

When air moves through a hole in the building enclosure, it transports all the water vapour held within it. This is a far more powerful moisture transport mechanism than vapour diffusion (see below), by a factor of about 100:1. For instance a small 2cm^2 hole could allow about 30L of water to pass into a wall via air leakage over a single heating season, compared to just 0.3L through the same area via diffusion.[18]

3.7.3 Vapour diffusion

Vapour diffusion is the slow movement of water vapour directly through solid materials. This property is critical for designing assemblies that can dry out. It's a problem when it is unplanned and vapour is moving in the wrong direction through a building assembly. But done well, vapour diffusion plays a crucial role in drying moisture that has made its way into a building assembly.

17 Illustration by Sustainable Engineering Ltd, based on image from Hazleden, D.G., "Designing for durable wood construction: The 4Ds", Durability of Building Materials and Components 8. (1999) Edited by M.A. Lacasse and D.J. Vanier. Institute for Research in Construction, Ottawa ON.

18 Joe Lstiburek. 2024. Slide Rules, Pocket Protectors, Cigarettes and an Iconic Building Science Image. ASHRAE Journal December 2024

Assemblies are imperfect: moisture ingress should be assumed at design stage and a pathway for it to drain or dry established. The belief in a perfect wall assembly 100% impervious to rainwater was one of the causes of the leaky building crisis of the 1980s and 90s.

Many modern materials do not allow as much vapour flow as traditional materials or methods. For instance, the use of rigid air barriers instead of building paper can increase the risk of condensation inside the wall assembly. Outcomes depend heavily on climate and the assembly design. Colder climates and higher insulation levels increase risk.

3.8 The hygrothermal balancing act

Here's the golden rule for designing and constructing durable, healthy home: a building assembly's capacity to dry must always be greater than its potential to get wet.

Getting wet is not a problem if a building material or assembly can store that moisture safely and then dry out again. Standard roof underlay is a successful example of this balance in action. It acts like a moisture battery by absorbing small amounts of condensation overnight and safely releasing it to the ventilated space during the day. The system fails only when wetting, say from large air leaks or insufficient ventilation, overwhelms the capacity to dry out.

Successfully retrofitting wall insulation is a technically complex undertaking that must rest on a solid understanding of the building science. *Adding insulation to walls reduces the drying potential, fundamentally shifting the hygrothermal balance.* The entire wall assembly becomes colder and wetter. In particular, the exterior side of the assembly, once kept relatively warm and dry by escaping heat, is now much colder and is at a higher risk of moisture issues.

Many older uninsulated New Zealand homes don't suffer from moisture problems solely because of the constant heat loss and incidental airflow in uninsulated cavities that dries out moisture from minor flashing leaks or construction defects. Blowing insulation into these wall cavities without first improving the water, air and vapour control layers is fraught and if done badly can cause rapid damage to the structure.

Retrofit designs must do good and avoid harm. A successful retrofit is not about adding a single product. Rather it requires re-balancing the entire system to ensure the structure stays dry.

4 The deep retrofit workflow

A deep energy retrofit needs a well-structured process, involving research and planning before any construction starts. The workflow outlined below breaks the project into four distinct stages, ensuring a logical progression that manages risk and delivers quality at every step.

It's important to focus on how to retrofit specific as-built walls, roof and floor assemblies. Don't approach a retrofit project with assumptions based on building typologies: villa, bungalow, state house style etc. When it comes to a deep energy retrofit, every home has a unique history and condition that must be assessed and addressed individually.[19]

19 Page I., Fung J. 2008. Housing Typologies - Current Stock Prevalence. Report EN6570/8. Beacon Pathway Limited.

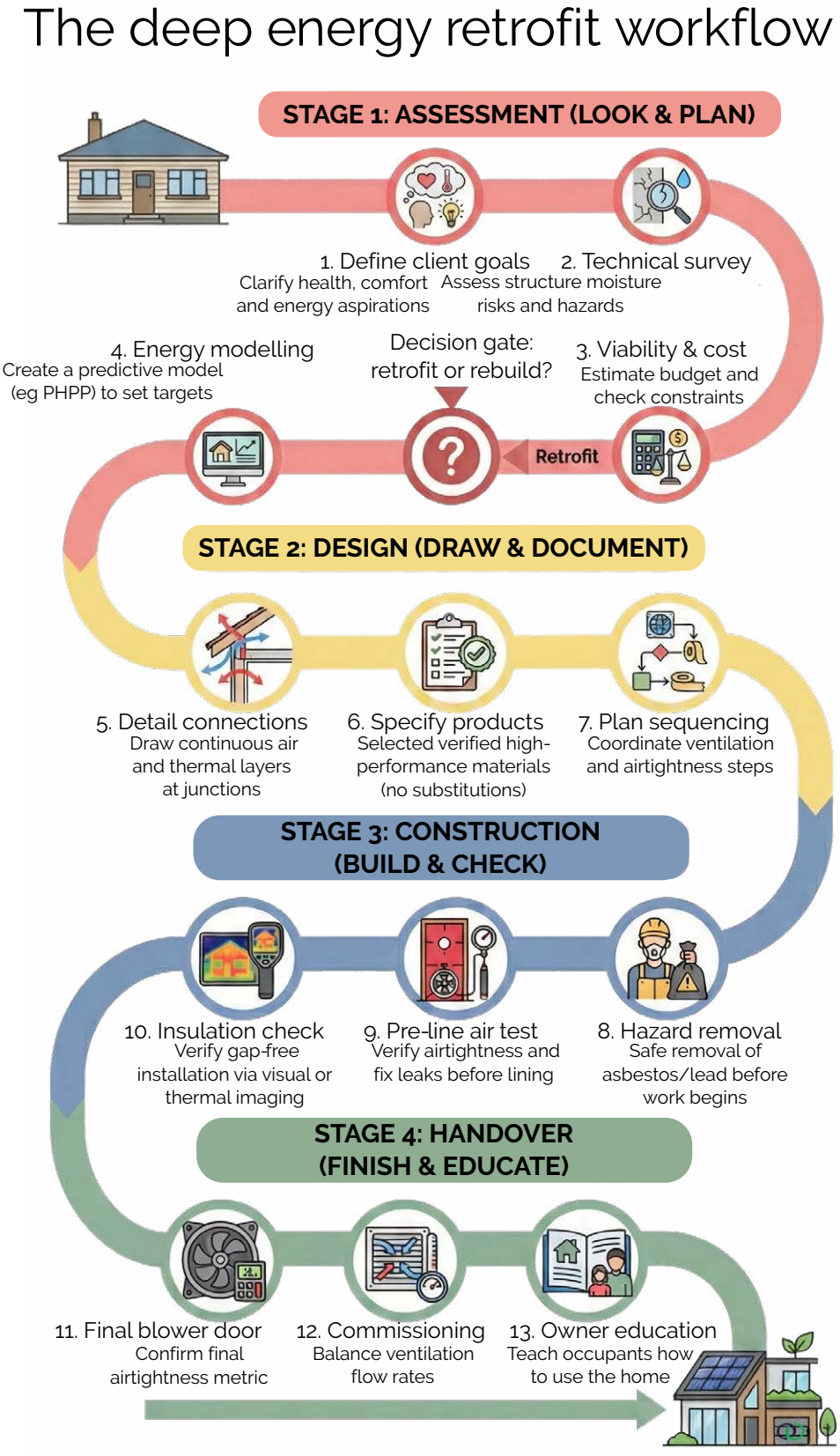


Figure 9: The deep energy retrofit workflow. This same workflow can be applied to step-by-step retrofits and at each step, work will cycle between stages.

4.1 Stage 1: Assessment and retrofit roadmap

STAGE 1: ASSESSMENT (LOOK & PLAN)

A thorough assessment of the project brief and the existing building, plus development of a roadmap for all project work, provides an important foundation for a deep energy retrofit. It requires an honest appraisal of the existing building, defining the project goals and creating a robust plan.

This is where the first crucial assessment must happen: is this building suitable for renovation or is it in fact a knockdown-rebuild project? If both the interior *and* the exterior of the building need to be replaced or the existing structure is fundamentally compromised, starting over is regretfully sometimes the more appropriate choice. This is discussed at more length in Section 4.1.3. Full information must be gathered before an informed decision can be reached.

4.1.1 Understanding the client and defining project goals

The process begins by translating the homeowner's desires into a clear project brief, as for any architectural design process. Have exploratory conversations with the clients to clarify what is important to them and their expectations. What motivates them? For some clients, it may be about greater comfort (a warm house, that also stays cool in summer) or a healthier home (one that isn't damp and cold and where people are frequently sick). Others may have broader aspirations, understanding the connection between energy efficiency and climate change mitigation.

4.1.1.1 Help clients understand energy efficiency outcomes

Some clients will be very well-educated about high-performance, Homestar or the Passive House standards in particular. Others will only have a general idea based perhaps on visiting better-performing homes. Consider how to explain key concepts in a way that resonates for the individual and accords with physics. For instance, if reducing energy demand is an important goal, ensure the client understands that some active heating will still be required.[20] Consider translating kWh/m^2/year numbers into an estimated winter power bill – see section 4.1.4.1 on energy modelling to predict outcomes.

The prebound effect may mean energy savings are not as great as on-paper predictions. The corresponding rebound effect explains how occupants will often change the way they live in their newly comfortable home. When it becomes affordable to heat the whole house to a comfortable temperature, people often start doing so, rather than just a single living space. They may heat (or cool) for a longer period of the year. Accordingly, while people's comfort and health increase dramatically, their energy bills may not reduce by the full amount predicted on paper. This is a well-studied phenomena and an entirely logical response to new circumstances. See the sidebar 30, "Managing expectations: the prebound and rebound effects".

4.1.1.2 Advocate for better choices

Design the building your clients want but do what's right for their current and future selves and for the building. Educate yourself in order to effectively influence better choices. Consider these examples.

20 This is true even of a newly built home certified to the Passive House standard. Sara Wareing. 2024. Passive House buildings still need heating. Sustainable Engineering Ltd.

- Cooking on a gas flame creates dangerous particulate pollution and the cost and uncertainty of supply is rising. Induction cooktops are a far better alternative: safer, cleaner, faster and instantly responsive.
- Wood burners are likewise a cause of air pollution (inside and outside the home).[21] Heat pumps are a cleaner, more efficient choice and better suited to the much lower heating demands of a retrofitted home. Some homeowners are very emotionally attached to the ambiance of burning wood. Some designers now channel that desire into outdoor fire pits or fireplaces, preventing overheating and poor indoor air quality.
- A client may profess to not care about airtightness or think 'living in a sealed box' sounds like a bad idea. Be ready to explain, in non-technical terms, how airtightness is a vital part of a systems approach, not an end in itself. It pairs with better insulation to keep the warm air inside the building in winter rather than allowing it to leak out. It also prevents uncomfortable draughts caused by external air moving through and around building components. And it is necessarily paired with continuous mechanical ventilation that ensures outstanding indoor air quality.

Designers should also pay attention to opportunities where a small increase in budget could bring about a disproportionately large increase in performance and comfort and be proactive in recommending these alternatives. In cases where a client is adamant about a choice that will negatively impact performance, it is prudent to put your advice in writing. *Buildings should outlast people: consider what is best for the building too.*

Consider the benefits of designing for universal accessibility or at least making provision for basic accommodations to be more easily retrofitted in future.

- For instance, if internal wall linings are being removed, specify the installation of blocking in appropriate places in the shower and toilet walls that will make fixing grab rails simple and inexpensive in the future. Document this clearly.
- If internal walls are being remodelled, consider slightly wider doorways to make room for mobility aids: 860mm wide doors are among standard sizes and will provide for wheelchair access.
- Can new or remodelled entranceways be made level access?

Young and healthy people can be immobilised for periods following injury or surgery and older visitors will appreciate a physical environment that makes their visits easier and safer. Universal access benefits everyone.

4.1.2 Assessing viability and cost

The value of a deep retrofit goes far beyond simple financial payback on energy savings. The analysis must focus on the cost to achieve the real goals of the project: a healthy, comfortable and durable home. These non-financial returns—such as improved health,[22] better sleep and peace of mind—are often the most valuable outcomes for a homeowner. The conversation should be framed around money as a tool to achieve these greater ends, not as an end in itself.

21 Jason Quinn. 2026. Burning stuff indoors is a $12 billion health bill. Sustainable Engineering Ltd. 18 January 2026.
22 Jason Quinn. (2025). NZ homes are still cold, damp and unhealthy. Sustainable Engineering Ltd. 19 May 2025.

Managing expectations: the prebound and rebound effects

When presenting the business case for a deep retrofit, designers must be careful not to overpromise on financial savings based solely on energy models. Theoretical models assume the existing, uninsulated home is being heated to a healthy 20°C year-round. In New Zealand, this is rarely the case.

The prebound effect

Most occupants in thermally inefficient homes do not consume the energy required to maintain 20°C. Instead, they reduce energy use by enduring cold temperatures, heating only a single room or at specific times or wearing extra layers. Research shows actual energy consumption in poor-performing homes can be 30% to 40% lower than the calculated energy rating predicts. This missing energy consumption is the prebound effect: underheating.

The rebound effect

Conversely, once a home is retrofitted and becomes affordable to heat, occupants often *take back* some of the potential savings in the form of increased comfort. They often choose to heat the whole house rather than one room, or maintain a temperature of 22°C rather than 20°C.

The reality gap

If you promise savings based on the theoretical gap between the old, leaky house model and the new, airtight house model, the client will likely be disappointed when their heating bill doesn't drop by the predicted 80% or 90%.

The solution

Do not sell deep retrofits on financial payback alone. Frame the conversation around the value of the upgrade: moving the household from a state of thermal discomfort and fuel poverty to one of exceptional health and comfort. The energy reduction is real, but the true return on investment is a home that is no longer making the family sick.

4.1.2.1 The technical assessment

A comprehensive technical investigation of the existing house is essential. This is when the designer or project manager identifies opportunities, risks and existing conditions.

Investigate any risks or constraints which a deep energy retrofit needs to consider, such as heritage overlays or other planning requirements, risks from flood, ground conditions or air pollution and site-specific shading.

- Retrofit survey and risk report: A formal survey should document the building's condition and identify potential issues like mould, damp and structural problems before they become costly surprises during construction. Specifically note untreated timbers in settings where current building regulations would require the use of treated timber, unreinforced poor-quality perimeter foundation walls, condition of piles (is re-piling required?), inadequate ground clearance and ventilation to suspended timber floors and leaking cold water and rainwater services.[23]

23 When retrofitting a property that has been effected by an insured event like a flood or earthquake, ensure any underlying damage is thoroughly assessed and remediated before new work begins to prevent latent issues from being permanently locked in.

- Hazardous materials survey: For any home built before 2000, assume hazardous materials are present until proven otherwise.
  - Asbestos: This can be found in textured ceilings, vinyl flooring, fibrolite cladding, old pipe lagging, heating/electrical services and some forms of insulation. Professional testing and a licensed removal plan are mandatory.
  - Lead-based paint: Common in homes built up to 1980, lead paint poses a serious health risk, especially to children. Surfaces must be tested and a plan for lead-safe removal or encapsulation put in place.
  - Other hazards: Consider arsenic in older CCA-treated timber, mercury in old thermostats and fluorescent light tubes and foil-backed insulation under old floors.
- Problematic building products: The assessment must identify and plan for the replacement of known high-risk materials used in the past in New Zealand, such as but not limited to Dux Quest plumbing, Weatherside cladding or outdated electrical wiring.
- Combustion safety assessment: Assess all existing gas appliances, wood burners or open fireplaces and identify the risk of carbon monoxide (CO) spillage and back drafting. The connection to an attached garage, a common source of CO, must also be evaluated.
- Seismic and site risks: Identify any unreinforced masonry chimneys or insecure roof tiles that pose a seismic risk, as well as any site-specific issues like land slips or contaminated soil. Consider flood or inundation risks, risk of erosion (to access and ancillary structures, not just the house), air pollution (from proximity to major roads, tunnels, industry, bush fire and smoke etc). Check for any unresolved natural disaster damage and potentially fractured sewage pipes.
- Ventilation: Evaluate the home's existing indoor air quality and measures to control indoor humidity. Make certain that intermediate steps do not make this worse.
- Constraints: Identify any heritage overlays, setbacks and other planning requirements from local bodies, as well as the existence of covenants.

Discuss with the homeowner the replacement of all gas connections with electric alternatives. Fossil ("natural") gas is undesirable from the point of view of carbon emissions and also indoor air quality. Its future supply is not assured and cost is climbing. A deep energy retrofit is an ideal time to switch off gas connections and create an all-electric household.

The following checklist has been developed by a local company specialising in retrofitting insulation into wall cavities. It is published below with permission. This is an excellent example of the kind of thoroughness that a project manager should be expecting from suppliers and sub-contractors.

1. All retrofit wall installations should follow a formal assessment process.
2. A hazard inspection is essential to identify risks such as power entry points, fuse boxes, gas flues within walls and site hazards including sloping ground.
3. Wiring must be modern thermoplastic sheathed (TPS). If not, it must be replaced prior to installation.
4. A weather tightness inspection should be undertaken, including checks for cladding damage, flashings (around doors, windows, building corners and other openings), sealed protrusions and wall vents. Any vents must remain breathable while being appropriately protected.
5. All weather tightness issues must be recorded for future reference.
6. All identified weather tightness issues must be remedied before installation proceeds.
7. A minimum 100 mm clearance from ground level is required, both vertically and horizontally.
8. All unsealed (unpainted) brick walls must be sealed with a long-life, water-vapour-permeable sealant.
9. Cladding type must be considered for both suitability for wall insulation and whether installation should occur internally or externally. Common cladding such as weatherboard, brick, and stucco are generally suitable for either approach, while fibrolite is best suited to internal installation due to possible asbestos and high risk of repair failure.
10. House types with a known history of water ingress or a propensity to develop leaks should be avoided. The E2 risk matrix used in new-build design should be applied during assessment to screen out higher-risk retrofit projects.[24]
11. The insulation system selected should have a proven history of performance and be supported by appropriate certification for the specific application.

4.1.2.2 Building consent requirements

Understanding whether the proposed work requires a building consent is very important and this should be clarified as early as possible during conversations with the relevant building consent officials. While minor repair and maintenance jobs are generally exempt, a deep energy retrofit often involves work that does require building consent.

The Building Act principle to keep uppermost in mind is whether the work goes beyond simple repair or like-for-like replacement. A deep retrofit by its very nature is about fundamentally changing and improving the building's performance, which means most of the work can't be considered like-for-like.

24 Risk matrix from E2 External Water Acceptable Solution (E2/AS1). This is a simple process that first assesses the risk of the building based on wind zone, number of storeys, design features and complexity and assigns a risk score from 0 to over 20. This score is then compared to a table of suitable wall claddings. For stucco and EIFS a nominal 20mm drained cavity is required even with a risk score of zero.

- External walls, cladding and windows: weatherboards being replaced with new timber weatherboards might be exempt. However, if the cladding system is changing—for example, by adding a layer of external insulation—the building's weathertightness risk profile changes and this will almost certainly need a building consent. Similarly, replacing windows with new units that require different flashing details is not "like-for-like" and will need consent.
- Insulation: simply replacing old, damaged insulation with a modern equivalent of the same type may be exempt. However, adding insulation to a previously uninsulated wall[25] or roof fundamentally changes the hygrothermal balance of that assembly. This can introduce new moisture risks if not designed correctly. Because this work affects the building's durability and compliance with the Building Code, adding external wall insulation typically requires a consent. This is not the case with retrofitting *roof* insulation—even though this also carries risk.
- Structural changes: any work that modifies the building's structure—such as removing a load-bearing wall, changing the size of window openings, or altering the roof structure—will always require a building consent.
- Internal linings: generally, replacing internal wall linings like plasterboard is exempt from consent, as long as it doesn't affect a structural or fire-rated element. Wet area or level entry showers are generally outside the scope of this exemption and typically require building consent.
- A practical challenge in retrofit project can be securing confirmation from the manufacturer or supplier that their product complies with the Building Code when used outside its standard application. Some suppliers are hesitant to support less common use of their materials, which makes the consent process more complex.

All aspects of the project must be verified as acceptable according to the Building Code and supplier requirements.[26] The rules can be complex and the final decision rests with the relevant building consent authority. As a first step, make use of the free online tool at canibuildit.govt.nz. The architect/designer should discuss the plans with the local council early in the assessment stage.

Treat the consent process as an integral part of the quality assurance framework rather than simply a hurdle to be cleared.

4.1.3 Decide: demolish or retrofit

One of the biggest and most consequential decisions facing a homeowner is whether to retrofit the existing building or demolish it and start over. This choice is driven primarily by the condition of the property and the full scope of work intended to be undertaken. It should be assessed once the above data has been considered and at least an initial budget developed.

Consider a scenario where a building needs a full exterior reclad, new windows and perhaps even new piles. The interior however needs little work, functionally or aesthetically. In such a case, an exterior-led retrofit often makes good financial sense. This will deliver a brand new, high-performance building envelope with excellent durability and efficiency, while little money is spent inside.

25 Note the installation of thermal insulation in an existing building is exempt except for external walls and internal fire walls – see Building Act 2004 Schedule 1, exemption 13.

26 Under Sections 14B to 14G of the Building Act 2004, all parties in a building project have clearly defined responsibilities.

Alternatively, a house with a well-maintained exterior but dated interior or floor plan that needs reconfiguring can be an excellent candidate for an interior-led retrofit. This can be a cost-effective choice even when specifying new high-performance windows.

However, the calculation changes dramatically if the exterior needs replacing and the homeowner also wishes to remodel the interior. If there are changes to the floorplan, upgrades to the kitchen or a new bathroom added, the total cost including labour may exceed that of a new build. A middle option is to demolish the entire home and rebuild new upwards from the existing slab footprint. This saves considerable embodied carbon and can be cost-effective.

The other opportunities offered by a knockdown-rebuild should also be objectively considered. This might include improved orientation for sun, greater privacy, a better spatial relationship with the site or even subdivision. This should be weighed against the embodied carbon cost of tearing down a house and building again from new. These are the emissions related to building materials and processes that stretch over the entire lifecycle from mining or manufacture of components through to their decay at end of life.

Removal of the existing house so it can be renovated on another site or a salvage demolition that ensures as many materials as possible can be reused are strategies that could reduce the carbon footprint of a knockdown-rebuild.

4.1.4 Developing the integrated retrofit roadmap

With the assessment data gathered, the next step is to create an integrated roadmap, a comprehensive plan for the entire project. This roadmap lays out the strategy for achieving the project goals, whether that's all at once or step by step.

4.1.4.1 The engine of the roadmap: predictive energy modelling

The most effective way to develop a deep retrofit roadmap is through predictive energy modelling. This acts as the engine of the entire process. Predictive software tools can create a digital twin of a specific building that predicts the building's as-built energy efficiency.[27] This stands in contrast to modelling designed only to show compliance with the Building Code. These compliance tools routinely exclude building features that have a massive impact on real-world performance, such as thermal bridging in midfloors and the thermal impact of common window installation details. These factors are ignored simply because the Building Code allows it, but a deep retrofit cannot afford to overlook these impactful energy losses.

Any model is only as good as the quality of the data provided. The designer enters specific details about the location—including local climate, site-specific shading and orientation to the sun—along with the areas and R-values of every building element. Critical data points include the target airtightness level, the ventilation strategy (including heat recovery efficiency) and the efficiency of major systems like heat pumps and LED lighting.

The model then calculates the integrated impact of all these factors, showing how they interact. It produces key performance metrics, predicting how much energy will be needed for heating and cooling. Crucially, it also assesses the risk of summer overheating. This is a vital check in a warming climate.

This digital twin allows the designer to compare different retrofit options instantly, showing the client a clear pathway to increase performance from the home's current state to the equivalent of a new

27 The usual garbage-in, garbage-out caveat applies: the output relies on accurate inputs, which is why using a professional experienced with the modelling software is recommended.

Code-compliant home, an 8 Homestar rating, or all the way to the EnerPHit standard, an international best practice standard for deep energy retrofits. Modelling can *save* clients money by enabling choices based on objective data rather than assumptions. This is especially the case in warmer climate zones.

There are growing numbers of professionals skilled in using the Passive House Planning Package (PHPP) software to create design-stage energy models. It is not a significant cost in the context of a major retrofit. ECCHO is a viable alternative, offering a simplified user interface that uses the same math engine as PHPP.[28] ECCHO is the minimum level of energy modelling recommended.

Design-stage energy modelling is the only way to confidently find the sweet spot between outcomes and cost, ensuring your client gets value for money and no surprises. However, the EnerPHit component method can offer reliable targets in the absence of a whole-building model.

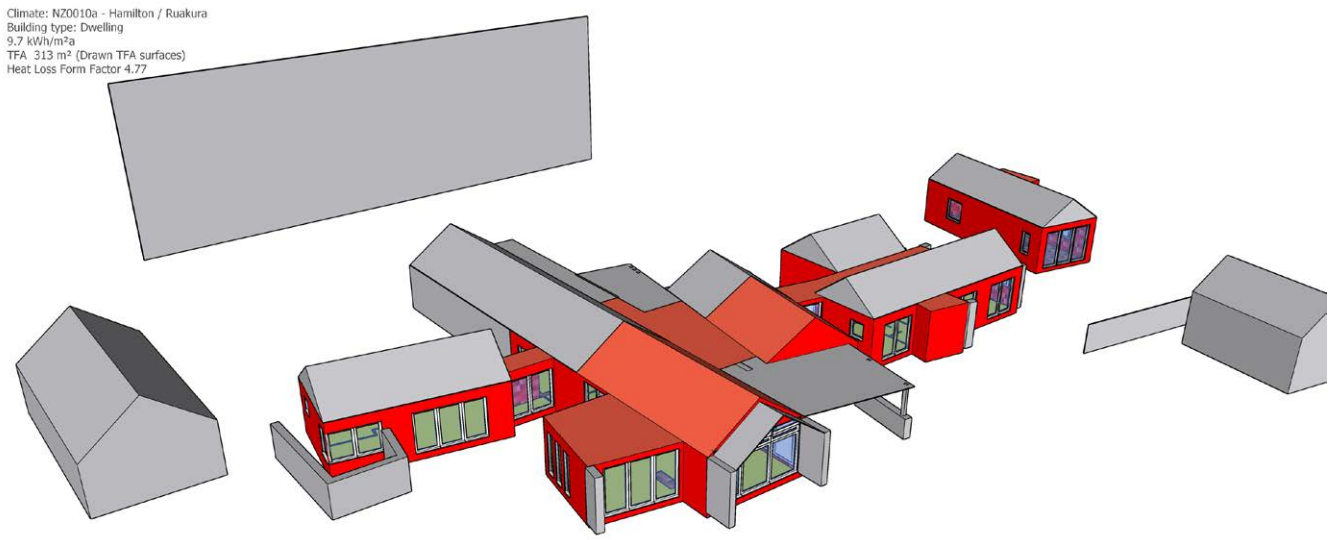


Figure 10: Energy model of a complex home that accounts for site shading, overhangs and form. Red shading indicates the conditioned space inside the thermal envelope. Grey surfaces represent shading, which needs to be calculated with regard to solar gain and shading predictions. Image © Sustainable Engineering Ltd

4.1.4.2 Establishing the performance target

The roadmap requires a destination. In the current absence of a consensus about which international benchmark best suits New Zealand's unique conditions, designers and homeowners are encouraged to consider a range of international standards for healthy, energy efficient buildings and to weigh up what best matches the homeowner's values, goals and budgets. Both the building fabric and systems need to be included.

The baseline for a deep energy retrofit is improvement to the building envelope so that condensation or mould (visible or otherwise) never occur, while occupants can enjoy good thermal comfort with excessive heating requirements. Insulation levels should approach the EnerPHit component method requirements.

28 NZ Green Building Council. (2021). ECCHO – Energy and Carbon Calculator for Homes.

Deep energy retrofit standards from Europe and the UK.

EnerPHit certification from the Passive House Institute *mandates exceptional whole-house efficiency, requiring comprehensive upgrades to both the building envelope and mechanical systems. It offers two compliance pathways:*

1. Energy demand method: this pathway treats the house as a complete system. Using a predictive energy model like PHPP, the designer must demonstrate that the entire retrofitted home meets a target for annual heating and cooling demand. This is a holistic, performance-based approach.
2. Component method: this pathway is simpler and is often compared to the R-value requirements in the NZ Building Code. Instead of meeting an overall energy budget, the designer must ensure that every individual retrofitted element of the building's fabric (walls, roof, floor and windows) meets a specific minimum thermal performance (R-value).

The specific targets for both pathways are climate dependent. This is a key feature of the EnerPHit standard, ensuring the requirements are optimised for local conditions. In a warm climate like Auckland, for example, the heating and cooling demand targets for the EnerPHit standard are the same as the full Passive House Classic standard. In contrast, a retrofit in a cool-temperate climate like Queenstown permits nearly double the heating demand: this represents the economic sweet spot for an upgrade in that environment.

The EnerPHit standard has in-built flexibility, providing exemptions where upgrades are physically impossible to carry out due to as-built realities. Meeting mould and comfort requirements is not optional.

CarbonLite Retrofit Standard from the UK's Association for Environment Conscious Building (AECB) focuses on significant reduction in carbon emissions and moisture safety. It provides a highly effective performance target that is less rigorous than EnerPHit (eg an airtightness limit of twice the allowable leakage of EnerPHit and a higher space heating demand limit, typically around 50 kWh/(m²a), roughly 2-3x the EnerPHit allowance).

LETI Retrofit Standards developed by the London Energy Transformation Initiative establishes a range of performance targets based on space heating demand reduction:

1. LETI Exemplar: The highest performance tier, aligning closely with the rigorous limits of EnerPHit (targeting approximately 15 kWh/(m²a) space heating demand).
2. LETI Best Practice: A rigorous standard serving as the benchmark for a typical deep energy retrofit. It generally targets a space heating demand of around 50 kWh/(m²a)—roughly double the EnerPHit baseline, but still a massive improvement over existing, uninsulated stock.
3. LETI Basic retrofit standard: A newly proposed, low-cost baseline designed for UK mass-market rollout. Rather than a hard absolute physics target, it aims for a 50% reduction in an existing home's heating demand (which often leaves the home operating well above the 50 kWh/(m²a) mark). It achieves this by pairing a "just sufficient" fabric external insulation upgrade with a simplified exposed MVHR system and a right-sized heat pump. This approach seeks to minimise cost and disruption to residents.

The LETI Basic approach is very specific to the British context. It improves the building envelope just enough to allow the home's existing radiators and pipework to be re-used with a lower-temperature air source heat pump. This amounts to a large cost savings for most UK households. It doesn't translate to the New Zealand context as these heating systems are virtually non-existent here.

The approach to external wall insulation assumes the typical British brick construction and deliberately avoids the more complex front facade. Heat pumps are designed to work alongside phase change materials so that they can fit into the space that accommodated the decommissioned fossil-fuelled boiler—again, not a feature of New Zealand homes.

This target strongly focuses on process and delivery improvements via a one-stop-shop model. Retrofit co-ordinators drive the process and the programme describes a goal of seven day turnarounds and high volumes. Pre-retrofit and post-retrofit performance is measured rather than calculated.

It should be noted that relying on a simple metric, such as halving utility bills, is a blunt tool and a fundamentally flawed approach, as discussed in **section 2.2**. Utility bills are easily skewed by occupant behaviour (see sidebar in **section 4.1.2** on the well-documented prebound and rebound effects). A bill reduction target fails to guarantee any actual improvements to the building fabric. Without improving the building envelope, occupant health and comfort are ignored and the risk of mould remains largely unmitigated.

"Good, better, best"

The international retrofit standards described in the sidebar provide a spectrum of performance, but all share the core foundations: improving the building fabric by managing water, air, vapour and thermal control layers and introducing systems upgrades.

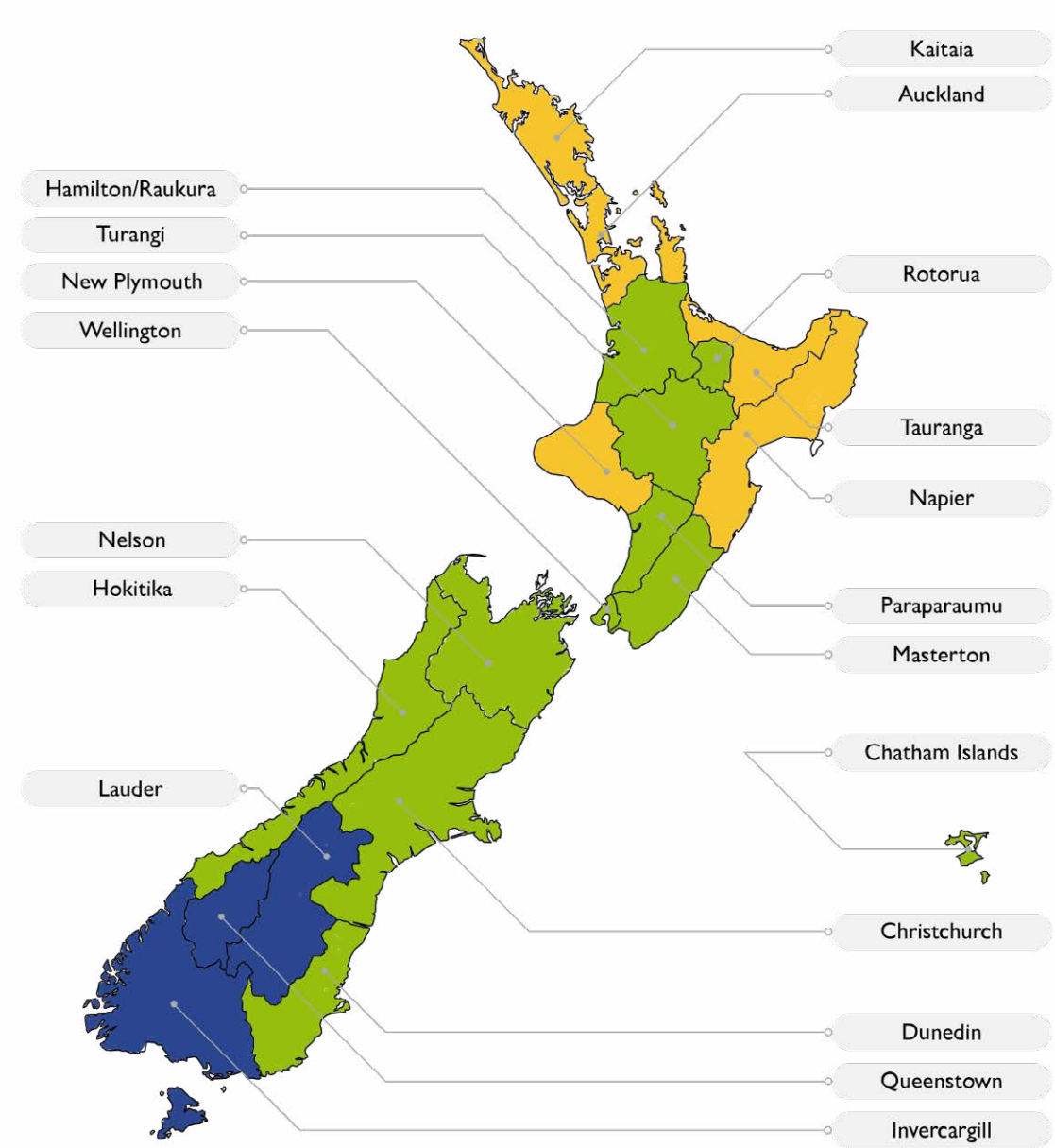
Possible targets for New Zealand deep energy retrofit projects include the following.

Good practice Similar to the LETI Basic retrofit standard, this would deliver significant reduction in heating demand to 30–60 kWh/(m²a), continuous mechanical ventilation, all-electric systems with heat pump space and hot water heating. The challenge is ensuring the improved constructions and details do not suffer from moisture accumulation and related impacts.

Better practice Target EnerPHit component method construction R-values, but with reductions in window performance (double glazing in New Zealand climate zones 1-3) and air-tightness levels (twice that allowed by EnerPHit). Establishes an all-electric household, complete with continuous mechanical ventilation with heat recovery and heat pumps for space and hot water heating. This is similar to the AECB CarbonLite Retrofit standard or LETI Best Practice and offers a pragmatic, stepped approach focusing on significant savings in carbon emissions.

Best practice EnerPHit standard via the energy demand or component method. EnerPHit explicitly sets overall utility energy targets to ensure whole-house efficiency. This overall energy target requires highly efficient mechanical systems for heating, cooling, ventilation and hot water alongside the fabric improvements.

EnerPHit is a flexible standard with provision for practical exemptions that take into account the as-built reality of existing buildings. For example, in concrete slab-on-grade homes, adding floor insulation on top of the slab might reduce ceiling and door heights below practical minimums. EnerPHit allows for insulating just the slab edges, provided this passes the mould risk assessment.



Climate zone	EnerPHit energy demand criteria Max. heating demand	EnerPHit component method criteria (simplified)				
		Exterior insulation	Interior insulation	Window installed	Skylight installed	Min. heat recovery eff.
	kWh/(m²year)	m²K/W	m²K/W	m²K/W	m²K/W	%
Cool-temperate	25	R6.7	R2.9	R1.2	R0.9	75%
Warm-temperate	20	R3.3	R2.0	R1.0	R0.8	75%
Warm	15	R2.0	R1.3	R0.8	R0.7	-

Figure 11: EnerPHit criteria is here shown simplified for the energy demand criteria (based on an overall energy demand model for the home) or the component method criteria where the building assemblies must meet the criteria.[29] For example the R3.3 limit for warm-temperate climate for exterior insulation means that the area weighted R-value for all the building envelope surfaces (roof, walls, etc) must exceed R3.3.

29 The EnerPHit criteria is based on the local climatic conditions which in PHPP and ECCHO are adjusted for building elevation. The climate zones above assume that the buildings are built at the same altitude as the weather station used for that climate zone. This is usually a good assumption but if the site is different to the weather station altitude the criteria might be slightly different.

Predictive energy modelling of various types of New Zealand homes would provide valuable, objective evidence that would help establish consensus on New Zealand-specific targets that find the sweet spot between improvements, outcomes and costs—taking into account unique factors like the high cost of construction and our distance from overseas suppliers.

4.1.4.3 Design to avoid overheating

Overheating primarily happens because of design decisions that don't consider the heating effect of the sun's energy entering the building. Solar gain is double-edged. It's very valuable in winter to have sun penetrate deep into the house; its free warmth can dramatically reduce the heating demand. But in summer, solar gain can quickly trigger overheating. It is widely understood that the pitch and depth of overhangs on the northern face can be designed to both allow winter sun and block summer sun. However, overhangs are not helpful on eastern or western faces due to low sun angles early and late in the day. These require other strategies, such as external shading of various kinds, changing glazing placement and ratios or specifying solar control glazing.

A detailed understanding of heat gains through windows for a specific site is needed, which considers site-specific shading like outbuildings, neighbouring buildings, fences, trees and geographical features. In most retrofits, a skilled designer will be able to use ECCHO or PHPP energy modelling to understand areas of overheating risk. More complex shading situations, such as depicted in Figure 10, will almost certainly require most sophisticated tools such as designPH, or bracket assumptions in shading inputs in PHPP or ECCHO. For the most challenging designs, a dynamic multi-zonal model may be needed to test solutions.[30]

Overheating exemplifies the need for a systematic approach to improving building performance. Increasing insulation levels *protects* a home against overheating. Just as a better-quality chilly bin will keep chilled food cold for longer, so will better insulation help maintain cooler temperatures inside on a hot day. It is effective when working together with an airtight building environment, which prevents conditioned air from leaking out through uncontrolled gaps in the building envelope.

4.1.4.4 Plan for mechanical ventilation

Ventilation cannot be an afterthought. Continuous mechanical ventilation is an essential part of decent homes. It's unrealistic and inadvisable to rely on occupants opening windows for ventilation. For a majority of the year, there is an unwelcome thermal cost to opening windows: warm air escapes in winter, hot air rushes in during summer. People shouldn't have to choose between acceptable indoor air quality and comfortable temperatures or have to wonder whether ventilation levels are adequate.

Windows are also kept closed for a lot of other reasons too; to shut out noise, air pollution or insects or for home security. Yet adequate ventilation is essential for occupant health and building durability even when the windows are closed. Air exchange is needed to keep CO_2 levels at a safe level and to dilute VOCs and particulate pollution created from within the home. In tandem with adequate internal temperatures, ventilation keeps relative humidity at a healthy level. A robust, high-performance home requires a reliable, continuous ventilation system that delivers fresh, clean air.

Best practice is a MVHR (mechanical ventilation with heat recovery) system which delivers these benefits with only minimal impact on heating or cooling demand. While the incoming filtered air and outgoing stale damp air never mingle, heat is exchanged between them so that the incoming air is very close to the temperature inside the house. This reduces heating or cooling costs and ensures there is no perception of draughts, even while air is constantly circulating through the house.

30 For more information, see "Energy modelling: use the right tool for the job".

The roadmap must identify where the mechanical ventilation unit will go and how the ducts will run before any construction drawings are started. In a retrofit, space is at a premium. The roadmap must reserve space for the MVHR unit (ideally within the thermal envelope), if one is being specified, and identify routes for ducting through existing floor or ceiling cavities. Ignoring this in the planning stage often leads to compromised, noisy or inefficient systems installed ad-hoc during construction.

Avoiding these ad-hoc compromises requires creative spatial planning. Unlike new builds, where the structure can be designed to accommodate mechanical services, existing structures often lack the necessary internal cavities for ductwork. When routing through existing floors or ceilings is impossible, designers must establish new pathways without severely impacting headroom or aesthetics. If the design allows for an industrial look, exposed metal ducting works well. For a conventional finish, ducts can be run below the existing ceiling and concealed within custom gypsum board bulkheads or specialist pre-finished duct-in-boxing. Alternatively, dropping the ceiling in a central hallway can create an unobtrusive spine for distributing air to adjacent rooms. Finally, if structural constraints make traditional ducting entirely unfeasible, decentralised or semi-centralised MVHR systems that require little to no ductwork can be specified, as detailed further in the systems section.

Positive pressure ventilation is not the same thing as balanced ventilation. Positive pressure ventilation is not recommended for insulated buildings in heating-dominated climates as they can push moisture into the building assembly. Depending on the state of the ceiling cavity, incoming air is potentially polluted. While a positive pressure system might have reduced condensation in a draughty old villa, it should not be retained after a deep energy retrofit.

Continuous extract ventilation has considerable downsides but is still recommended when a balanced system is unfeasible (extensive detail is provided in 6.1.3). While cost-effective for removing moisture, it creates negative pressure inside the home that draws uncontrolled replacement air from potentially polluted spaces like garages or subfloors. Crucially, this negative pressure can pull dangerous combustion gases back into the living space. Therefore, any existing combustion devices must be removed or made safe before installation.

Clients need to understand how heating and ventilation work together to keep relative humidity levels in a healthy and safe zone and prevent mould. During winter, ventilation brings in fresh outdoor air that has a high relative humidity at outdoor temperatures. This outdoor air is then heated, which reduces its relative humidity so that it can be used to dry the home out. If relative humidity is regularly above 60%, either additional ventilation or additional heating is needed. In humid climates such as Northland, active dehumidification will likely be necessary. There is no particular temperature that controls relative humidity as different climates and homes require different levels of drying. Often building designers assume that the home will be heated to 20°C and don't check that ventilation will be sufficient at lower temperatures. If the home is not heated to at least 20°C then moisture problems can occur.

Independent checks and balances

An advantage of targeting EnerPHit levels of performance is the involvement of an independent accredited Passive House certifier. They review the energy model and architect's drawings before consenting and the start of construction. The certifier reviews all this information to make sure there are no mistakes and to verify the accuracy of the predicted energy use.

Passive House certifiers are very often a frequent and trusted source of advice for architects while they are evaluating different options. They are also called on by builders needing advice on the practicalities of novel construction details.

4.2 Stage 2: Integrated design and specification

STAGE 2: DESIGN (DRAW & DOCUMENT)

This stage turns the high-level retrofit roadmap into a detailed, buildable set of instructions: it's where *what* becomes *how*. Success in this phase hinges on creating clear, unambiguous documents that leave nothing to chance on the construction site.

4.2.1 Developing construction details sequencing and timeline

The quality of a retrofit is determined firstly by selection of durable, low risk building element upgrades and then by careful detailing at their junctions. Clear drawings are required for all critical connections to ensure the continuity of the water, air, vapour and thermal control layers. Ambiguity on paper risks a failure of execution on site. Here's a good low-tech test: can the designer take a red pen to a printed drawing of floor plan and sections and trace an unbroken line that represents the air control layer?

For step-by-step retrofits, this requires thinking ahead. If for instance, the roof is being upgraded now and the walls will be upgraded in five years, the design must detail at least notionally, how the new roof's control layers will connect to the future wall system. Only the current phase of work needs to be fully detailed, but the conceptual plan for future connections must be established from the outset to avoid costly rework or squandered opportunities down the track.

Duty of care: retrofitting and the Building Code

Retrofits must comply with the New Zealand Building Code only to the extent they did when first built. *Treat this as a legal minimum, not a target or a free pass.*

Ideally a retrofitted assembly would meet the requirements of the current Building Code. For example, while the E2/AS1 risk matrix for weathertightness might require ventilated cladding on battens for a new build, a retrofit could replace direct-fix cladding with direct-fix again, even though this is a higher-risk option. A homeowner might choose to accept this additional risk to save money, but it is a professional's duty of care to ensure they fully understand the trade-off and the attendant risks and costs.

Sequencing is critical to avoid adverse consequences. Ventilation must be sufficiently upgraded before or at the same time as airtightness is improved. For instance, replacing the roof often significantly reduces a home's air leakage. Installing adequate, continuous ventilation at the same time avoids the likelihood of trapping more moisture inside the home, leading to rise in indoor relative humidity and increasing the risk of mould. Installing continuous extract ventilation may be the best interim solution, even if a full MVHR system is planned for a later stage.

4.2.2 Specifying materials and products

Any design is only as good as the materials used to build it. The first step is selecting appropriate, durable materials and constructions for each element, using the guidance in Chapter 4. A full, detailed specification list is essential and ensures the correct products are ordered. Contractors must be clearly advised that substitutions are not acceptable without prior authorisation. It is common practice for builders and subtrades to substitute products for reasons of cost, convenience, faster delivery or supplier incentives. What may appear an identical product to an uninformed tradesperson will very likely not share the same performance characteristics and the building performance can be jeopardised. This is particularly important if objective performance standards such as EnerPHit certification are being targeted.

Beware of seemingly magic materials and extraordinary claims: if they sound too good to be true, they almost certainly are. Be deeply sceptical of products that promise to skip critical steps or that wouldn't be consented if used in a new build. For instance, there is no such thing as insulating paint that prevents conductive heat loss. While certain coatings can be very effective at reflecting radiative heat and keeping a roof cool in the sun, they do not stop heat loss in winter.[31]

Occasionally building product and services salespeople can be a source of significant misinformation. Watch out for insulation R-values quoted in imperial units (an American R-30 material is only R-5.3 in metric) or thermal performance data that neglects the real-world aging impacts of foam insulation.

4.2.2.1 Choosing insulation products

There are many types and brands of building insulation available to choose from. They each have advantages and disadvantages and the best choice will depend on the individual project, client values and budget and contractor preferences. There are many factors to take into account, such as carbon emissions intensity/life cycle analysis, ability to repel or absorb moisture, flammability, toxicity, ease of handling during install, its healthfulness or otherwise for occupants post-installation and expected lifespan (and whether its effectiveness degrades over time).

4.3 Stage 3: Quality control during construction

STAGE 3: CONSTRUCTION (BUILD & CHECK)

A deep energy retrofit is a complex undertaking where the final outcome is highly dependent on the quality of the construction. Appointing a dedicated retrofit supervisor is a good idea. This role is crucial for quality assurance, providing specialist oversight to verify that critical details such as airtightness layers and thermal bridge mitigation are installed correctly and to the specified standard. This is not a common role in the New Zealand industry currently.

31 Jason Quinn. (2026). Beyond the hype: do thin insulating coatings actually work? Sustainable Engineering Ltd. February 15 2026.

Retrofit supervisors act much like a traditional clerk of works[32] for the high-performance aspects of the project. They serve as an independent, on-site inspector whose primary mandate is to ensure the physical construction complies exactly with the specialised plans, specifications and building physics principles. They verify quality, document progress and identify defects early, acting as an independent quality-assurance bridge between the client and the contractor.

Because their objective is to protect the building's performance and the client's investment, the retrofit supervisor must be contracted directly by the building owner, not the main contractor. Finding someone with the precise blend of practical construction experience and building science knowledge can be challenging. A professional certified as a PHI Retrofit Expert is ideal, or a local PHI certified Passive House tradesperson. These practitioners have demonstrated their understanding of high-performance construction.

The supervisor's role changes slightly depending on the project's goals. If the home is pursuing formal EnerPHit certification, they compile the rigorous photographic evidence and installation documentation required by the independent Passive House certifier. If the project is uncertified, the supervisory role must shoulder all the responsibility for quality assurance. In such circumstances, homeowners should make sure to specifically detail the supervisor's responsibilities and authority within the main building contract. The main contractor must clearly understand that the supervisor has the authority to inspect and approve critical hold points—such as the completion of airtightness layers and thermal bridge mitigation—before those elements are permanently covered up.

Without expert oversight, there is a significant risk that unfamiliar details will be poorly executed, compromising the home's final performance and the durability of the building fabric.

4.3.1 Hazard mitigation

A professional and safe site is a prerequisite for high-quality work. The first priority is to have licensed professionals safely removal and dispose of any hazardous materials identified in Stage 1, such as asbestos or lead-based paint. Any foil underfloor insulation present should be treated as electrically live. Turn off the power supply before inspecting and during removal.[33]

Hazard mitigation and containment protocols must be significantly more stringent when occupants remain living on-site, given the work area cannot be fully isolated from the living space. This is especially important during the removal of legacy hazards like asbestos and lead-based paint, where any airborne contamination poses a direct and serious risk to the health of the residents. Silica dust (from cutting concrete, fibre cement or plasterboard) and dust and sawdust from cutting treated timber must also be carefully contained.

4.3.2 Critical checkpoints and inspections

The most expensive mistakes to rectify are those that are no longer visible or accessible after project completion. This is why critical checkpoints and inspections should happen before linings or claddings are installed. This is when the quality of crucial control layers can be verified while they are still visible and relatively easy to fix. Start with a visual inspection to check the quality of the insulation install and the continuity of the insulation and the air and vapour control layers.

Best practice would then follow this visual inspection with a diagnostic blower door test. This is scheduled once the designated air control layer is complete but before it is made inaccessible

32 Jason Quinn. (2020). The champions of quality. Sustainable Engineering Ltd. August 15 2020.

33 Ministry of Business, Innovation and Employment Hīkina Whakatutiki. (2016). Ban 2016/001 Ban on the installation or repair of foil insulation in residential buildings with an existing electrical installation. 24 June 2016.

behind wall linings or cladding.[34] The blower door test kit and software enable a qualified operator to pressurise and depressurise the house and measure the rate of uncontrolled air leakage.[35] It's a useful proxy for build quality and also very effective for tracing tiny holes in the air control layers. When the test is in the depressurisation phase leaks can be quickly located with a smoke pen, stick of incense or by simply feeling the air flow with one's hand. Fixing a leak at this stage is usually quick and simple, a case of applying a small piece of specialist tape to seal the hole.

Remember that airtightness is not sought for its own sake. Rather it's a means to an end, delivering energy efficiency and building durability. Airtightness plays an important role in maintaining stable, comfortable indoor temperatures without much active heating or cooling plus prevents moisture entering building assemblies.

Blower door testing is required for projects targeting PHI EnerPHit certification but is valuable on any project focused on superior airtightness and thermal performance. The result is expressed as a unit of air changes per hour at 50 pascals of pressure or ACHn50. EnerPHit requires a result of less than 1.0ACHn50.



Figure 12: A blower door installed during the prelining airtightness test.

34 A *pre-lining test* is used when the air control layer is on the inside of the structure (eg an air and vapour control membrane or taped plywood). A *pre-cladding test* is used when the air control layer is on the outside of the structure (eg a rigid air barrier or taped external sheathing).

35 ATTMA. (2025 (updated)). Registered air tightness testers – New Zealand.

A thermal imaging survey is also highly recommended, ideally in conjunction with the preliminary blower door test. It provides a visual check of the building's thermal performance. It can quickly identify any gaps or defects in the insulation, find hidden air leaks and spot unexpected thermal bridges that would otherwise remain invisible. It is the best way to verify the quality of the thermal control layer.



Figure 13: Pre-retrofit, the thermal imaging reveals uninsulated wall cavities and higher than expected timber fractions. Darker colours show colder areas due to heat loss.

4.4 Stage 4: Commissioning and handover

STAGE 4: HANDOVER (FINISH & EDUCATE)

This final stage answers two simple but critical questions: does the home work as designed and do the occupants know how to use it? Commissioning and handover are fundamental to a successful project. This should be part of the designer's scope of work rather than assuming individual suppliers will adequately brief the occupants.

4.4.1 Verification testing

A final blower door test provides a clear and objective rating of the building's final airtightness. It confirms whether the design target has been met and provides contractual proof that the homeowners have received the performance they paid for. It is highly recommended for any deep energy retrofit that relied on energy modelling at design stage. In usual circumstances, the airtightness improves slightly between the preliminary and final blower door test.

If the project is seeking EnerPHit certification, at project completion the accredited Passive House certifier will carefully review

- documentation gathered by the construction team to confirm the design and specifications have been followed,
- any as-built changes (which were already checked and approved by the architect before being made),
- commissioning statement from the installers of the balanced pressure ventilation system and
- the results of the final blower door test.

4.4.2 Commissioning of mechanical systems

Commissioning is the systematic process of testing and adjusting all mechanical systems to ensure they perform according to the design specifications. For a single-family home, commissioning typically only involves mechanical ventilation systems.

Commissioning is not a case of simply turning a system on to see if it runs. Mechanical ventilation systems need to be tested and balanced to verify they are doing their job.

- MVHR systems: confirm correct supply and extract airflow rates in every room.
- Simpler continuous extract ventilation systems: measure the flow rates at each extract grille to ensure effective removal of moisture from wet areas (bathrooms, kitchen and laundry).

If the project is aiming for PHI certification, commissioning of the ventilation system must be thoroughly planned and documented.[36]

36 Jason Quinn. (2025). Ventilation commissioning basics for certified Passive House buildings. Sustainable Engineering Ltd. October 15 2025.

4.4.3 Homeowner education and documentation

Schedule a thorough walk-through with the homeowners to explain how to use the key systems.

Ventilation

- how to activate boost functions if manually operated (otherwise explain the automatic humidity detector function),
- any relationship between windows and direct extract rangehoods,
- necessary settings on MVHR controller such as summer bypass of heat exchange core and
- the location of filters in the MVHR unit and on extract terminals, how to remove them and how often to check them.

High-performance windows

- tilt-turn functions (two or three way),
- how, why and when to use these different settings and
- any cautions on use in high winds.

Heating and cooling systems

- use of active heating and cooling and
- how to employ passive systems, for example how to night-purge heat in summer, when to keep windows closed).

This is the final opportunity to ensure homeowners' expectations about heating input are realistic.

The designer or project manager should also prepare a clear and concise manual, a practical reference for the occupants that compiles all the essential information about living in a deep energy retrofitted home. This is particularly important if the intended occupants will be short-term paying guests or tenants, who should be assumed to know nothing about high-performance dwellings.

The homeowner's manual should include the following:

- a summary of the design and its performance goals,
- all product warranties and manuals for key components like windows and mechanical systems,
- a clear maintenance schedule, outlining tasks like when and how to clean or change ventilation filters and the recoating schedule for timber windows pre-finished at the factory,
- contact information for the original installers and for service technicians and
- as-built drawings or markups detailing all deviations from the consented documentation.

The Homestar rating tool provides an excellent format for a homeowner's manual. Passive House designers are encouraged to follow its lead. A template is freely available from NZGBC.[37]

37 New Zealand Green Building Council. (2021) Homestar Home User Guide Template_May 2021. May 2021.

5 The building enclosure

This guide is not organised around generic housing typologies because every retrofit project will offer unique opportunities and challenges. There are sure to be surprises along the way. Instead, this chapter details each *building element* in turn, analysing them through the lens of the four essential building control layers that manage movement of water, air, vapour and thermal (energy eg heat). A failure in any one of these control layers can compromise the entire building.

This chapter provides core technical guidance for upgrading a home's building enclosure (also known as the building fabric or envelope). Building systems are discussed in the following chapter.

Any alteration to a building must ensure it continues to comply with all other provisions of the Building Code to at least the same extent as it did before the work (see Section 112 of the Building Act 2004). This obligation must be taken very seriously when making changes to the building enclosure. Adding insulation to improve the performance of the building enclosure is a good idea but it must not be done in a way that compromises weathertightness.

There is currently a lack of understanding in the building industry about the risks involved in retrofitting insulation and how to safely design and install insulation into existing houses.

5.1 Foundations

5.1.1 Suspended timber floors

Goal

Transform this weak link into a warm, dry, airtight and durable floor assembly that is isolated from ground moisture and pests, forming a robust foundation for the rest of the high-performance enclosure.

Challenges

The suspended timber floors seen in many older New Zealand homes are historically prone to a host of problems. Many were built with inadequate subfloor drainage, no effective ground moisture barrier and poor ventilation, creating a damp, musty environment. They are notoriously draughty, a route for cold, damp and potentially unhealthy air to infiltrate the home. Pest incursion into the home is also common. Access for humans is frequently limited, making any upgrade work difficult. Remember to assume existing underfloor foil insulation is electrically live.

If subfloor ventilation openings do not meet the current Building Code, either improve access to meet Code requirements or consider full encapsulation and dehumidification. Expert advice should be sought if considering encapsulation.

Retrofit strategies

The right strategy for any specific project depends on the condition of the existing subfloor, its accessibility and the overall scope of the renovation.

5.1.1.1 Suspended timber floor from above

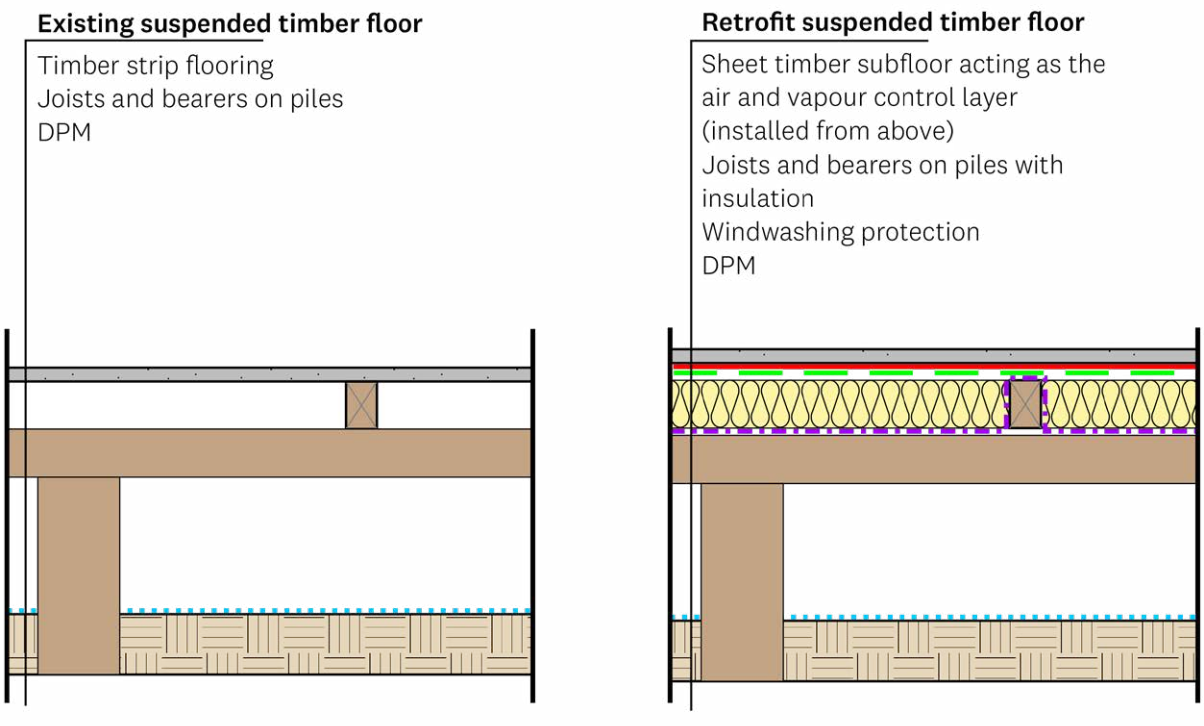


Figure 14: Retrofitting a timber floor from above.

If access from below is poor then insulating from above is often the best (sometimes the only) option. Existing flooring is lifted to gain access to the floor joists and underside of internal walls. Achieving good airtightness is easier with new sheet subflooring, such as plywood or strandboard. Penetrations in timber bottom plates for wiring and plumbing need to be sealed while the flooring is removed.

5.1.1.2 Suspended timber floor from below

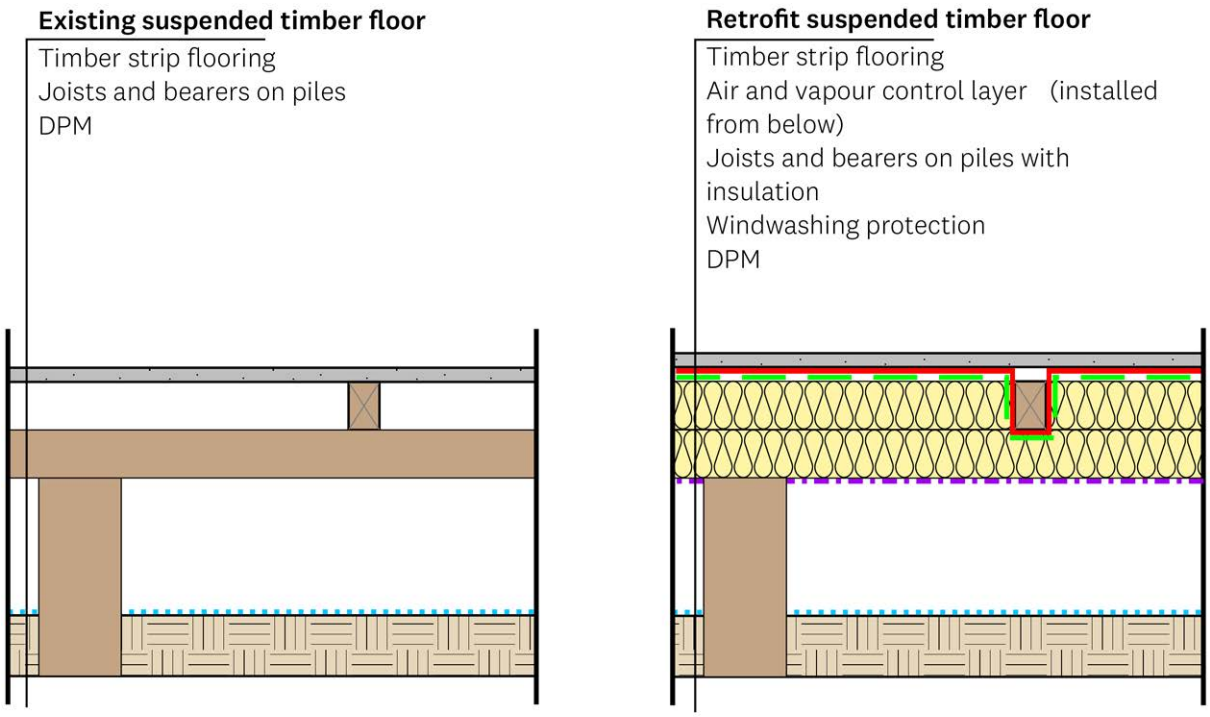


Figure 15: Retrofitting a timber floor from below.

Insulating from below is the most common and least disruptive approach but it requires good access and presents significant challenges for a deep energy retrofit. Achieving a truly continuous and durable air control layer from below the floor is extremely difficult. Options include membranes, spray-on airtightness sealant and spray foam.

In either case, inspect the piles before starting work. Re-piling may be necessary, and the home could potentially be lifted to improve future access at the same time. This is the most robust but also the most invasive and expensive option. It involves lifting the entire house off its foundations to build a new, high-performance subfloor from the ground up. This is often the best choice when the existing piles and bearers are failing or when a major reconfiguration is planned. It also provides an opportunity to use modern foundation systems, such as screw piles or other systems that can be relevelled if needed.

Applying the control layers	From below	From above
Water control	First, identify and remedy any surface water issues caused by site drainage problems or leaking gutters etc. Lay a durable ground vapour barrier or DPC over the entire subfloor ground area, lapping it up any piles and foundation walls. This is the primary defence against ground moisture. Soil that appears dry to the touch can be evaporating a significant amount of moisture into the subfloor area.	
Air and vapour control	Very difficult to achieve when working from below. Liquid spray on membranes may be an option.	A specialist membrane or sheet subflooring (ie plywood or strandboard) that is taped at all seams and penetrations.
Thermal control	The insulation must be cut and fitted snuggly between the floor joists, with no gaps or compression (see the case study for loose blown fibreglass). It must be well-supported (by strapping or using netting or membrane or using a rigid sheet product) to prevent it from sagging over time. If the subfloor is exposed to the elements, for instance when there is no concrete ring foundation, the insulation must also be protected from wind washing.	

Common questions and concerns: what about...

...using only insulating underlay and carpet?

This is a shallow fix but it does provide a thermal benefit that can be felt underfoot. This is a good interim step and its contribution to thermal performance can be considered in the energy model. But the R-value improvement will be small, around R0.5.

...inserting EPS foam insulation from below?

Rigid foam panels can be an effective insulator plus they block draughts, however they are time-consuming to install effectively in a retrofit. Joist spacing in older homes is rarely consistent, requiring every single panel to be custom-cut. Any gaps should be meticulously sealed with expanding foam. Do not specify or install a vapour-impermeable layer (eg a foil-faced product) on the cold (exterior) side of the foam or combine rigid foam and fibre insulation without a full hygrothermal analysis. These combinations can trap moisture in the floor assembly, with an attendant risk of mould and decay.

...new ways to air-seal from below?

New technologies are emerging and the industry continues to hope for new products or solutions that make it easier to airtight floors from below. Spray-on liquid air control membranes are a promising option. While the material cost is higher than sheet membranes, the labour savings can be significant. Another potential solution is a thin layer of closed-cell spray foam (CCSF). However, retrofitting old timber floors makes them liable to move or shrink and there is a risk the foam may crack.

...just putting batts between the joists from below?

This works well from an insulation level point of view, but it doesn't help with airtighting the floor. Improving thermal performance of floors can increase draughts: the timber will slowly dry out and shrink, creating tiny gaps between the floorboards. One solution is to install a top layer of flooring such as cork or marmoleum. Improving airtightness in future would likely require removal of the insulation, as the air control layer is most often fitted on the warm side of the insulation.

5.1.2 Concrete slab-on-ground floors

Goal

Thermally isolate the existing slab from the ground and the cold outdoor air, creating a warm, dry and comfortable floor surface while managing the critical thermal bridge at the slab edge.

Challenges

Older concrete slab-on-ground floors are typically completely uninsulated. They are difficult and expensive to retrofit. Many have a compromised or non-existent damp-proof membrane (DPM), making them a source of moisture in the home as well as a drain on a home's energy balance.

Retrofit strategies

5.1.2.1 Concrete slab-on-grade add edge and wing insulation

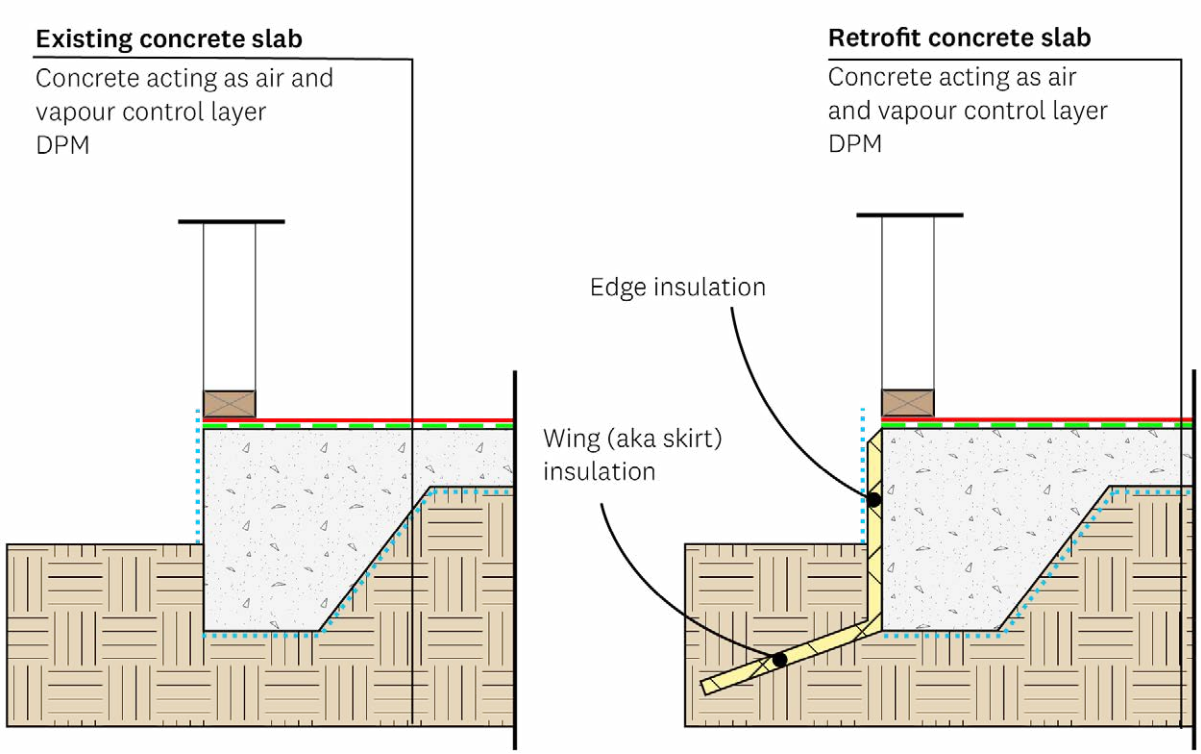


Figure 16: Slab edge and wing insulation.

The majority of heat is lost from the slab perimeter. One option is to excavate around the external perimeter in order to install a vertical layer of rigid insulation to the slab edge. Do not dig underneath the slab, rather line up insulation with the bottom of the slab edge. A wing of insulation extending out from the foundation will further reduce heat loss.

This is much less disruptive internally but exterior paths, property boundaries and landscaping may be significant barriers. Edge insulation is sufficient to meet EnerPHit requirements in the warmer climate zones in New Zealand as well as for larger buildings. Adding 600mm wing insulation can be adequate in all New Zealand climate zones.

5.1.2.2 Concrete slab-on-grade insulate on top of slab

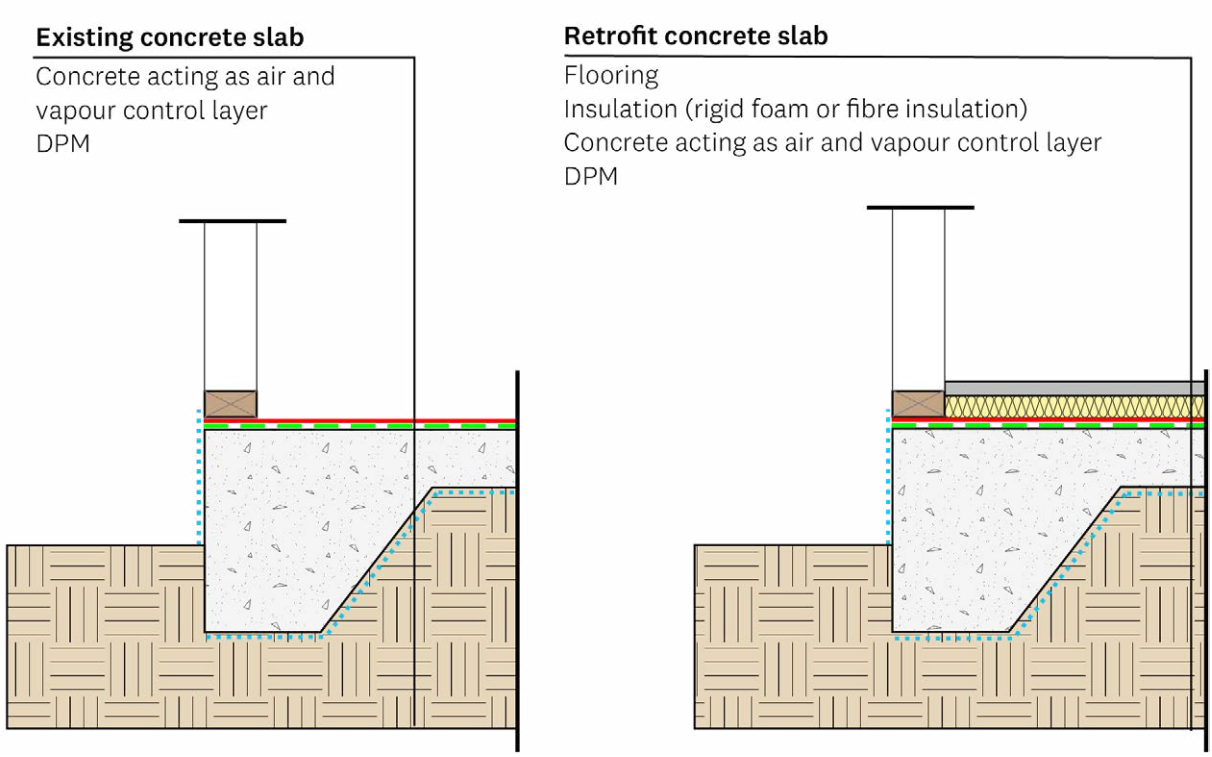


Figure 17: Insulation on top.

Insulating above the slab is the most practical and high-performance approach but is quite involved and typically very expensive unless a complete overhaul is already planned. It typically involves three layers.

1. A new damp-proof membrane or coating on the top of the concrete.
2. Next a continuous layer of insulation directly onto the existing slab. This is typically rigid foam such as XPS or EPS but fibre insulation and timber battens are also an option.
3. New flooring.

It is essential to use a high-compressive-strength rigid insulation designed for this application and to install a solid substrate like plywood or proprietary flooring board over the insulation to provide a stable, durable base for the final floor finish. Several projects have used timber battens to mechanically fix the plywood through the foam insulation to the slab as the design team was concerned about bowing or lifting of the plywood. Other designs have glued or even loosely laid the plywood.

In areas with tile flooring, all existing projects at time of writing have used timber battens to support cement board to ensure a warranty on the tile work could be obtained. Fibre insulation between timber battens has been used in several projects but involve an expert who can assess the moisture risk of this assembly in a specific project.

The major implication to consider with this approach is the resulting increase in finished floor height. This impacts all doors, stairs and joinery and reduces the floor-to-ceiling height.

Applying the control layers	Slab edge and wing insulation	Above slab insulation
Water control	Protection of the insulation from impact and UV by foamed uPVC board, stucco render or other board.	Ensure a dry site and check for a DPC under the slab. If there is not good evidence for one, add an above slab DPC (either coating or membrane).
Air and vapour control	Existing concrete slab remains the air and vapour control layer.	Existing concrete slab remains the air control layer. If using rigid foam this may suffice as the vapour control layer but this should be checked.
Thermal control	Edge (and optionally wing) insulation can significantly reduce heat loss from the slab edge.	Combining slab edge insulation with insulation on top is best practice but is only recommended in colder climates. In general, either edge insulation or insulation on top of the slab is sufficient to meet even EnerPHit requirements.

Common questions and concerns: what about...

...using fibre insulation between battens instead of rigid foam?

This is possible from a thermal and moisture point of view as discussed above. The so-called spilled soup test does however raise valid concerns about this material choice. If liquid is spilled on the floor and soaks down through the flooring and into the insulation, it will be very slow to dry out and there is a risk of unpleasant odours. Fixing it would require lifting the flooring and replacing the insulation. However fibre insulation between battens above the slab has been specified in new builds, including a certified Passive House home, and there have been no issues reported at time of writing.

...if there is no DPM under the slab?

Apply an epoxy sealer directly to the concrete. This will drastically slow the moisture transfer from the slab into the home. Use of a vapour open flooring material is important, in order to prevent mould forming under these layers. Timber flooring is one option, there are also vapour open (aka vapour permeable) carpet underlays.

5.1.3 Timber-framed walls

Upgrading walls is often one of the most complex and expensive parts of a deep retrofit. Unlike a roof or floor, walls are integrated with windows, doors and multiple structural junctions. Older wall assemblies got wet and then readily dried out due to the significant heat loss and air flow moving through them. Adding insulation dramatically reduces this drying potential. Therefore, the design must either perfect the wall's ability to stay dry or significantly increase its ability to dry without that inefficient heat flow.

Goal

Transform the existing wall into an airtight, well-insulated assembly that has a robust and reliable drying potential, ensuring its long-term durability.

Challenges

The typical New Zealand timber-framed wall is under-insulated and possibly not insulated at all. It's a notoriously leaky assembly and often contains hidden moisture issues from decades of minor flashing leaks. In worst cases, window flashings may be non-existent. Timber-framed walls are the riskiest to retrofit with insulation, as doing it wrong can lead to moisture build-up that causes structural decay and even failure.

Retrofit strategies

The key decision is whether to work from the outside in or the inside out. Note that while it's permissible to not upgrade to a drainage cavity cladding system if one didn't exist prior (see Section 112 of the Building Act 2004), it is strongly advisable to complete the E2/AS1 Risk Matrix.[38] If the result is not low risk, then a drained cavity should be installed.

An external reclad is often the most cost-effective method to insulate timber-framed walls *if* the cladding is in poor condition and needs replacing anyway. The process is straightforward. Strip off the external cladding, clean the timber frame, insulate the stud cavities, add building wrap (and flashings) to the exterior side and then replace the cladding on battens to provide a ventilated cavity. One very successful deep retrofit project took this approach but added external insulation and then also reinstated the original cladding (see 7.1 Deep energy retrofit of a timber bungalow).

38 The E2/AS1 Risk Matrix, a component of the New Zealand Building Code, is a method for assessing a building's weathertightness risk. It calculates a risk score based on specific design and environmental factors, such as the wind zone rating, building height, eave width and overall design complexity. The final score dictates the required wall cladding installation method. A score of 6 or less is considered low-risk, permitting the cladding to be direct-fixed. Conversely, a score of 7 or more signifies a higher risk, which mandates the use of a drained and ventilated cavity behind the cladding to manage moisture.

5.1.3.1 Timber framed wall external insulation over weatherboards

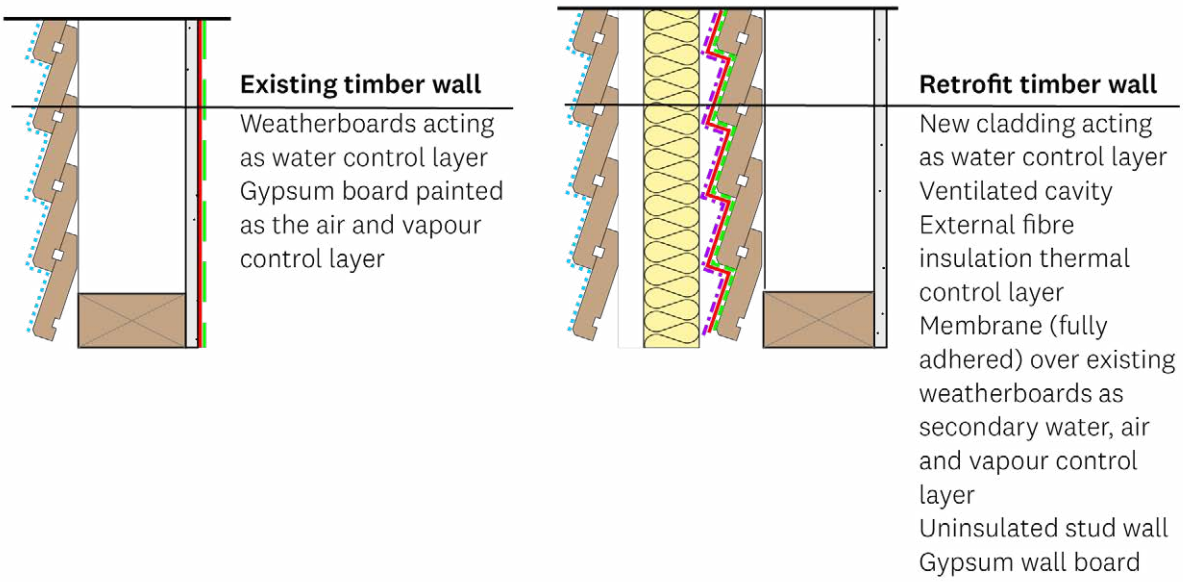


Figure 18: External fibre insulation added (without removing original cladding).

External insulation is the preferred, most robust, and lowest-risk approach, but it usually requires re-cladding and replacing the windows at the same time. The approach shown below (Figure 23) is a proprietary New Zealand system that applies the insulation over the top of the existing cladding. This limits disruption and makes it possible for occupants to continue living in the house during construction works.

A continuous layer of insulation is added to the exterior of the timber frame along with new air and water control layers. This keeps the entire existing timber structure warm and dry and protected within the new thermal envelope, effectively creating a new, high-performance wall. The existing stud cavities can be left uninsulated or filled with additional insulation, depending on the climate and performance targets.

There are several local companies that are actively promoting these solutions for external insulation retrofits but at time of writing they are still reasonably uncommon and building councils should be consulted early. Note that there are New Zealand retrofit projects that successfully used wood fibre sheets or SIPs as external insulation (see 5.1). A supplier's guide has more technical detail.[39]

39 Nuralite. (2021). A Designer's Guide: Outsulation for High-Performance Walls V2. December 2021.



Figure 19: A proprietary external wall insulation system including air vapour control layer over the existing timber cladding, external rockwool insulation and batten clips. The next step is installing battens and new ventilated cladding. Credit Parka Wrap.

5.1.3.2 Timber framed wall external insulation remove old cladding

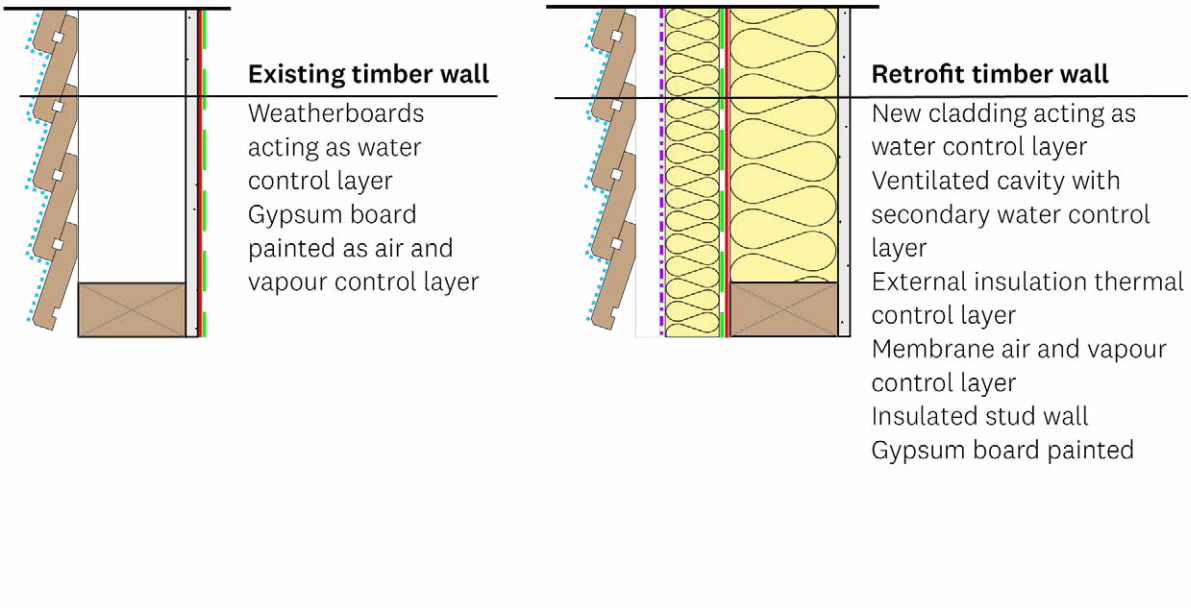


Figure 20: External wall insulation with full reclad.

The timber stud cavities can potentially be insulated with fibre insulation. This hybrid wall insulation is usually safe from mould if the R-value of the fibre insulation is less than the R-value of the external rigid insulation but a hygrothermal model is recommended. This ratio of internal fibre to external insulation is dependent on climate, internal building conditions and the types of insulation. For example, the R-value of fibre insulation can be higher if the external insulation is vapour permeable. See the first case study in Chapter 7 for a specific example.

An **internal retrofit** is more disruptive for occupants but can be a valid approach when re-cladding is not desirable. There are two main internal strategies.

5.1.3.3 Timber framed wall insulate between studs with new drainage cavity

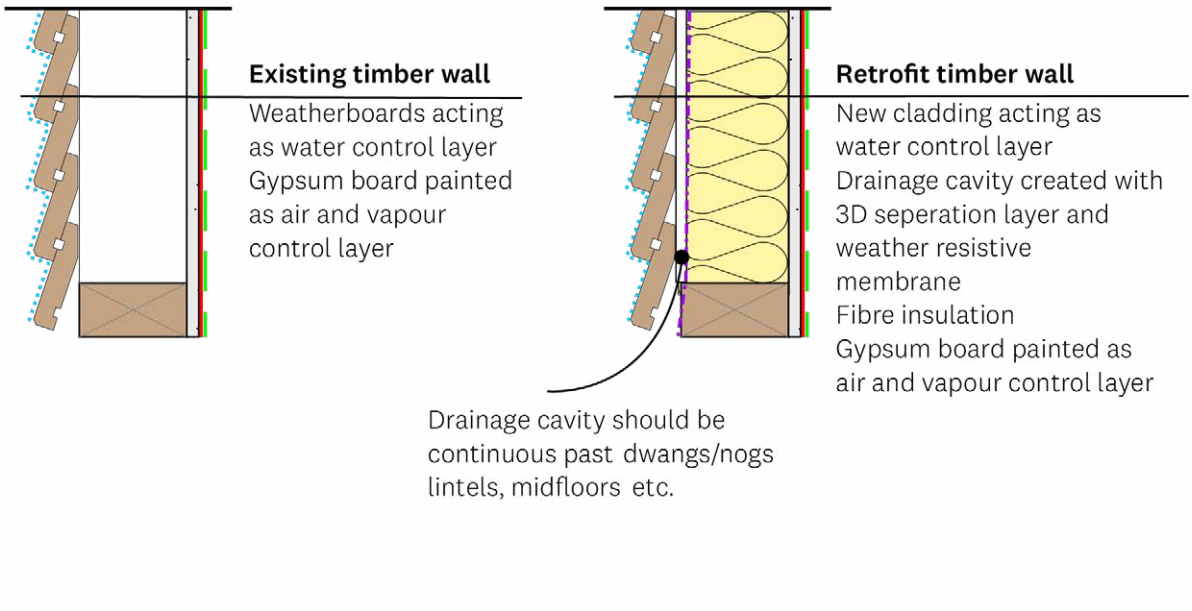


Figure 21: Retrofitting internal insulation to a timber-framed wall.

Retrofitting a wall with an **internal drainage plane** involves removing the interior linings to install a drainage underlay with 3D separation layer against the backside of the cladding to create a small, drained cavity. This is a complex and slightly risky approach, especially in walls with dwangs: any water managed by the membrane should be carefully drained out of the bottom of the wall to prevent it accumulating onto the bottom plate and intermediate dwangs. This approach is recommended in BRANZ *Assessing retrofitted external wall insulation techniques*.[40] [41]

Older homes may still have sarking in the walls, which must be removed to provide access to the wall cavities. Plasterboard bracing would likely be used to replace sarking, which would in turn require the introduction of dwangs to conform to the supplier's bracing calculations. This means most or all of the existing dwangs and braces could be removed. This is beneficial because it allows for the drainage underlay with a 3D separation layer to be installed continuously and potentially redirected out of the wall at the floor level.

40 Assessing retrofitted external wall insulation techniques, BRANZ Research Now: Warmer drier healthier 7 | September 2023
41 Ian Cox-Smith et al. (2023). SR484 Assessing retrofitted external wall insulation techniques BRANZ. August 1 2023.

5.1.3.4 Timber framed wall insulate to interior of existing studs

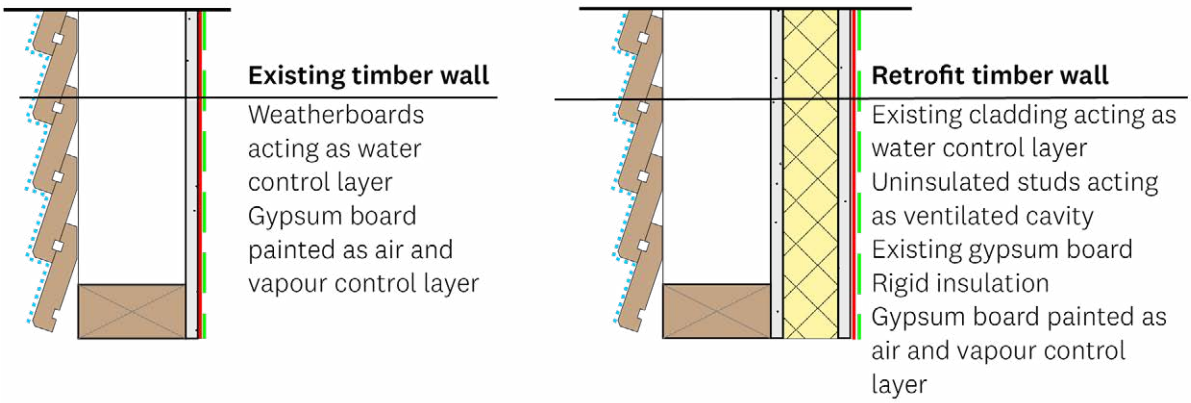


Figure 22: Retrofitting internal insulation via a secondary internal wall.

In the case of a **secondary internal wall,** a new non-structural wall is built on the inside of the existing wall, either creating a service cavity that can be filled with rigid or batt insulation or using a specialist insulated plasterboard (plasterboard glued to rigid phenolic insulation is one example). The existing stud cavities are left empty to allow them to ventilate and dry. Insulated plasterboard reduces the internal floor area as little as possible. Rigid thermoset phenolic insulation provides an overall R1.8 (50mm—including plasterboard) or R3.7 (90mm).

Applying the control layers	External	Internal
Water control	A new, continuous water-resistive barrier (WRB) is installed outside the new insulation layer.	The performance relies on the existing, often inadequate, water control of the original cladding and wrap (if any) but the wall ventilation capacity is maintained somewhat. The drying potential will still be reduced as less energy will flow through the wall. This may impact the cladding lifespan.

Air and vapour control	A dedicated air control layer is installed on the outside of the existing sheathing, providing a continuous seal. This also acts as the vapour control layer.	A new air control layer should be installed (often this is gypsum plasterboard and paint). Its location depends on the type of insulation specified. Vapour control can be provided by the insulation or a membrane or sheet product.
Thermal control	A continuous layer of exterior insulation is the most effective way to eliminate thermal bridging through the timber studs. Note that most councils are requiring PS1 for fastening through the insulation with brackets and battens etc. Discuss early with your structural engineer to identify the best approach. The most cost-effective option is often 50mm screws through timber battens into the studs.[42]	Either insulation between the studs (ensure timber fraction is accounted for) or continuous internal insulation.

Common questions and concerns: what about...

... installing insulation into stud cavities without building wrap?

A missing building wrap is often accompanied by a lack of or deficient window flashings. Either/both create a high risk of minor leaks and trapped moisture. Installing a drainage membrane from the inside before fitting insulation is not ideal but reasonably low risk.

The author has consulted on several projects where the homes had no flashings. There was clear evidence that the inside of the weatherboards was being soaked in every rainstorm. The owners were advised to not insulate these external walls by installing fibreglass batts into the wall cavities. They could have installed an insulated wall to the inside of the timber studs (retaining the existing timber stud wall function as a ventilated and drained cavity) or replaced the poorly installed cladding and retrofitted from the outside.

... blowing insulation into the wall cavity?

This approach adds risk and this needs to be carefully assessed prior (see 4.1.2.1). Timber weatherboards are designed to get wet and then drain and dry. Filling the cavity eliminates any drainage path and presses the insulation directly against the damp timber. Even if there is an existing building wrap, the process of blowing in the insulation often involves drilling holes that compromise this layer. In timber-clad walls, blown cavity-fill insulation is considered high risk and not recommended unless a drainage cavity behind the cladding is installed or is already present, existing wall underlay is in nearly new condition, or rain is substantially diverted from the wall, e.g. through eaves as deep as they are tall. Even with these mitigating factors the increased moisture risk needs to be considered and installation quality well controlled.

42 Jason Quinn. (2022). Assessing the thermal impact of conductive fasteners. Sustainable Engineering Ltd. May 15 2022

5.1.4 Ventilated brick over timber

Goal

Increase the insulation and airtightness of the timber-framed structure while ensuring the wall stays dry.

Challenges

A brick veneer's drained and ventilated cavity is a critical part of the wall's water management system. The primary challenge with retrofitting brick veneer walls is to improve the thermal performance of the inner timber frame without compromising this drainage and ventilation function. It is very common for the original building wrap (the secondary water control layer) to be missing or damaged.

Retrofit strategies

Three options for retrofit are discussed: insulate like a modern new building, add a secondary internal insulation keeping the ventilated wall voids and blow fibre insulation through the entire brick and timber frame cavity. This third option is risky.

5.1.4.1 Brick veneer wall add wall underlay and insulate between studs

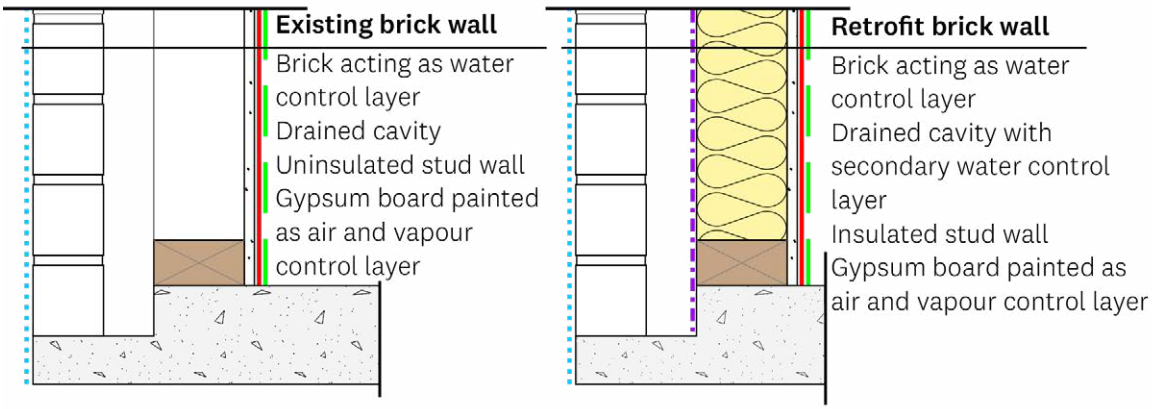


Figure 23: Installing of insulation into the timber frame cavity of a brick veneer wall.

Insulating the timber frame cavity involves carefully filling the stud cavities of the inner timber frame with insulation from the inside, which means removal of interior linings. This strategy can be very labour intensive because of the brick ties, especially if installing a new wall underlay (the secondary water control layer). The cavity behind the brick cladding must be left completely open. Make sure that the new secondary water control layer laps into the brick set-down to ensure water drains out of the wall and doesn't focus on the sill plate. Replacing this layer is very difficult and time consuming.

5.1.4.2 Brick veneer wall insulate to interior of existing studs

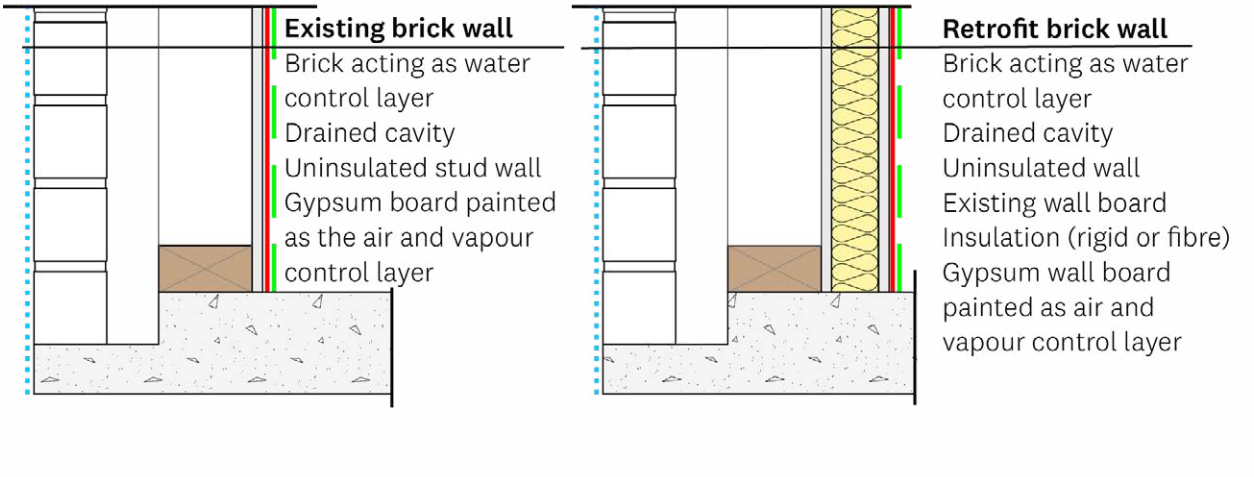


Figure 24: Installing of insulation inside of the original uninsulated brick veneer wall. This maintains the drainage and ventilation drying of the original assembly.

With a **secondary internal wall**, a new layer of insulation is added to the inside of the existing wall linings, typically as a secondary wall. The existing timber frame cavity is left uninsulated to maximise its drying potential. See the above section on timber walls for details on designing and constructing secondary internal walls.

5.1.4.3 Brick veneer wall blown fibreglass filling drained cavity

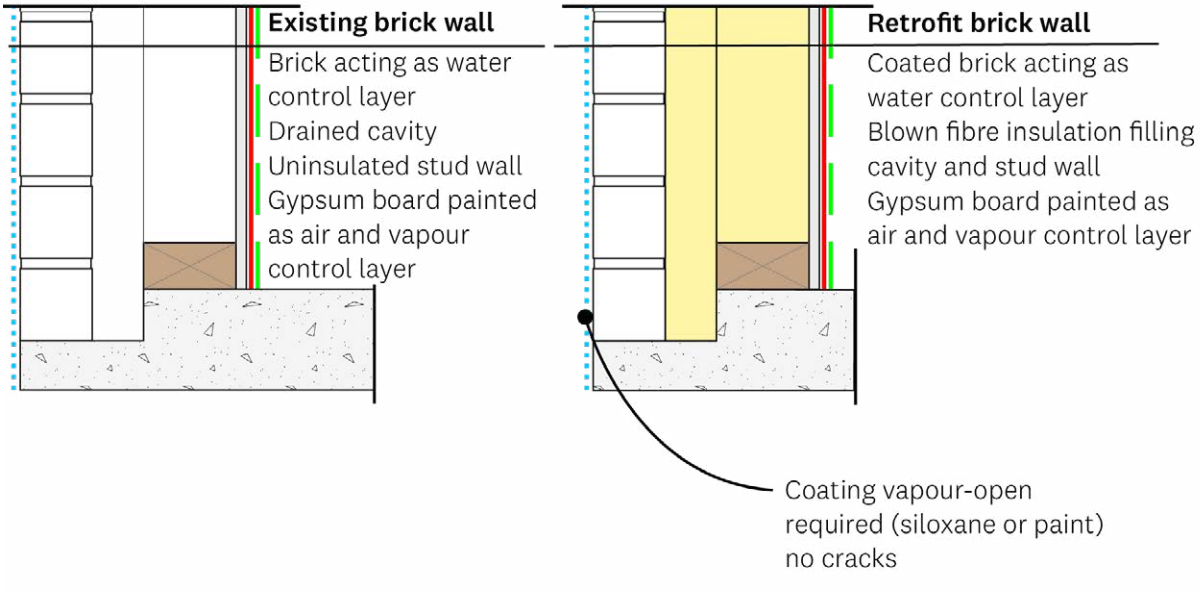


Figure 25: Higher risk. Full cavity-fill fibreglass insulation blown into the timber stud and brick cavity.

Adding **blown-in fibre insulation** (via holes made in the brick cladding) is less risky compared to timber-clad homes as the brick can handle being wet. However, concerns remain about water transfer across the insulation to the timber framing and the ability of the timber studs to dry out. This approach is higher risk as it completely removes the ventilation and drainage of the original wall assembly.

If external water penetrates the retrofitted wall, there is very little potential remaining for that moisture to dry out. Full blown cavity-fill solutions are inherently higher risk and generally not recommended. They should only be considered where building suitability and moisture risk, have been assessed, the proposed system is appropriate for the application, and suitable installation and quality controls are in place. While there are systems in New Zealand that are CodeMarked, that alone is not a guarantee. Success rests on the quality of the install.

Reducing risk to a reasonable level requires coating the brick to prevent water adsorption, almost no external water leaks into the wall, vapour control on the interior of the building and control of the home's internal relative humidity. See case study 7.3.

Applying the control layers	Insulated cavity	Secondary wall	Filled cavity
Water Control	The water control function is left to the existing brick veneer and its empty cavity		Making certain that the brick is coated to prevent water adsorption while still being vapour open is critical, plus careful maintenance to prevent any external water leaks is required. Clear coatings are available (typically Siloxane-based) but all coatings require maintenance.
Air and Vapour Control	A new or improved air and vapour control layer should be installed on the interior		A hygrothermal model (eg WUFI) should be completed for the specific building and ventilation design to ensure adequate vapour control
Thermal Control	Insulate as shown		

Do no harm: lessons from UK cavity fill failures

Cavity wall insulation installed as part of a government retrofit scheme in Scotland has been blamed for homes filled with black mould.[43] The installer has gone into liquidation, while the industry body that guaranteed the work tried to shift blame to occupants. Some homeowners have been forced to live with rampant black mould for a decade.

The report suggests the insulation stopped the building from "breathing"— an attempt to use non-technical language but it lacks precision. There are two likely failure modes. First is external moisture. If insulation is pumped into a cavity without inspecting the outer brick wall, rain can penetrate cracked brickwork, bridge across the sodden insulation and soak the internal wall.

The second mode of failure is reduced ventilation. Retrofit failures are often wrongly attributed solely to the insulation. When a cavity is insulated, airtightness is often inadvertently increased. If ventilation is not simultaneously upgraded—for example an open fire is replaced with central heating without adding continuous mechanical ventilation—internal moisture is trapped. High relative humidity is a breeding ground for mould.

In contrast, cavity wall insulation has been successfully installed for decades in Germany. There the process is carefully managed and includes a proper assessment of the outer wall, an endoscopic inspection of the cavity to check for debris and ties and filling under infrared supervision to ensure completeness. It is not the technology that is inherently flawed, but the process by which it is assessed and installed.

5.1.5 Concrete block or tilt slab or solid brick

Goal

Create a well-insulated, moisture-managed wall assembly.

Challenges

Solid masonry walls have excellent thermal mass but are very poor insulators. They are often unreinforced and often absorb water from the ground and driving rain which must be managed in a retrofit.

Retrofit strategies

There are two approaches outlined: work from the outside or the inside.

43 Jason Quinn. (2023). Retrofitting wall insulation is not risk-free. Sustainable Engineering Ltd. June 20 2023.

5.1.5.1 Masonry or concrete wall external insulation

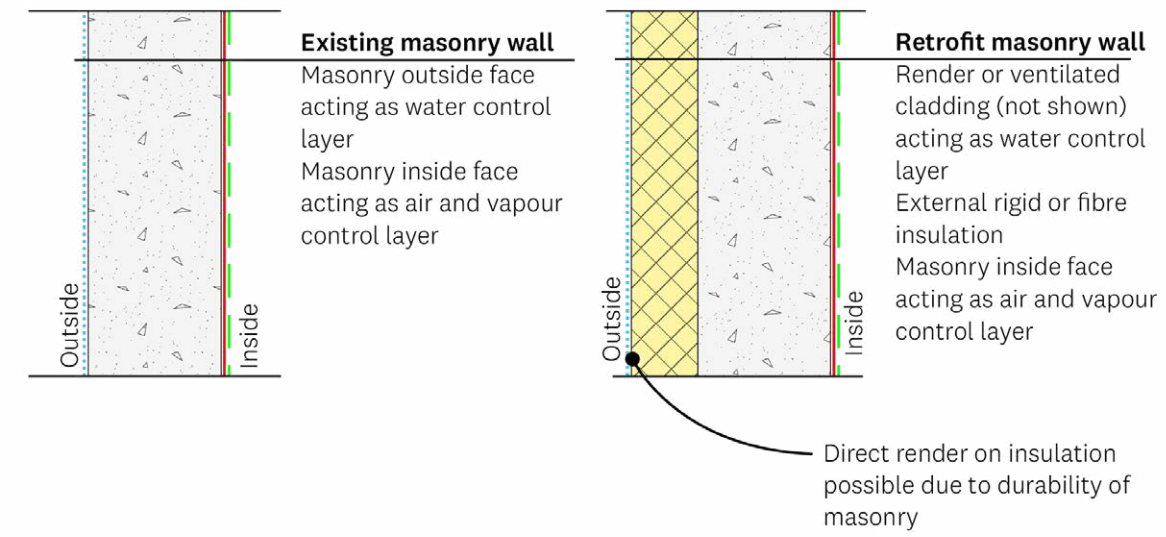


Figure 26: External insulation of masonry or concrete wall. Building exterior is depicted on the left.

External insulation is the most durable and effective approach. A continuous layer of insulation is fixed to the exterior of the masonry, which is then covered with either a new render directly on the insulation or a ventilated cavity cladding system. This keeps the structural mass warm and dry and fully within the building's thermal envelope where it can help moderate internal temperatures. Ideally the external insulation would be vapour open (eg mineral wool) but rigid foam insulations work well in this case also. See 7.2 for an example of a successful retrofit of a concrete block house.

5.1.5.2 Masonry or concrete wall internal insulation

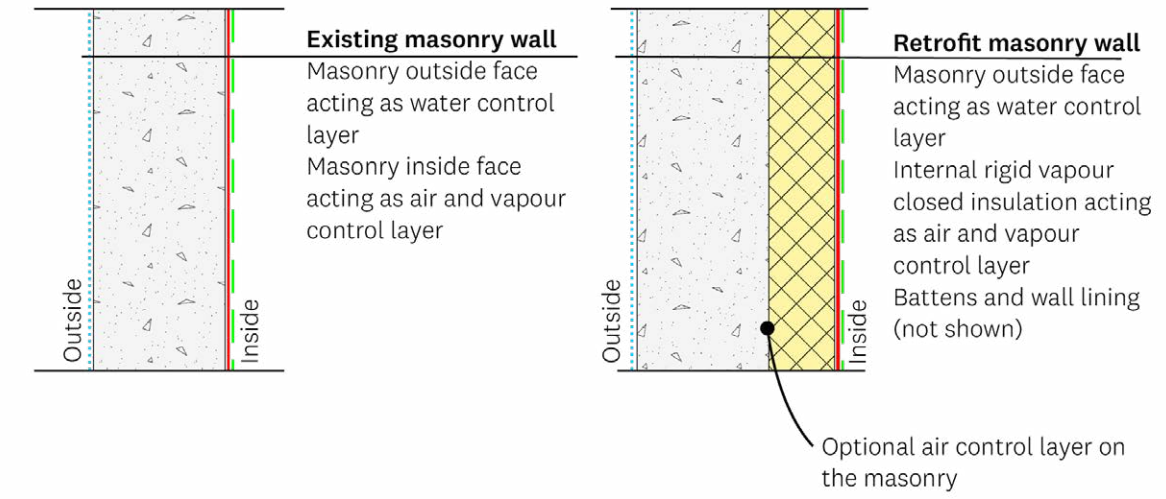


Figure 27: Higher risk option. Internal insulation of masonry or concrete wall. Building exterior is depicted on the left.

The **internal insulation** strategy leaves the structural masonry cold and exposed to the elements. It is essential that the internal insulation controls moisture flow to prevent condensing on the cold surface of the masonry. To achieve this, the internal vapour control layer must be more resistant to moisture vapour flow than the coated masonry or concrete. Any thermal bridges, such as concrete midfloors, will significantly undermine the performance of this approach.

Applying the control layers	External	Internal
Water and vapour control	The render or cladding system acts as the water control layer. The external wall needs to be coated with a vapour-open paint to prevent water absorption. There will be water leaks into the block wall. Small leaks are usually managed well by the masonry (unlike a timber-framed wall).	The new interior layer needs to be more vapour-tight than the external masonry. A rigid foam product is typically specified but other options could be considered as long as appropriate moisture analysis is carried out. Meeting the criteria in the international standard on moisture control design analysis is recommended in all cases (ASHRAE 160:2021).
Air control	Either repair original external render as air control layer or add liquid, membrane or internal plaster on the blockwork for air control.	Air control via liquid, membrane or internal plaster on the blockwork for air control.
Thermal control	A continuous layer of exterior insulation is the most effective.	Thermal bridging, especially at midfloors and internal masonry walls can significantly impact performance.

Common questions and concerns: what about...

...using fibre insulation on the inside?

In general, using vapour-open fibre insulation on the inside of a solid masonry wall will not meet the ASHRAE 160:2001 standard. It is possible with a smart vapour retarder layer and vapour open masonry finishes.[44]

5.1.6 Retaining walls to conditioned spaces

Goal

A completely waterproof, warm and dry living space behind the retaining wall. This goal is absolute and non-negotiable: failure will mean a damp, mouldy and unusable area.

44 Jason Quinn (2026). Hygrothermal simulation: Understanding WUFI modelling and ASHRAE 160 criteria. Sustainable Engineering Ltd. April 15 2026.

Challenges

Retaining walls that form part of a home's conditioned space are in constant contact with the ground and can be subject to significant hydrostatic pressure (the pressure of groundwater pushing against the wall). This creates a high risk of bulk water leakage and persistent vapour issues. Existing drainage systems on older homes may be failing or non-existent. Additionally, the retaining wall cannot let moisture flow through the wall and needs to dry to the interior.

Retrofit strategies

There are three main options: working from the exterior or the interior of the assembly or draining to the exterior and insulating the interior. Getting drainage right is the absolute priority.

5.1.6.1 Retaining wall external insulation

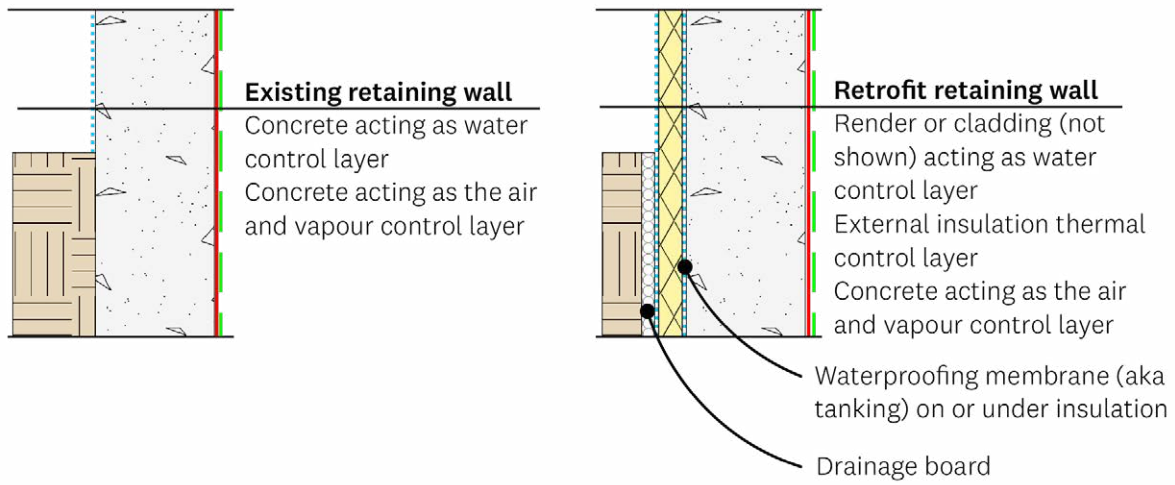


Figure 28: Exterior waterproofing and insulation of a retaining wall. Building exterior is depicted on the left.

Exterior waterproofing and insulation of a retaining wall is the preferred method, being safest and most robust. It involves excavating along the retaining wall to install a new, robust waterproofing membrane, a drainage mat, and a continuous layer of exterior insulation. While it is the most disruptive and expensive approach, it is also the most likely to succeed. There have been trials overseas with hydro excavation techniques but they are not well known in New Zealand.

5.1.6.2 Retaining wall internal insulation with internal drainage to outside of building

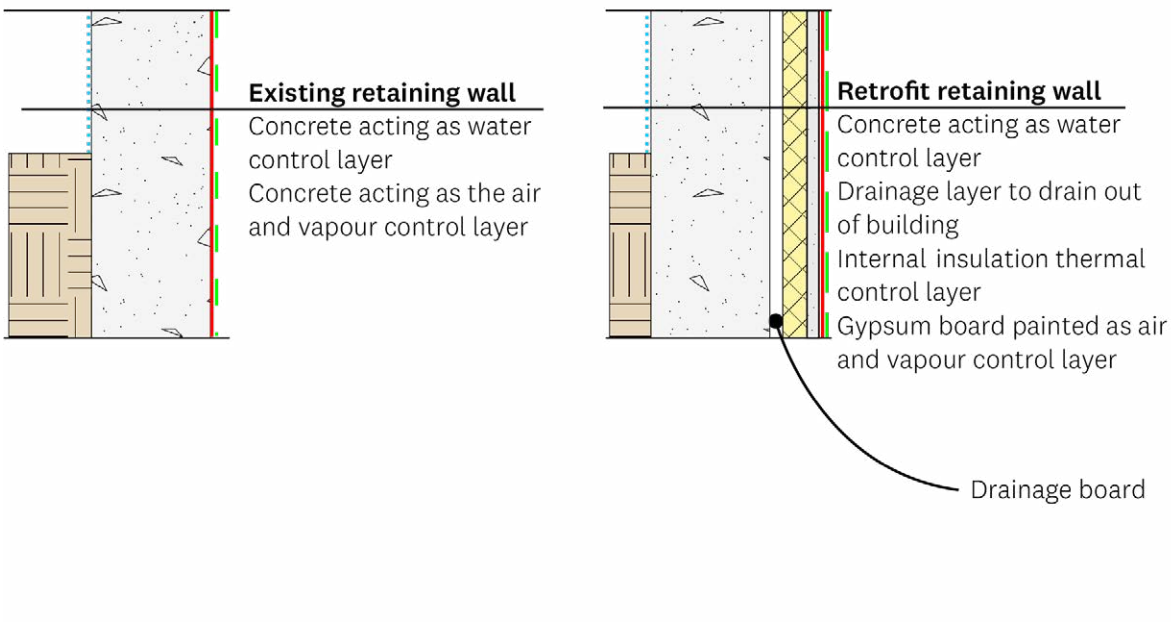


Figure 29: High risk option. Internal drainage and internal insulation of a retaining wall. Building exterior is depicted on the left.

Use of **internal drainage and internal insulation** is a higher-risk strategy that should only be considered when excavation is not practical. It requires an internal drainage system to manage any water that leaks through the wall, combined with a continuous internal air and vapour control layer. This prevents warm, moist indoor air from reaching the cold structural wall and potentially causing mould and/or condensation. The insulation needs to be durable—usually rigid foam insulation is specified. There is a high risk that mould will be present in the drainage layer and this needs to be sealed from the habitable space in the building's interior.

5.1.6.3 Retaining wall internal insulation with external drainage layer

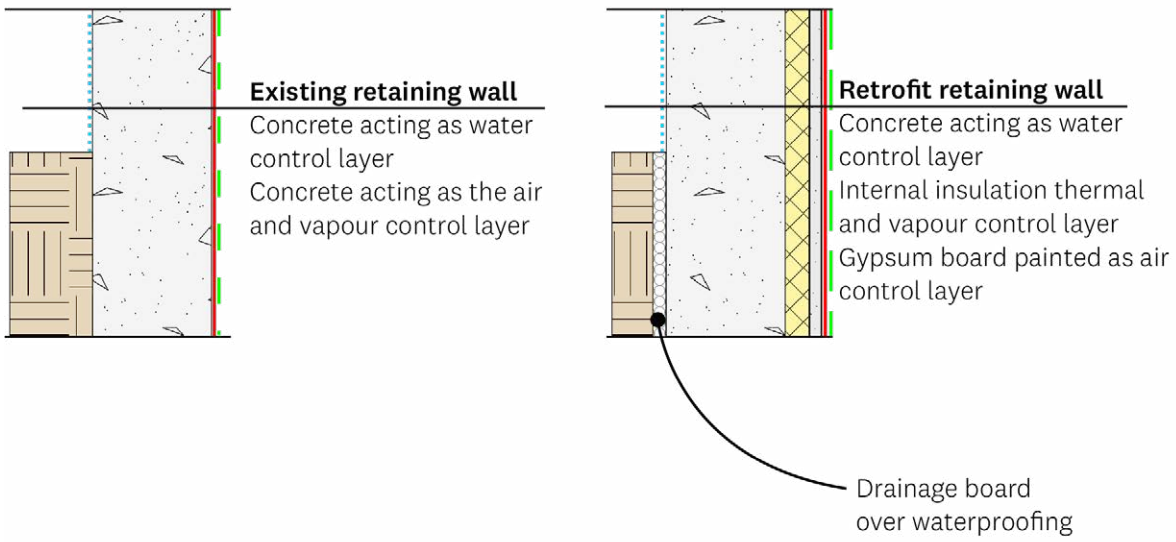


Figure 30: High risk option. External drainage and internal insulation of a retaining wall. Building exterior is depicted on the left.

As a third alternative, if the existing drainage is in good condition, then it is possible to **continuously insulate on the interior of the wall** with EPS, XPS or foil-faced PIR insulation. Best practice is to cover the wall continuously and seal the bottom and top of the insulation to the concrete, tape the seams between insulation boards and then batten over and through the rigid insulation. These materials do not let moisture move through them very quickly. The concrete is now isolated from the warm interior of the house so relative humidity is reduced along with the risk of mould forming.

Using fibre insulation on the interior of a concrete retaining wall is very high risk and not recommended due to the high potential for mould on the cold side of the fibre insulation. Even the use of EPS, XPS or foil-faced PIR insulation can be high risk as leaks or diffusion through these materials can cause moisture issues.

Applying the control layers	External	Internal
Water control	A primary waterproofing membrane and a secondary drainage mat is essential even with the normal perimeter drainage approach	Where there is any potential for external water entry, use a dimple drain mat to create a drainage path to daylight or a sump pump
Air and vapour control	Usually the concrete is the air and vapour control layer.	The air and vapour control layer is to the inside of the insulation to stop any interior moisture from reaching the cold masonry
Thermal control	Vapour-open insulation like mineral wool or more vapour-closed rigid foam can be used	Vapour-closed insulation like closed-cell spray foam, EPS, PIR or XPS is often required to act as the combined thermal, air, and vapour control layer

Do No Harm: Managing Below-Grade Water Pressure

The biggest mistake with a below-grade retaining wall is blocking its ability to drain. Simply painting a supposedly waterproof coating on the inside of a leaky block wall will almost certainly fail. Hydrostatic pressure will push the water through, causing the coating to blister and peel. Worse, by blocking the path of least resistance, water can be forced to find new, more destructive paths. The water must be managed with drainage, not just blocked.

5.2 Roofs

The roof provides the primary defence against the weather and in most homes it is responsible for the greatest amount of heat loss. Roof retrofits can be broadly divided into three categories. Each option presents a unique set of challenges and requires a different strategic approach.

5.2.1 Timber truss roof insulation at ceiling (vented attic space)

Goal

Create a clear, continuous thermal and airtight boundary at the ceiling line, completely separating the warm, conditioned living space below from the cold, well-ventilated attic space above.

Challenges

The typical New Zealand attic looks like an afterthought. It often has patchy, compressed, or contaminated insulation that is performing far below its intended R-value. Ventilation paths at the eaves are frequently blocked and the ceiling plane riddled with air leaks from downlights, hatches and unsealed penetrations. This allows warm, moist air from the house to leak into the cold attic space. Unless it is ventilated away, this can condense on the underside of the roof and framing, leading to mould and decay.

Retrofit strategies

The strategy for a ventilated roof is straightforward: airtight the ceiling first, then insulate.

5.2.1.1 Truss roof

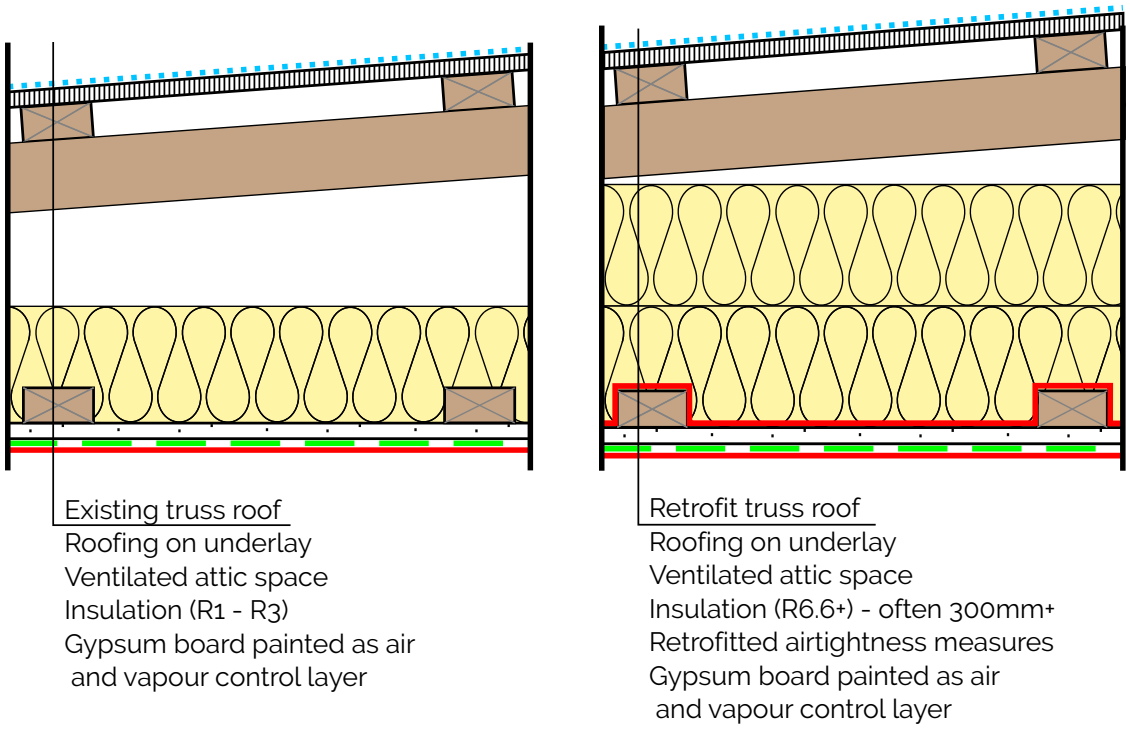


Figure 31: Truss roof with additional insulation and air sealing measures applied.

The most critical step is airtighting the ceiling plane. All recessed downlights must be replaced with modern, airtight, IC-rated LED units. The attic hatch must be sealed with gaskets and latches. All penetrations for pipes, ducts, and wiring must be meticulously sealed to the ceiling air and vapour control layer (often gypsum board) or lining with appropriate tapes or sealants. This includes penetrations in top plates for wiring etc.

Ensure underlay and ventilation. Some older homes have no roofing underlay. Fitting a new underlay is a significant undertaking but acts as a crucial moisture buffer, safely absorbing condensation until it can dry out. It's essential to ensure there is a clear 25 mm gap between the top of the insulation and the underlay, and that ventilation paths from the soffit vents to the ridge are unobstructed. Although uncommon, internal air leaks or external air moisture can overwhelm the moisture buffering capacity of the underlay.

Once the ceiling is airtight, a thick, continuous layer of insulation can be added. Loose-fill insulation is often used overseas as it naturally fills all gaps around framing, but New Zealand typically uses batts. These perform well if well-fitted.

Applying the control layers	External
Water control	This is the primary roofing and the underlay.
Air control	A dedicated airtight layer at the ceiling line. This can be a new membrane or a meticulously sealed gypsum board ceiling.
Vapour control	The airtight layer also acts as the vapour control layer. For a plasterboard ceiling, the paint provides the vapour control.
Thermal control	A thick, continuous layer of insulation installed on top of and directly in contact with the air and vapour control layer.

Common questions and concerns: what about...

...ducted heat pump systems in the attic?

If the roof space needs to contain services like ductwork or is used for storage, it is far better to bring it inside the thermal envelope. This means moving the insulation from the ceiling plane to the roof plane (see unventilated assemblies below), creating a conditioned attic space. Running ducts in a cold, unconditioned attic is unfortunately very common practice, despite being extremely inefficient. This is not recommended.

5.2.2 Timber skillion roof (conditioned attic)

Goal

The goal is to create a fully insulated, airtight roof assembly with a guaranteed, unobstructed 25 mm ventilation channel directly beneath the roofing underlay.

Challenges

With a skillion roof, the ceiling follows the line of the roof. It has been a common construction in New Zealand homes since the 1970s. Unlike a truss roof with a large attic, the space for insulation and ventilation is tightly constrained between the rafters. The primary challenge is installing sufficient insulation and ensuring a clear, continuous ventilation path is maintained above it. Any blockage in this ventilation channel can trap moisture, leading to condensation and decay. Furthermore, the ceiling plane is often leaky, allowing warm, moist interior air to get into the insulated cavity.

Retrofit strategies

Similar to a truss roof, the strategy for a ventilated skillion roof is straightforward: airtight the ceiling first, then insulate while maintaining ventilation.

5.2.2.1 Skillion roof retrofit from above

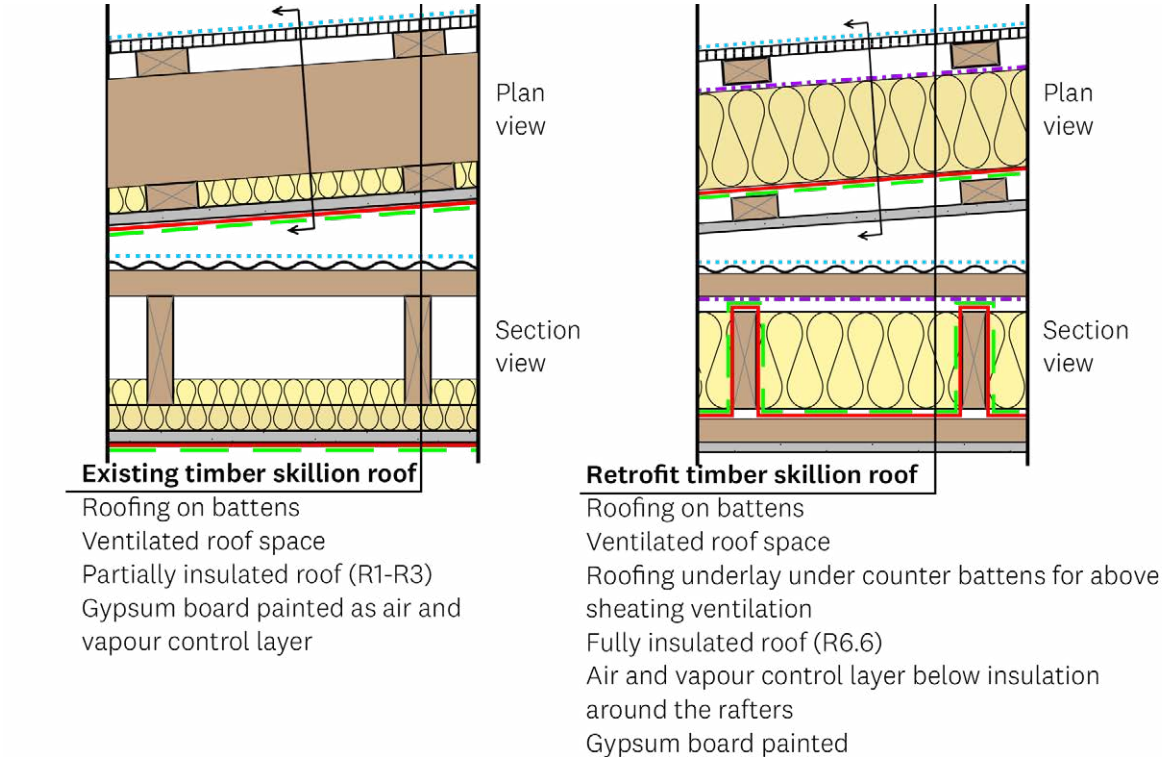


Figure 32: Skillion roof retrofitted by removing the roofing, retrofitting an air control layer (typically a membrane) and then insulating. The left image shows a plan view (top) and a section view of the existing roof (bottom). The right images depict the retrofitted roof in plan view (top) and section view (bottom).

Retrofitting from above is the most reliable method, usually done during a re-roof. This provides open access to the rafter cavities to airtight the existing ceiling lining from above and install new, well-fitted insulation.

One option is to maintain a gap between the insulation and the underlay, which must be ventilated; this is a typical E2/AS1approach and requires ventilation of the cavity between the underlay and the insulation. Alternatively, change to above-sheathing ventilation as illustrated above, where the ventilation gap is maintained above the underlay. Usually rigid sheathing is added above the rafters, which is why this is called above-sheathing ventilation. However, this term is also used where there is only underlay above the insulation and might better be called above-underlay ventilation. Using the option for above-sheathing ventilation requires improved airtightness and is usually part of a CodeMarked insulation and airtightness system.

Use a specialised membrane system to create a robust, continuous air and vapour control layer over the top of the rafters and down to the ceiling before the insulation is installed.



Figure 33: Retrofitting a low pitch skillion roof from above. Photos Pro Clima NZ.

5.2.2.2 Skillion roof retrofit from below

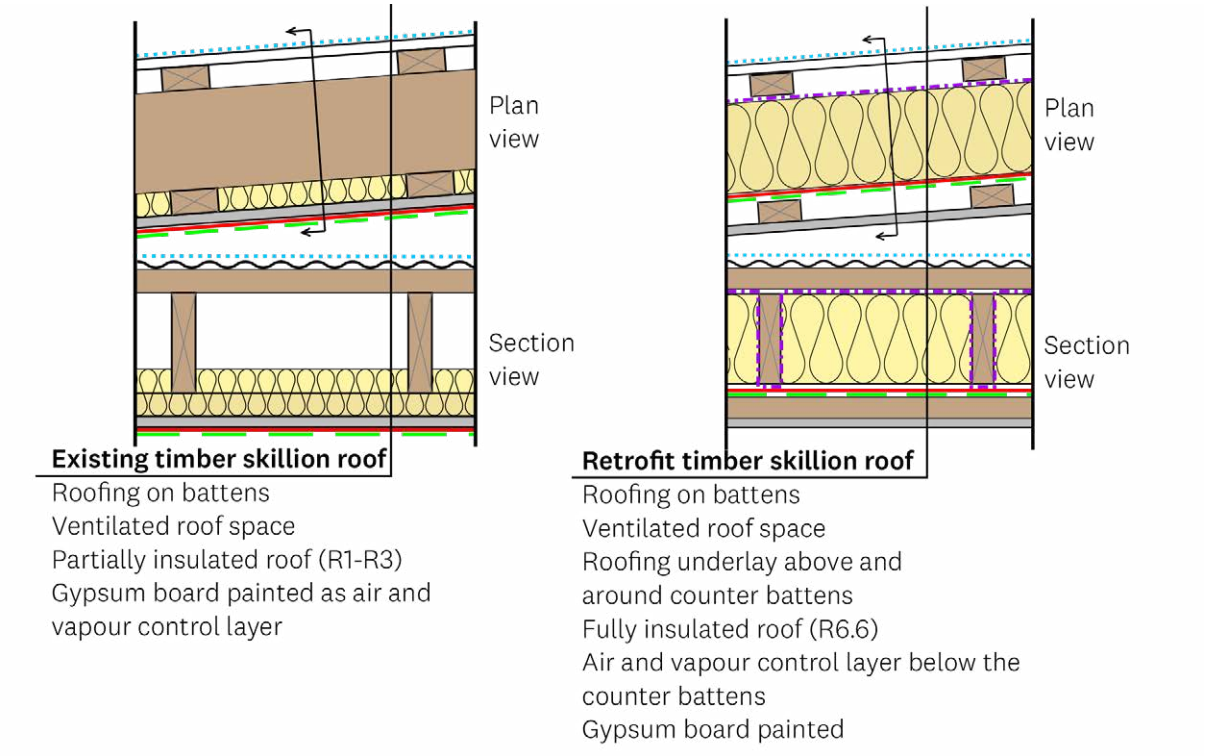


Figure 34: Skillion roof retrofitted from below. The left image shows a plan view (top) and a section view of the existing roof (bottom). The right images depict the retrofitted roof in plan view (top) and section view (bottom).

Retrofitting from below is a more disruptive option but still viable. The existing ceiling lining is removed to give access to the rafter cavities. New roofing underlay (or anther vapour open system) is installed in order to maintain the ventilation gap to the underside of the roofing required by E2/AS1. Insulation is fitted between the rafters below the underlay followed by a new continuous air and vapour control layer. A service cavity for services is established then finally the new ceiling lining is installed.

Applying the control layers	External
Water control	The primary roofing and the underlay. If no underlay exists, it must be installed.
Air control	A continuous and meticulously sealed air control layer is critical. All recessed downlights must be replaced with airtight, IC-rated units, unless the units are shallow enough to only protrude into the service cavity and the air control layer is above the service cavity. In this case it doesn't matter if these leak as they are below the air and vapour control layer.
Vapour control	The airtight layer also acts as the vapour control layer. For a plasterboard ceiling, the paint provides the vapour control.

Thermal control	Insulation must be fitted tightly between the rafters but a 25mm ventilation gap must be maintained between the top of the insulation and the bottom on the underlay as per E2/AS1. Otherwise, an Alternative Solution must be used. Baffles are very likely required at the eaves to ensure the airway remains clear.

Common questions and concerns: what about ...?

...stuffing the rafter cavity completely full of insulation for a higher R-value?

Do not do this. The 25 mm ventilated air gap is non-negotiable. It is the primary mechanism that allows the roof assembly to dry out. Filling the cavity completely creates a compact, unventilated roof, which is an extremely high-risk assembly that requires a different and far more robust design approach (see warm roofs below).

5.2.3 Over-rafter insulation (external insulation, conditioned attic)

Goal

Create a super-insulated thermal-bridge-free roof assembly by placing a continuous layer of insulation over the top of the entire roof structure.

Challenges

The primary challenge of an over-rafter approach is logistical: it requires a full re-roof and careful detailing.

Retrofit strategies

A warm roof is a good option if the roofing material is in poor condition and needs replacement anyway; or in the case of a cold climate and/or project performance goals that cannot be met by the above strategies. (Even in a well-insulated skillion roof, the rafters themselves create thermal bridges that reduce overall performance. Furthermore, the existing rafter depth is often insufficient to achieve the high R-values required for a deep retrofit.)

The strategy is to create a warm vented roof on a pitched structure. This involves removing the existing roofing and underlay to expose the structural deck or rafters and then rebuilding as follows.

1. Install a new, continuous and robust air and vapour control layer over the entire roof structure.
2. Install a continuous layer of rigid insulation (such as rigid foam, wood fibre or structural insulated panel) over the air and vapour control layer.
3. Install a counter-batten system over the insulation to create a ventilation cavity.
4. Install a new roofing underlay and the new roofing on top of the battens.

This approach keeps the entire timber structure warm and protected inside the thermal envelope and completely eliminates the thermal bridging effect of the rafters.

5.2.3.1 Skillion roof retrofit with external insulation and between rafter insulation

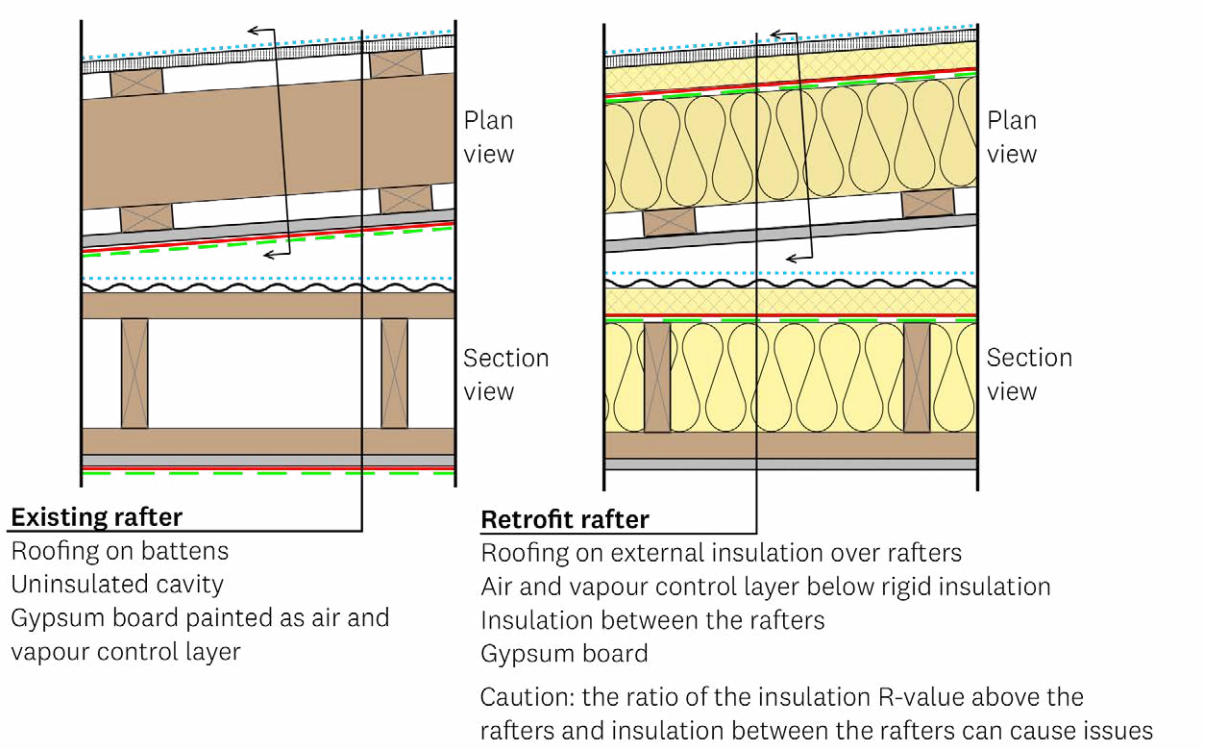


Figure 35: Higher risk option. Continuous external insulation over the existing rafters. The left image shows a plan view (top) and a section view of the existing roof (bottom). The right images depict the retrofitted roof in plan view (top) and section view (bottom).

Insulate between the rafters with an external air control layer and insulation. Ventilation above the rigid insulation is required for vapour open insulation and recommended for all types of insulation. The key is sufficient airtightness below the external insulation to control convective moisture movement. Rigid external insulation products can cause issues with moisture movement by diffusion through the fibre insulation between the rafters and high relative humidity under the external insulation. This depends on the R-values, moisture load in the building and the vapour permeability of the layers. A hygrothermal model is recommended.

5.2.3.2 Skillion roof retrofit with external insulation above rafters

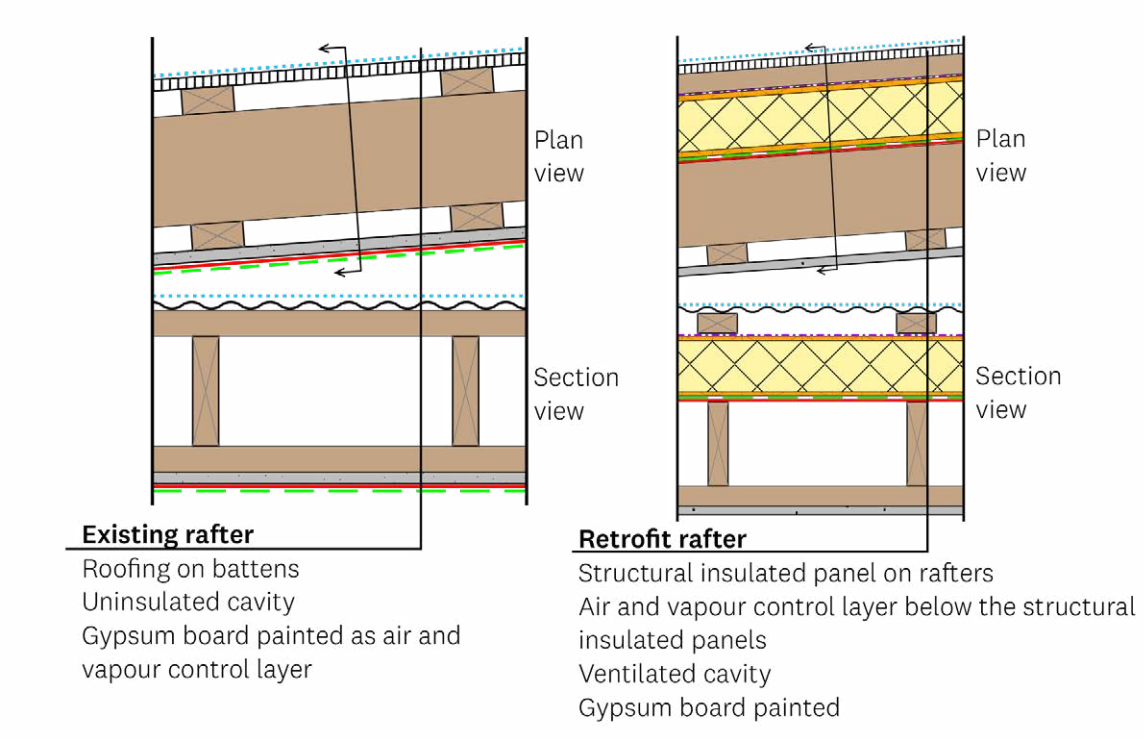


Figure 36: Continuous structurally insulated panel (SIP) over the existing rafters. Ventilation above the rigid insulation is recommended. The left image shows a plan view (top) and a section view of the existing roof (bottom). The right images depict the retrofitted roof in plan view (top) and section view (bottom).

Insulated over the rafters. Another option is to remove the purlins and then add a structurally insulated panel (SIP) on top of the rafters. Check with your structural engineer that this additional load is acceptable for the specific structure.

Applying the control layers	External
Water control	The new primary roofing and underlay, installed on battens over the insulation.
Air and vapour control	The continuous air and vapour control layer installed on top of the structural deck, beneath the insulation. This layer is of critical importance.
Thermal control	The continuous layer of over-rafter insulation and/or insulation between the rafters. The ratio of the insulation between the rafters and the external insulation is important and a function of the vapour permeability of the layers. In general, if the R-value of the external insulation is more than half of the total R-value of the roof any insulation material choice is suitable. If more vapour permeable external insulation (eg wood fibre) is specified, a larger fraction of the total insulation can be specified to the inside.

Common questions and concerns: what about...

...the extra thickness and weight?

An over-rafter insulation system will raise the height of the roof, which requires careful detailing at the eaves, verges, and any roof penetrations. Setbacks and recession planes must be considered where necessary. The additional weight of the system must also be checked by a structural engineer to ensure the existing structure can support it.

Do no harm: Lessons from UK spray foam failures in ceiling

The widespread retrofitting of spray foam insulation in roofs has led to a significant and ongoing crisis in the UK. Homeowners are discovering that the presence of spray foam makes their properties difficult or impossible to mortgage or sell. The issue is so prevalent, affecting an estimated 250,000 homes, that the Royal Institution of Chartered Surveyors has issued specific consumer guidance warning of the risks. What went wrong and what can New Zealand design and build professionals learn from it?

Closed-cell spray foam (CCSF) is not very vapour permeable. It can trap external moisture leaks when sprayed directly onto the underside of roof sheathing and timbers if there is no ventilation above the CCSF allowing the roof to dry out. A drying pathway and ventilation above the CCSF is required. A minor roof leak that would previously have dripped harmlessly into the attic (or drips into the home, causes visible damage and is repaired) is now likely to become trapped between the CCSF and the timber. Because the foam also completely hides the structure from view, this trapped moisture can lead to advanced rot and decay that goes completely unnoticed until it becomes an expensive structural failure.

It's important to note that spray foam is a chemical product manufactured on-site. Its final properties and performance depend entirely on the skill of the installer, the correct mixing of chemicals, the ambient temperature and humidity and the application thickness. When installed well, it can provide good R-values and airtightness. When installed poorly, the results can be disastrous.

5.2.4 Membrane roofs - ventilated cold roofs and warm roofs

Goal

Create an exceptionally durable, completely waterproof and moisture-safe roof assembly.

Challenges

Membrane roofs, common on low-slope or flat-roofed buildings, are extremely unforgiving. Compared to pitched roofs, they have very little drying potential. There are two main types: older cold roofs, where a vented cavity exists between the insulation and the roof deck, and modern warm roofs, which are unventilated, compact assemblies. Retrofitting older cold membrane roofs is exceptionally high-risk.

Retrofit strategies

Cold roofs should be converted to a warm roof. (An inverted roof is another version of a warm roof that can work the same way but is relatively uncommon in New Zealand.) This is the best option because of the risks involved in attempting to retrofit a cold roof. That option is illustrated below in order to explain why it is a high-risk option and not recommended.

5.2.4.1 Membrane cold roof converted to warm roof

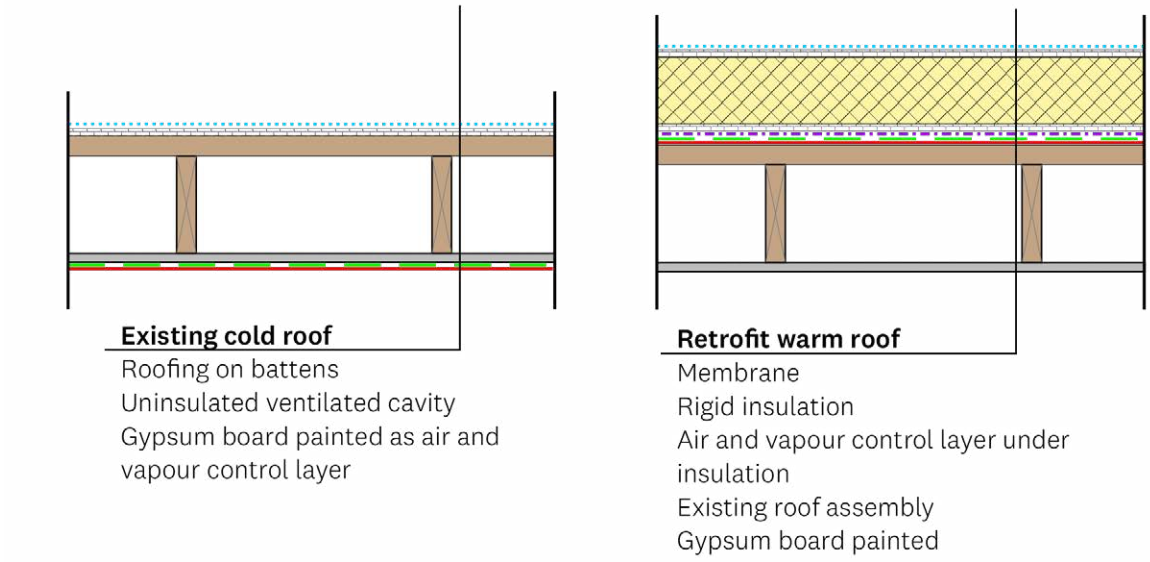


Figure 37: Classic warm roof system over existing structure.

This robust strategy involves removing (or repairing) the old membrane to install a new, continuous air and vapour control layer over the structure, followed by a thick layer of rigid insulation and then a new membrane on top.

5.2.4.2 Membrane cold roof insulated and ventilated

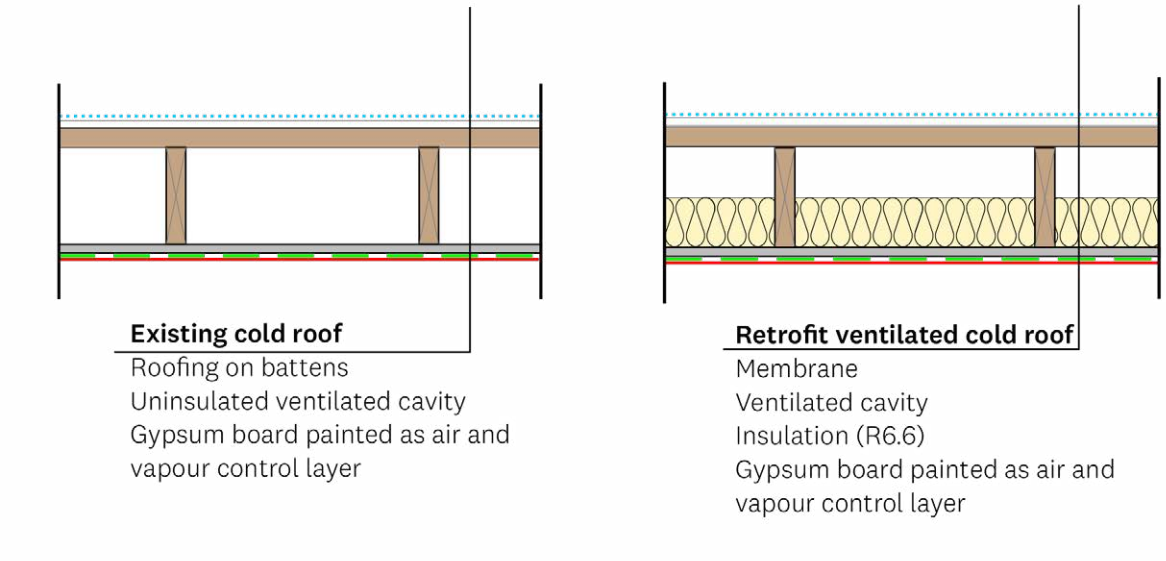


Figure 38: Higher risk option. Insulation fitted under existing cold timber membrane roof.

Attempting to improve a cold timber membrane roof requires two improvements, each of which is hard to achieve. First, a ventilation gap must be maintained above the insulation across the entire roof deck and it must actually be ventilated. This ventilation is difficult to achieve in the limited space and is made even more difficult with parapets and gutters. Ventilating every portion of the roof in order to manage internal air and vapour leaks is difficult even with new construction. This option is high risk and generally not recommended. Second, an air and vapour control layer must be installed below the insulation. This is difficult to airtight because of penetrations and the space required for ventilation.

Unfortunately, even with an adequately ventilated roof, mould may still appear in the roof cavity because of the effect of night sky cooling and exterior ventilation air.

Applying the control layers	External
Water control	The final exterior waterproofing membrane, which must be flawlessly installed. A system capable of detecting leaks is strongly recommended. This can be as simple as a conductive foil tape connecting all the foil-faced insulation panels in the roof and a wire that runs out to an accessible access point on the roof. A specialist contractor can then use electricity to detect any leaks. Ensure builders and other contractors stay off the roof unless a trafficable roof deck has been installed to protect the membrane.
Air and vapour control	This is the most critical layer. In a warm roof, it is the air and vapour control layer installed on the warm side of the insulation, directly on top of the structural deck. A full vapour barrier (eg a foil-backed layer) is often required so that no moisture migrates from the building into the insulation layer.
Thermal control	A continuous layer of rigid insulation with high compressive strength, suitable for a roof application.

Common questions and concerns: What about ...

...just adding insulation under an existing membrane roof?

Do not consider this approach as the risk of trapping moisture is very high. New Zealand experience shows mould will often occur even when attempts are made to maintain or create ventilation in these old assemblies. Converting to a proper warm roof during a scheduled re-roof is a reliable, low-risk solution.[45]

5.3 Windows, skylights and doors: specification and installation

Many components or assemblies are improved in a retrofit, but glazed doors and windows are usually replaced. This provides an excellent opportunity to jump to the best available components. They are a big-ticket item but the additional cost between the new minimum Building Code standard and units with much better thermal performance is not large.

45 Jason Quinn. (2019). Adding insulation: Not always good. Sustainable Engineering Ltd. Jun 15 2019.

Keep in mind that upgrading windows isn't just about saving money by improving thermal performance and therefore energy efficiency. It also improves people's comfort and allows for fuller use of indoor space. Occupants can sit right next to a window on a cold winter's evening and not feel draughts or chills.

Select appropriate performance window, door and skylight units that are suited to the specific climate and orientation and correctly and durably integrated into the four control layers of the surrounding wall or roof. Triple-glazing is often the most cost-effective choice for homes south of Auckland.

Solar control—preventing overheating—should be addressed at early design stages (see 4.1.4.3) and appropriate glazing specified. Reducing solar gain through glass selection is a balancing act, as it reduces free winter heating as well as protecting against summer overheating.

5.3.1 Windows

Goal

Specify windows with the most appropriate thermal performance for the specific location and client requirements, using energy modelling to understand the trade-offs between winter solar gain and preventing summer overheating. Ensure the install details will integrate neatly with future upgrades if relevant.

Challenges

Older windows are the thermal holes in a home's fabric. Typically single-glazed with highly conductive aluminium frames and no air seals, they are a primary source of heat loss, uncomfortable drafts and condensation. Even new windows that meet the minimum requirements of the New Zealand Building Code can have cold frames and edges that lead to condensation and persistent surface mould. Furthermore, even the most expensive, high-performance window unit can have similar issues if they are installed poorly, creating new pathways for air and water to leak into the wall.

Retrofit strategies

Full replacement involves completely removing the old window unit, including the frame and any subframe, preparing the rough opening and installing a completely new, high-performance unit with modern flashing and air-sealing systems. This is the most robust approach and offers the best long-term performance and durability. This is also best done when the wall cladding is being replaced as flashings are hard to retrofit without at least some cladding and trim removal and often these items cannot be reused.

Insert windows involves installing a new, self-contained window unit within the existing timber frame of the old window. It is significantly less disruptive to the interior and exterior linings and can be more cost-effective. However, it relies on the old frame being in good condition or at least reparable. Some insert systems are European-style windows that can be relocated into the middle of the wall assembly during a future re-clad, making them an excellent choice for a step-by-step retrofit.

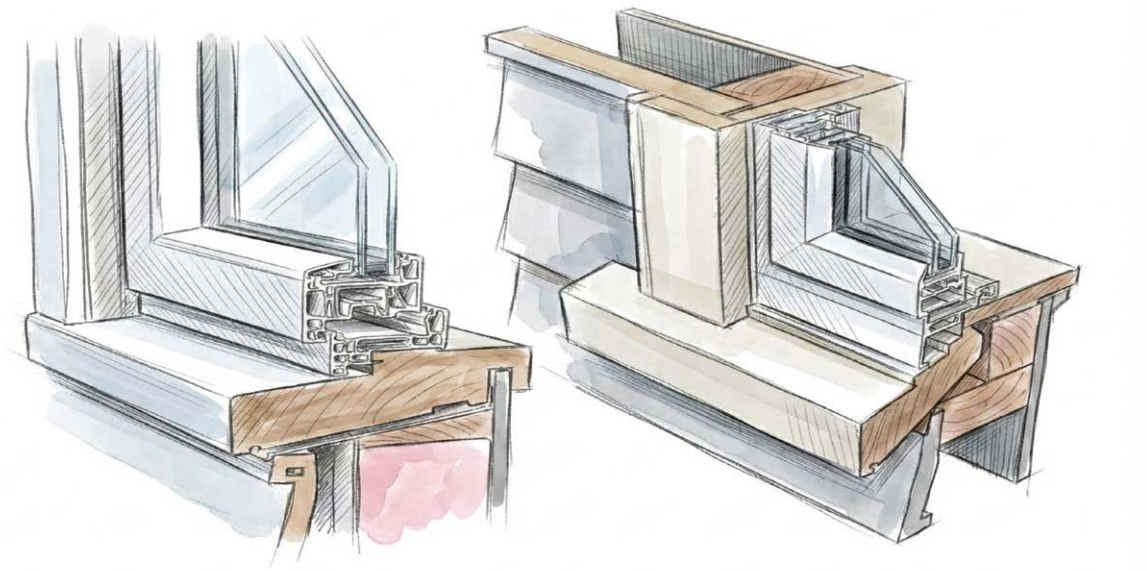


Figure 39: uPVC insert window on left and aluminium insert window on the right. Only some inserts allow for future relocation when/if the wall cladding is later replaced.

Re-glazing: This involves replacing the single glass pane from an existing timber sash with an Insulated Glazing Unit (IGU), which is double or triple-glazed. This is a job for a skilled joiner and should be approached carefully. The existing frame must be structurally sound and able to support at least twice the weight of the original glass. The rebate must be deep enough to accommodate the thicker IGU.

Optimally, there's 16-20mm between the two panes of glass in a double-glazed window. It's possible to specify slimmer IGU specifically designed for retrofitting into timber sashes. Some reduce the space between panes down to 8mm, which reduces thermal performance. And the IGU is still 16mm thick for a double-glazed unit. Vacuum-glazed IGU can be imported that have a total thickness of just 10.5mm and much higher thermal performance; however the grid of structural support is visible as tiny white dots across the entire glazing area.

5.3.1.1 Specification: deconstructing installed window performance

The real-world performance of a window unit is not just about the glass. There are multiple things to consider: the glazing, the spacer (between the panes of glass), the frame and how the unit is installed. A weakness in any one of these will compromise the entire system.

Understanding the metrics: R-values, U-values and SHGC

For consistency, this guide uses R-values (m^2K/W) for thermal resistance. However, the window industry and NZBC H1/AS1 use U-values ($W/(m^2.K)$). Both will be provided where appropriate.[46]

The solar heat gain coefficient (SHGC) measures how much of the sun's energy that hits the outside pane of a glazing unit passes through and is trapped inside the home.[47] Low SHGC glass reduces summer overheating, especially on east and west-facing windows which are not shaded by eaves due to low sun angles. On the other hand, higher SHGC glass helps keep the interior warmer in winter. The right choice depends on a project's individual specifics.

Part 1: The glazing unit (glass and spacers)

Modern glazing uses invisible low-emissivity (low-e) coatings and inert gas fills, typically argon, to dramatically improve thermal performance. The key is to select the right combination of high thermal performance for winter warmth and appropriate solar control for summer comfort.

High-performance coatings and gas fills increase the cost of the glass (with very high performance low-e argon-filled double glazing 1.5x to 2x the cost), but the cost of the frame, hardware and installation won't change. Compare the total cost of the installed window when weighing up the affordability of different glazing specifications as even with glass 1.5x the cost the windows only cost 5-10% more. Real world experience on New Zealand projects indicates that the price difference for much higher-performance glass is often surprisingly small. Meanwhile it delivers a massive leap in comfort and energy savings.

The spacer separates the panes of glass at the perimeter. Avoid standard, highly conductive aluminium spacers. Instead, specify warm edge spacers made of stainless steel, composite plastics or foam. Upgrading from an aluminium spacer to a warm edge spacer can improve the total installed R-value of a window by around 10%.

46 The two units are reciprocals of each other. For example, a R2 wall has a U value of 0.5 or 1 divided by the R-value. R-values measure resistance to heat flow (so higher numbers are better) and U-values measure the rate of heat transfer (lower numbers are better).

47 Note that SHGC is not exactly the same as Solar Factor (also referred to as g-value), which is slightly lower by a few percentage points for the same glass. For more information see Jason Quinn. (2025). Don't cook your client by confusing g-value and SHGC. Sustainable Engineering Ltd.

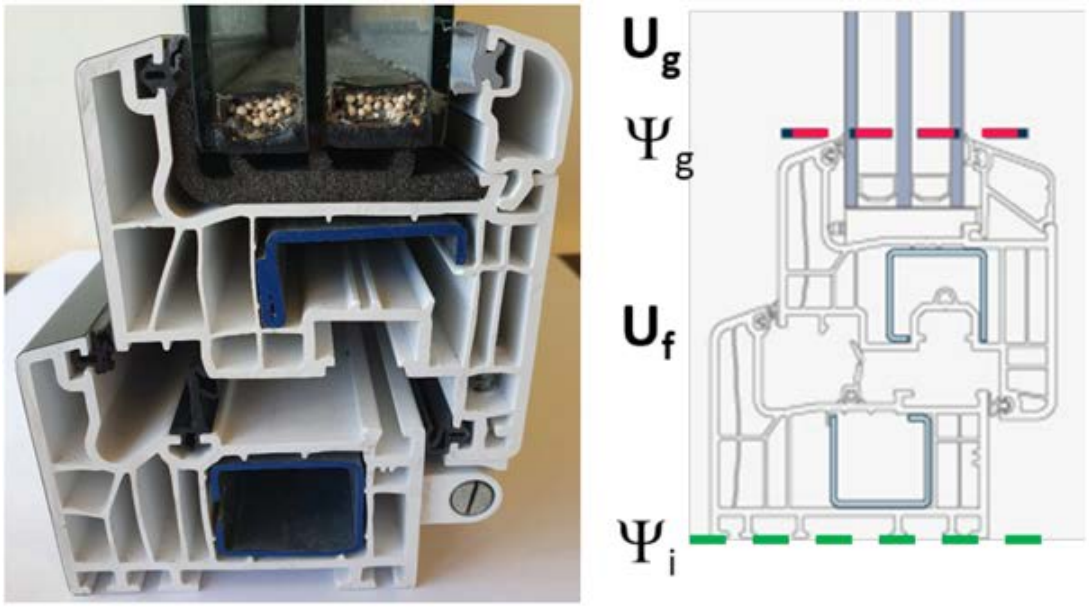


Figure 40: On the left is a triple glazed uPVC window with warm edge spacers. The little brown beads are desiccant to remove any moisture between the glass panes. The graphic section on the right labels the different performance numbers for a window installation: U_g for the glass, ψ_g for the spacer performance, U_f for the frame, and ψ_i for installation into the wall. The impact of ψ_i is not taken into account by the Building Code.

Practical considerations

High-performance glazing is thick and heavy: a typical triple-glazed unit can easily weigh over 50 kg/m². Take this into account during design and make appropriate plans for transport and installation. Specialised lifting equipment is sometimes required on site for large sliding doors. The structural engineer must consider the loading impacts of heavy glazing.

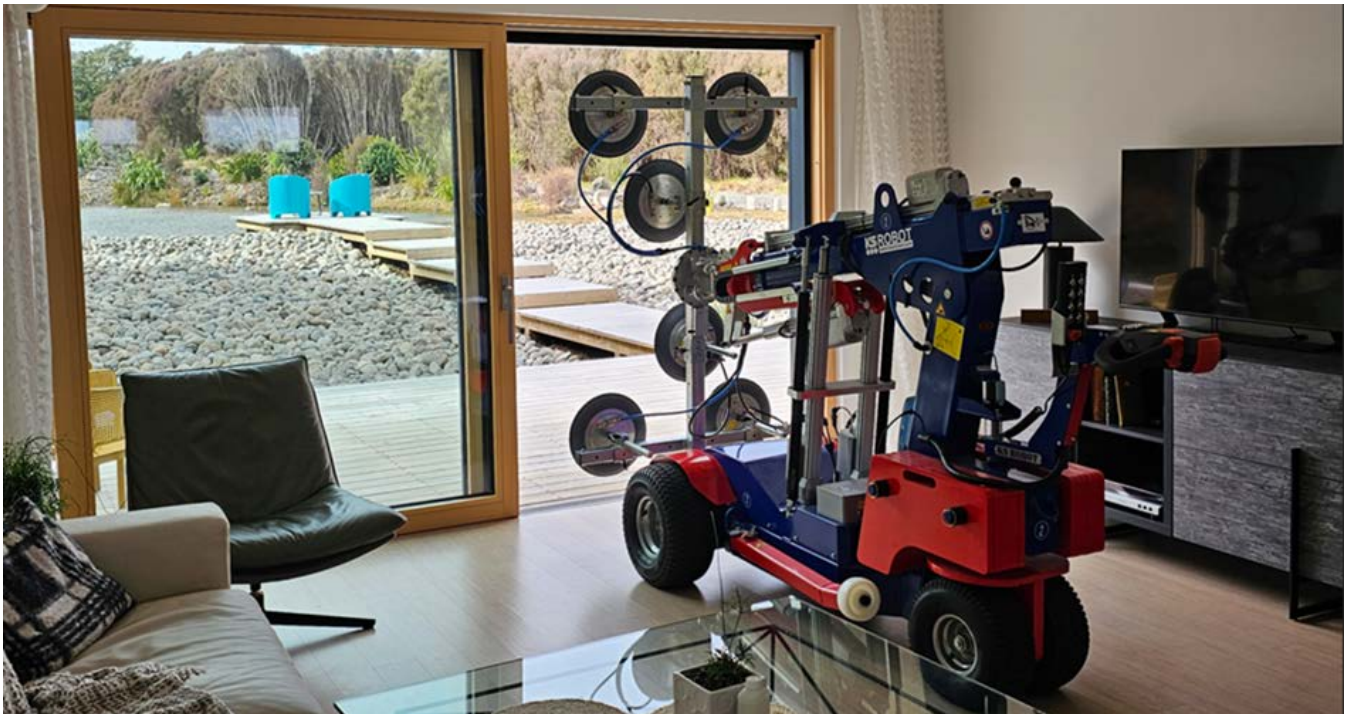


Figure 41: There are high- and low-tech options for moving heavy glazing units into place. A glass lifting robot is remote-controlled and uses vacuum cups to lift the glazing unit into place.

High-performance windows are a big investment. Measure carefully, especially when importing windows, as net frame size and rough opening measurements can cause confusion in translation.

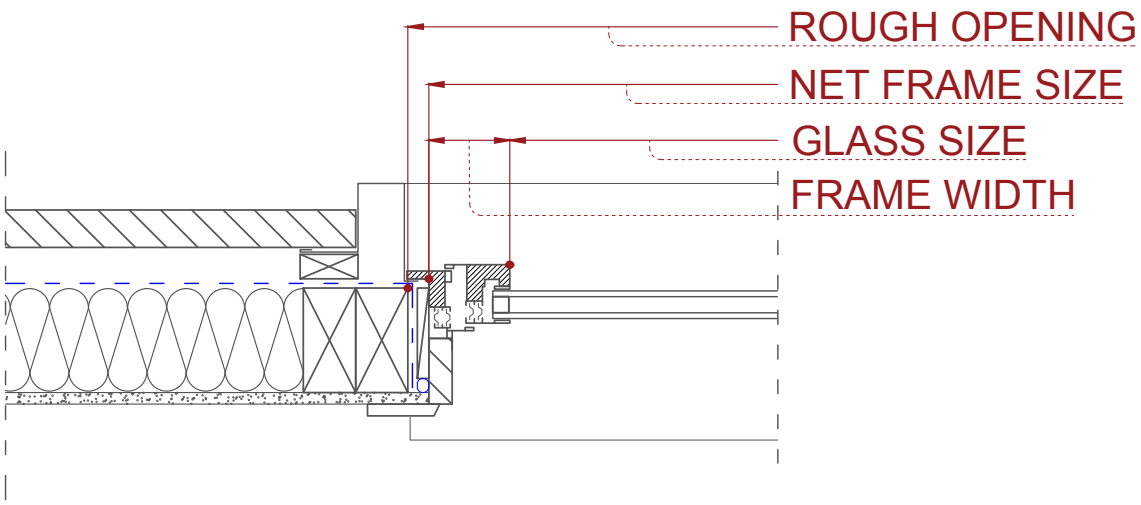


Figure 42: Careful measurement and communication with suppliers is important. Several New Zealand projects have confused rough opening and net frame size and required re-work to make the windows fit.

Part 2: The frame

Standard, non-thermally-broken aluminium frames are highly conductive and a primary cause of heat loss and condensation. High-performance window frame materials include thermally-broken aluminium, uPVC and timber. Not all aluminium frames labelled as thermally broken are high-performance.

The frame R-value has a significant impact on the total performance of the window. Its thermal performance is also key to preventing condensation and mould growth on the interior surface. Thermally-broken aluminium frames available in New Zealand vary greatly in terms of their thermal performance, from R0.25 to R1.25, so it's vital to get the R-value data from the supplier. This data will be required by consenting officials in many cases. It's also mandatory if seeking Homestar, EnerPHit or other PHI certification.[48]

If a frame is advertised as thermally broken but performance data can or will not be supplied, count on it being the lowest level of performance. Chasing bargains can backfire and be very expensive; the author knows of a case where windows offered by a small importer at a very keen price failed building inspection because of lack of documentation. The owner was faced with the removal and replacement of all the new windows and a sliding door or expensive site testing.

Note that the performance of uPVC and timber frames varies much less between models: about 2x range compared to 5x for thermally-broken aluminium.

48 Energy modelling software such as PHPP and ECCHO use the same standard for glass, spacers and frames as the New Zealand Building Code. Australia and the USA use a different standard for the glass, spacers and frame. As a result, the performance values in those countries for exactly the same product will be different from New Zealand performance data.

Part 3: The installation

For best thermal performance, the window should be positioned in-line with the wall's primary insulation layer, not installed to the outside flush with the cladding as is standard practice in New Zealand. This slightly recessed installation offers superior thermal performance.[49]

New Zealand's Building Code omits any reference to this vital aspect, even though best practice window installation can account for about 10% of the window's final installed R-value.

The installation details need to seal against air and water leakage and avoid creating thermal bridges. Modern, high-performance installation processes use specialised tapes and membranes to create a continuous, durable connection between the window frame and the wall's water, air, vapour and thermal control layers.

5.3.2 Skylights

Skylights almost always increase the risk of summer overheating. Specify them with caution and only where their benefits outweigh the downsides; design stage energy modelling will provide valuable guidance. Operable skylights can be an excellent way to night purge heat in most New Zealand climates but consider ease of operability (remote control vs telescopic pole) and the need for insect screens. Some imported high-performance models are hinged in the centre, making it impractical to fit screening or external shading. Consider the following factors.

1. Note that summer sun will still enter skylights situated on a south-facing roof.
2. Consider access for cleaning and maintenance and operability from inside the house (if opening).
3. The flashing details and materials supplied with imported units may be unfamiliar to local contractors.
4. Consider options for external shading in summer and shoulder seasons.
5. Specify the lowest possible SHGC glazing to guard against overheating.
6. Specify triple-glazing for thermal comfort.

Thermal performance decreases as an IGU is tilted because convection between the panes increases. A good double-glazed unit's performance will reduce by 30% when installed horizontally as a skylight.[50]

5.3.3 Doors

Airtightness is just as important for doors. All exterior doors must have robust, adjustable seals around their entire perimeter, including the threshold, to prevent draughts and uncontrolled leakage of heat or coolth. A door between the house and an attached garage must be treated as an external door. It requires full insulation and air seals to prevent heat loss and to keep pollutants like carbon monoxide from entering the house. Avoid standard aluminium-framed glass doors as the aluminium is a big thermal bridge. Well-insulated fibreglass or timber doors offer better thermal performance.

49 See detailed drawings and calculations in Jason Quinn. (2022). High-Performance Construction Details Handbook. *BRANZ ER70*. Aug 14 2022. The calculations show that most of the performance improvement for window location in the wall is accomplished by recessing so that the outside edge of the window is even with the outside of the timber framed wall. Recessing it to the centre of the wall is a much smaller improvement.

50 Jason Quinn. (2020). Skylights: can be evil. Sustainable Engineering Ltd. August 14 2020.

Common questions and concerns: what about...

...secondary glazing films and panels?

These can improve comfort by reducing drafts and increasing R-values but they are a shallow retrofit measure, offering a much lower level of performance than a proper window replacement or insert. There are higher performance options that add a full double-glazing unit (which allows high performance low-e coatings) but they are uncommon.

...What about flashings for these recessed window installs?

Leading New Zealand suppliers of high-performance window offer specific recessed flashing details for their windows. There are also generic recessed New Zealand flashing systems for European-style windows with cavity cladding. The industry body, Window & Glass Association NZ, is currently progressing an E2 Acceptable Solution for recessed window installation details that would, if accepted, simplify consenting.

5.4 Managing thermal bridges and junctions

A lot of deep retrofit performance is won or lost at the junctions through thermal bridges. These are parts of the building enclosure where the thermal resistance is significantly lower than the surrounding area, creating a path for heat to escape. These often occur at junctions where different building elements meet, where structural components penetrate the insulation layer or because of complex geometry. Steel and concrete are the most common materials that create thermal bridging

The *High-Performance Construction Details Handbook* detailed more than 80 common junctions found in New Zealand's diverse housing stock and is a very valuable resource.[51] However, it still barely scratched the surface of the thousands of possible combinations of materials and assemblies. This guide is accordingly focused on teaching the principles project managers and designers need to keep uppermost as they work through the implications of retrofitting junctions.

In a typical construction process, dealing with the complexity of insulating around thermal bridges is often left to the builder to figure out on-site. This is not appropriate in a deep-retrofit project. The design team must think through the construction sequence and the control layers in 3D and develop a clear, buildable plan for every junction.

The four control layers must be continuous. A designer should be able to trace each control line around the entire building on the plans without any break. This is especially important in a step-by-step retrofit, where junctions must be designed across time. Assemblies upgraded now need to connect to components installed in five or 10-year's time. For example, the first step may be a new roof but the junctions need to work for the existing structure as well as being capable of forming appropriate connections to walls that will be upgraded in the future.

51 Jason Quinn. (2022). High-Performance Construction Details Handbook. *BRANZ ER70*. August 14 2022

5.4.1 Steel beams. columns and lintels

Steel beams that penetrate the thermal envelope, steel columns and steel lintels over large openings embedded within external walls are significant thermal bridges. They are not common in older residential construction but careful management is required if present.

The key principle is to keep the steel warm. Insulating the inside of a steel structure will make the steel very cold in winter. Warm, moist indoor air that finds its way past the interior linings is likely to condensate on the steel. This in turn can lead to mould and also rot developing in adjacent timber.

The correct approach is to insulate on the outside of the building assembly, ensuring the steel structure is kept warm and well inside the thermal envelope. Retrofits present unique challenges; the structural elements can't be removed so highly site-specific solutions need to be creatively developed. The goal is to keep all the steel inside the thermal envelope warm enough so that condensation cannot form inside the assembly.

5.4.2 Concrete midfloors and internal walls

Concrete midfloors and internal walls are major thermal bridges and must be mitigated in a deep energy retrofit. They lose heat from the heart of the building, completely undermining any other performance gains and creating significant risk of mould.

A continuous layer of *external* insulation is always the most robust and low risk approach for retrofitting concrete structures. It keeps the entire concrete structure warm and dry.

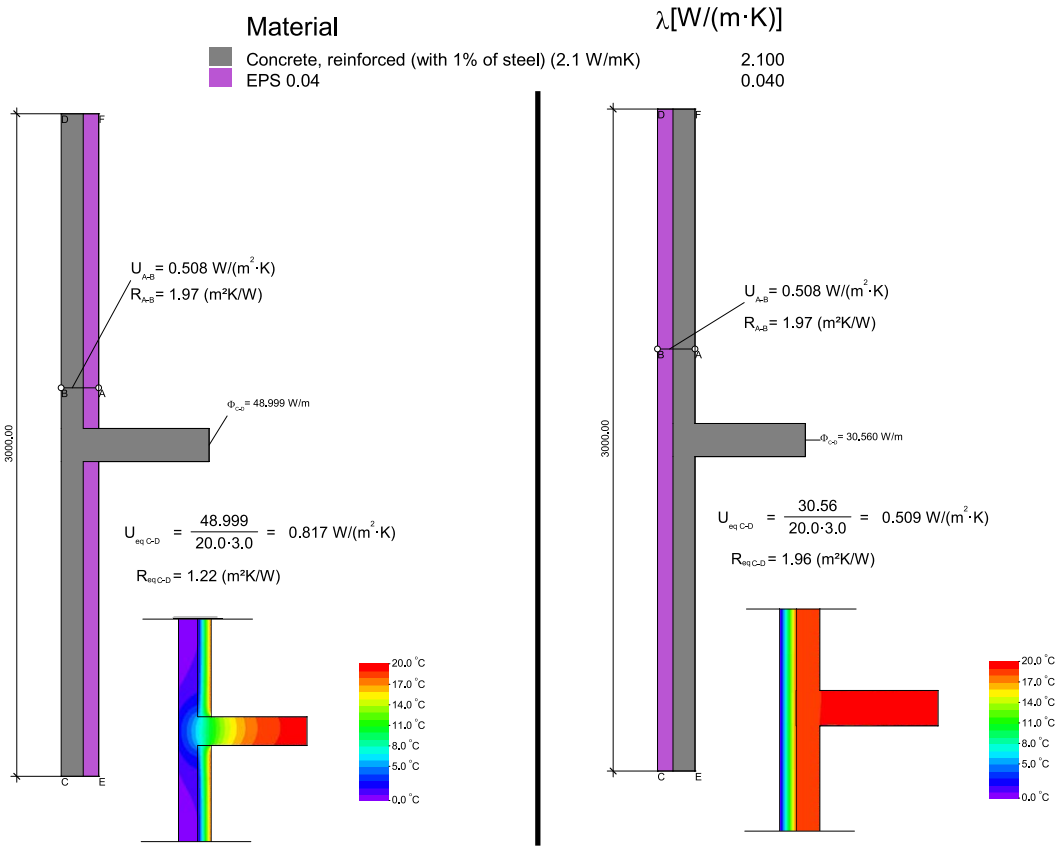


Figure 43: R-value impact of a concrete midfloor with internal insulation is quite large, lowering the wall R-value by nearly 40%. It is not uncommon to retrofit office towers to apartments with internal insulation and leave the midfloors as a thermal bridge.

6 Building systems

This guide promotes an integrated approach to deep energy retrofit, as discussed in Chapter 2. Upgrading the building envelope reduces the energy demand, which then allows for smaller systems to be specified. Deep retrofit levels of energy savings and comfort require highly efficient systems integrated into an upgraded building fabric.

Fabric and system improvements work together to lower a household's overall energy bill and provide a healthy indoor environment. For example, radically reducing a home's heating demand means a much smaller heat pump can be specified. Specifying highly efficient systems like a heat pump hot water heater reduce ongoing operational costs.

In some cases, a systems-first approach is justified. It can deliver immediate benefits with regard to energy savings, health and comfort while homeowners plan (and save) for future fabric upgrades. Adopted on a society-wide level, these system upgrades could deliver substantial energy savings.[52]

Recent New Zealand research lines up with the author's experience with energy modelling. For instance, the following substitutions are estimated to create the following savings, expressed as a percentage of the estimated total household energy bill. (This does not take into account the likely prebound/rebound effects discussed 27.)

- switch from electric resistance to heat pump water heating: 17%
- switch from electric resistance to heat pump space heating: 10%
- upgrade to LED lighting: 8%
- upgrade to a new, efficient refrigerator: 4%
- upgrade to a heat pump clothes dryer: 1%

These system upgrades could theoretically add up to a 40% reduction in a home's energy use. This will vary according to individual cases but also user behaviour can influence outcomes in either direction. For instance, a large household with a lot of hot water use will benefit most from switching to a heat pump hot water heater.

Decoupling the ventilation, temperature control and humidity control is a core principle in designing high-performance improvements. Each system can then be optimised for its specific job. A dedicated ventilation system provides fresh air all the time while a right-sized heat pump provides extra warm or coolth just when it's needed.[53] If the climate requires it, a dehumidifier or heat pump with a dedicated dehumidification mode maintains relative humidity in the sweet spot (40-60%). This separation gives occupants much greater control over their indoor environment. It's also far more energy-efficient, as energy is only used for the specific task required at any given moment.

52 David Dowdell and Roman Jaques. (2021). "Low Carbon Retrofit for Housing Workshop - BRANZ." Low Carbon Retrofit for Housing Workshop, Wellington, June 21 2021.

53 Sharing fans and ducting for ventilation and heating/cooling is not a good idea as it's very inefficient to use a combined system for ventilation only. For more detail, see Jason Quinn. (2024). Keep heat pump and ventilation systems separate for best results. Sustainable Engineering Ltd. April 10 2024.

6.1 Ventilation: selecting and designing for performance

A continuous mechanical ventilation system plays an essential role in a deep-energy retrofitted home. It is not an optional extra. Continuous mechanical ventilation guarantees excellent indoor air quality, controls moisture and protects both the occupants' health and the building's durability.

The New Zealand Building Code severely lags best practice understanding of ventilation and indoor air quality. It requires opening windows in all rooms and assumes that if windows *can* be opened, they *will* be opened. Research shows this is a false assumption.[54] For much of the year there is a significant thermal cost to adequate ventilation. Having doors or windows open can also be undesirable or impractical with regard to security, rain ingress, noise, insect and pest access and outdoor air pollution.

Goal

Provide a continuous supply of fresh air to all living spaces and bedrooms and continuously extract stale, moist air from wet areas (kitchen, bathroom and laundry), all while minimising energy loss.

Challenges

Few New Zealand homes have continuous mechanical ventilation. Rather they rely on occupant intervention and uncontrolled, accidental air leakage such as draughts from around poorly fitting doors and windows and through the building fabric. Not all homes even have intermittent extract fans in bathrooms or kitchen range hoods: these measures have only recently been required in rental properties and no guidance is provided for owner-occupied dwellings.

Under-ventilation leads to poor indoor air quality, high humidity, condensation and increased risk of visible and hidden mould. More than 40% of all New Zealand homes have visible internal mould according to BRANZ building surveys.[55]

Generally, both ventilation and heating are required to maintain healthy relative humidity levels in winter. Ventilation's primary role is to bring in fresh outdoor air. Cold winter air in most New Zealand climates has a high relative humidity (RH). Heating is needed to warm the indoor air, which dramatically lowers its RH and gives it the capacity to absorb the moisture generated inside the home from people breathing, cooking and bathing. This moister air is then extracted by the ventilation system, resulting in a net drying effect.

It is important to keep indoor air below 70% RH as the RH of the surfaces of the building enclosure will always be somewhat lower than that of the air. Many materials will grow mould with a surface RH above 80%.

Ventilation is also required to remove air pollution that builds up inside homes from various sources:

- combustion devices (gas stoves and cooktops, wood burners and open fireplaces) producing fine particulate matter,
- furnishings, building materials and household chemicals of-gassing volatile organic compounds (VOCs) and
- human respiration leading to a build-up of carbon dioxide.

54 Kara Rosemeier. Healthy and affordable housing in New Zealand: the role of ventilation. PhD thesis, Waipapa Taumata Rau, University of Auckland. 2014.

55 Mould and damp. BRANZ 2015 House Conditions Survey.

Retrofit strategies

There are a number of options for ventilation, from simple to more complex setups. Fully ducted mechanical ventilation with heat recovery (MVHR) is the gold standard; other solutions come with more significant trade-offs in thermal comfort and heating (or cooling) bills. Occupants opening windows is considered a ventilation strategy by the Building Code but it is manifestly inadequate and therefore not presented here as an option.

Indoor CO_2 levels are a reasonable proxy for indoor air quality and portable or wired monitors are available that report CO_2, RH and temperature. NDIR sensors provide accurate CO_2 readings; very cheap monitors will not be useful. Household grade monitoring devices for VOCs or fine particulate matter are not very accurate but show relative changes. These devices are very good at providing feedback and encouraging changes in occupant behaviour and are worth recommending to occupants.



Figure 44: An example of a portable CO_2 monitor with a quality NDIR sensor, which also reports temperature and relative humidity.

6.1.1 Balanced mechanical ventilation with heat recovery (MVHR)

An MVHR is the gold standard for high-performance homes. This system uses two fans to supply and extract air in a balanced, controlled manner. A heat exchange core transfers up to 90% of the heat from the outgoing stale air to the incoming fresh air in winter, providing significant energy savings and superior comfort.

6.1.1.1 Design and installation advice for MVHR systems

All MVHR ductwork must be located inside the thermal envelope. Running ducts through a cold, unconditioned attic space can negate the heat recovery benefit[56] and creates a significant risk of condensation forming on and in the ducts.

56 Jason Quinn. (2020). Local MVHR only 40% efficient, says BRANZ test. Sustainable Engineering Ltd. October 16 2020.

Specify rigid or semi-rigid ductwork and ensure subcontractors do not make unauthorised substitutions of flexi-duct. Currently there is a lack of HVAC expertise in residential projects and it can be a challenge to find suitable subcontractors in smaller centres. Some MVHR suppliers install all the systems they sell, while others have a great deal of technical information and advice they will readily share with designers and contractors.

Splitter boxers and silencers are common in high-performance systems. These are not an afterthought as they are a significant fraction of the cost of the system but keep the system nearly silent. These sit above the ceiling but within the thermal envelope and provide the ability to clean the entire ductwork system without breaking into the roof space.

Cone filters should be fitted to all the extract terminals in order to keep the ductwork clean. Specify these when ordering the MVHR system as not all suppliers include them as a matter of course. Likewise specify F7 grade filtration for the MVHR unit, which will remove pollen and most fine particulate matter.[57] These should all be fitted before commissioning as they affect air flow rates.



Figure 45: Ensure building owners or occupants understand the need to check and clean/replace filters at appropriate intervals. This cone filter on an extract vent hadn't been checked for several years and was very overdue for replacement.

MVHR systems shouldn't be turned on until construction is complete as construction dust will clog ductwork. It is important that the construction team does not install the windows and then leave the building closed up. When wet construction materials (concrete slabs, plastering or wet timber) have been installed, it is common for condensation and mould to develop in the absence of ventilation.

The system must be commissioned, which involves use of a calibrated balometer or powered flow hood to measure and adjust the airflow at every supply and extract valve. This ensures the system is balanced and delivers the specified flow rates to every room.

Turning the MVHR on is not the same as commissioning. The author was asked to troubleshoot the performance problems of a home that had been initially energy modelled to Passive House standards

57 Jason Quinn. (2024). More detail on filter grades is available here. Sustainable Engineering Ltd. March 17 2024.

but the owners had not then bothered with certification. They were unhappy with the lack of comfort and their heating bills. An investigation determined the MVHR was never commissioned. There was virtually zero air being extracted from the bathroom and so the occupants were opening the bathroom window to allow steam to escape. This came with a big thermal penalty in winter, significantly increasing heating demand. Once the ventilation system was operating correctly, the house performed very well and in accordance with the energy predictions made at design stage.

6.1.2 Distributed balanced mechanical ventilation with heat recovery

In many existing buildings, installing a fully ducted central mechanical ventilation system is unfeasible. Spatial constraints may prevent the routing of necessary ductwork, or the project budget may not be able to accommodate a comprehensive central system. In such cases, consider distributed, balanced mechanical ventilation options that eliminate or significantly reduce the need for ducting, while still protecting indoor air quality and thermal performance.

The first alternative is paired alternating fan decentralised mechanical ventilation with heat recovery (MVHR). These individual, through-wall units provide energy-efficient, demand-driven ventilation for specific rooms. They typically use a ceramic core to capture heat from the exhaust air and transfer it to the incoming fresh air. The primary advantages of decentralized units are cost and simplicity; they require no ducting, making them a highly practical solution for quickly improving ventilation in a problematic, damp room or an isolated area of a house. However, this approach carries disadvantages. Each unit requires a penetration through the external wall, their overall heat recovery efficiency is generally lower than fully ducted systems and having the fan situated directly within the living space plus the switching of fan direction tends to make them noisier.

A more sophisticated middle ground is the adjoining-room MVHR setup. This operates as a semi-centralised system that requires very little ductwork, often just a single duct run. In a typical configuration, the unit extracts moist air from a bathroom and supplies fresh, filtered, heat-recovered air directly into an adjacent main living room. To distribute this fresh air to the rest of the dwelling without requiring a network of supply ducts, the design relies on active overflow. CO_2-controlled transfer fans are installed in the walls of the bedrooms (typically above the doorway), constantly monitoring air quality and actively pulling the fresh air from the main living spaces into the sleeping quarters exactly when it is needed.

These adjoining-room systems offer an excellent balance of spatial efficiency and performance, often reaching heat recovery efficiencies similar to a fully ducted central MVHR. Because the main fan unit can be kept separate from the sleeping areas, acoustic performance is significantly better than decentralised through-wall units. They are an ideal, low-impact retrofit solution for apartments and small homes. For larger dwellings where a single unit cannot meet the required air volumes, the home can simply be divided into separate zones, using two or more of these adjoining-room setups can avoid the need for complex, long-run ductwork.

6.1.3 Continuous mechanical extract ventilation

This is simple and inexpensive but has significant drawbacks with regard to occupant comfort and energy efficiency. It relies on one or more fans continuously extracting air from wet areas. The simplest retrofit is replacing a bathroom fan with an improved model that is very quiet and draws very little power. They can be installed in the wall or ceiling cavity, ducted to the outside. Some can be run in humidity detection modes, increasing the flow rate automatically when RH rises above a specified level. The weakness is that incoming air will be drawn through leaks in the building enclosure so it may not be clean or all that fresh. If the building is very airtight, supply air openings may need to be added. This can be determined during commissioning of these extract fans by measuring the airflow.



Figure 46: Checking exhaust fan in bathroom with toilet paper test.

Pro tip: Place a piece of toilet paper over the fan grill. It should stick when the fan is operating. If it sticks when a window is open but not when it's closed, then supply vents are needed. If it doesn't stick in either scenario, then increase the fan flow rate.

More supply air can be provided by leaving selected windows ajar. This relies on occupants opening the right windows, opening them often enough and doing so regardless of outdoor conditions.

As an alternative, trickle vents in the walls or windows of living areas can be specified. These are typically slots cut in the window frame, sometimes with sliders that allow airflow rates to be modified. Acoustic baffles can be used to reduce noise transfer. Another option is to remove the window gaskets to deliberately make the frames leaky. Window frame slots are preferable to tubes that penetrate through the wall linings.[58]

All of these responses obviously undermine the improvements in comfort and efficiency gained by installing high-performance windows. It emphasises the need to consider early the ways different systems and goals interact—and to plan for a balanced ventilation system.

58 Trickle vents are much more common in the UK but British research conclusively shows they do *not* provide sufficient fresh air unless fans are operating. Occupants very often close or obstruct the vents, especially in bedrooms where cold draughts create a lot of discomfort in winter.

Trickle vents may become more common again in New Zealand because, in combination with small extract fans, they are the lowest-cost way to meet Homestar v5 requirements for continuous ventilation. If using this strategy, do not install trickle vents in bedrooms. They are best located in the same room as the main heat source.

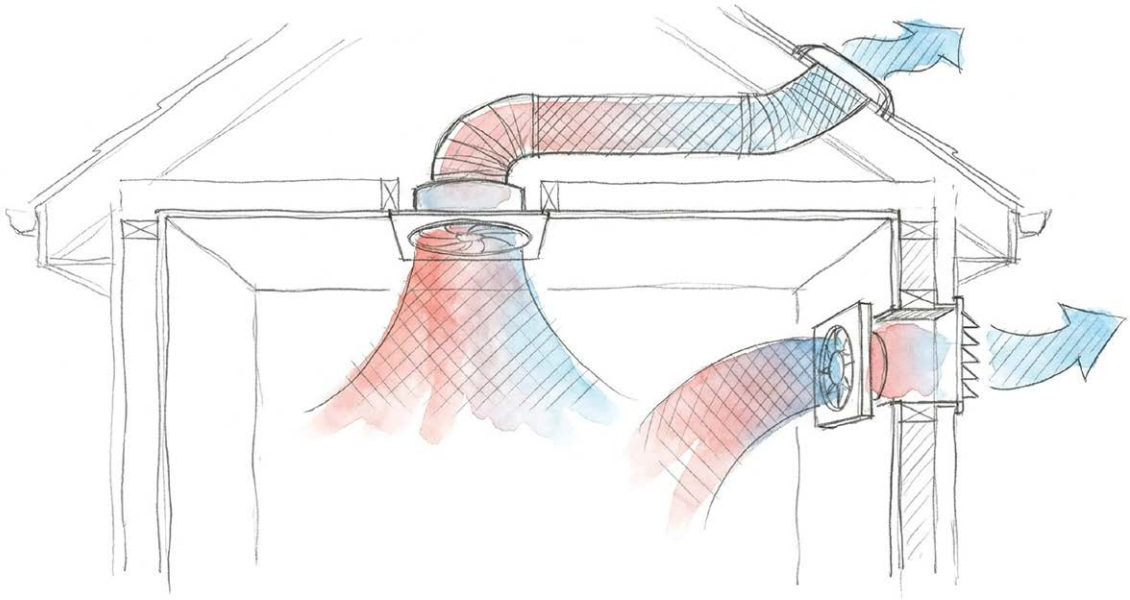


Figure 47: Continuous extract fans are widely available in New Zealand in either ducted or through wall format.

6.1.3.1 Design and installation advice for mechanical extract ventilation

Flow rates

The system must be designed to provide adequate air change rates. A good benchmark is a whole-house continuous rate based on the number of bedrooms. Assume two person occupancy for the first bedroom and one person for each additional bedroom and specify at least 7.5 L/s/person.

Winter relative humidity checks

Advise occupants to check the internal RH in the winter and increase the ventilation rate if necessary. Over 70% is not acceptable (excluding spikes when showering), increase the ventilation rate and/or heat the home more to bring RH to safer levels. Ideally RH would fluctuate between 40-60% across a typical 24-hour period.

Ducting

Use smooth, semi-rigid or rigid ducting wherever possible. This minimises airflow resistance and fan energy use, is easier to clean and much more durable.[59]

Supply vents

Check that the fan is moving the correct amount of air when it is installed. If the fan is not moving enough air, open a window. If the flow rate now increases to the correct rate, it indicates that more supply air is required. Passive supply vents may need to increase in area or occupants shown the amount of window opening required for the system to operate correctly, as discussed above. This has to be balanced against draughts and impact on heating demand.

59 Jason Quinn. (2023). Don't overlook these three things when specifying MVHR systems. Sustainable Engineering Ltd. Jul 19 2023.

Common questions and concerns: what about...

...positive pressure ventilation (PPV) systems?

These systems are not recommended for buildings with insulation in the walls, ceiling and floors. They work by pushing unfiltered air from the roof space into the house and can drive moist indoor air into the building structure, creating a mould and condensation risk in insulated assemblies. The supply air from the roof space may be unclean or stale and, in many cases, will negatively impact thermal comfort and energy efficiency.

Do no harm: avoid back drafting

Any home has a risk of back drafting carbon monoxide and other dangerous flue gases into the home from combustion appliances. As homes are draft-proofed, this risk of back drafting appliances increases, especially with continuous extract ventilation. Ideally all combustion appliances are replaced with electric alternatives in a deep energy retrofit. This includes open fireplaces, wood burners, gas heaters, gas hot water heaters, gas cooktops and gas ovens. Air quality is a concern in garages that house vehicles with combustion engines: attached garage doors must be airtight to prevent contaminated air from the garage entering the home.

If clients insist on retaining gas appliances, specify very effective rangehood extraction and consider whether make-up air is required. Wood burners should be power vented with a vacuum switch. But be aware even with these features there is still risk.

6.2 Heating and cooling

The heating system's job becomes much easier in a deep energy retrofitted home with a highly insulated and airtight fabric. Large systems designed to combat constant heat loss can be replaced with smaller, highly efficient systems that provide top-up heat for sustained comfort.

Goal

Provide healthy, affordable and efficient heating and cooling using appropriately sized equipment.

Challenge

New Zealand suffers from a legacy of inefficient, expensive and sometimes polluting heating sources. This includes flued and unflued gas heaters, direct electric resistance heaters, open fireplaces and wood burners.

Retrofit strategies

Electrifying all systems is a basic starting principle for a deep retrofit, or indeed for anyone concerned with a healthy living environment. This eliminates indoor air pollutants produced by gas combustion and future-proofs the home from expected gas shortages and cost increases in New Zealand.[60]

Heat pumps (air-to-air): Heat pumps are the most efficient technology for space heating and cooling in New Zealand.

60 New Zealand Green Building Council. (2025). Protecting industry, jobs and household budgets as the gas runs out, August 2025.

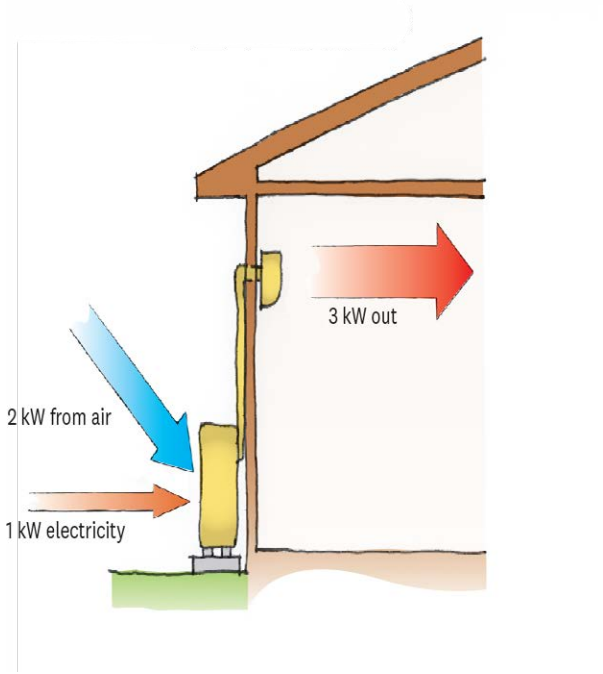


Figure 48: This heat pump provides 3kW of heating while only using 1kW of electricity, a coefficient of performance (COP) of 3. Credit: ECCA Heat Pump Guide.[61]

6.2.1 Key design considerations

System type

Options range from single-split high-wall units to multi-split systems or fully ducted systems. The choice depends on the home's layout and the retrofit's scope.

Sizing

This is the single most important design consideration. The heating load is very small in a deep energy retrofitted home. Sizing must be based on the results of the energy performance model, not on outdated rules of thumb. A substantially oversized system will short cycle (turn on and off frequently without completing its cycle), which is highly inefficient and provides poor comfort and dehumidification. It also costs more to purchase. Oversizing is a common and expensive mistake.

Placement

The location of both the indoor and outdoor units is important for performance and comfort. Indoor units must be positioned to ensure good air distribution without creating uncomfortable draughts for occupants. Outdoor units need clear space around them for airflow and should be located where noise will not be a nuisance.

Ducting

In the case of ducted systems, all ductwork must be located within the thermal envelope. Ducts should be insulated, and the design should use smooth, rigid or semi-rigid ducting to minimise airflow resistance and noise. It's easier to maintain and far more durable, as noted earlier. However, the industry is used to cheap flexi ducting and it can be hard to avoid.

61 ECCA. (2022.) Good practice guide Heat pump installation. March 2022.

6.3 Dehumidification

Many parts of New Zealand experience damp but not severely cold winters, meaning high indoor humidity is a major problem even at moderate temperatures. In these conditions, a dedicated strategy for moisture removal is necessary to ensure health and comfort.

Goal

Maintain a healthy and comfortable indoor relative humidity (between 40-60% RH) in an efficient and automated way, independent of the heating system.

Challenges

High ambient humidity combined with the moisture produced by humans breathing, cooking and bathing can lead to condensation and mould, even in a warm home. In warmer climates the drying capacity of the ventilation air may not be sufficient even with heating to 20°C and active dehumidification may be required.

Retrofit strategies

The solutions are to either maintain the home several degrees warmer (even above 20˚C), ventilate more and/or actively dehumidify. Note that active dehumidification is a more efficient heat source than resistance electric panels as the latent heat of the condensing process is captured.

Standalone dehumidifiers

An efficient dehumidifier is a practical and effective solution in many cases. Recent US research proves that a central stand-alone dehumidifier unit is capable of managing moisture throughout an entire home.[62]

- Sizing: A unit capable of extracting 17-24 litres of moisture per day is typically adequate for all except the largest houses.
- Drainage: A self-draining model is highly recommended—either one with a continuous drain hose or a unit that can be easily retrofitted with one. If placed in the laundry, the hose can be securely routed to the washing machine drain. Otherwise, a heavy tank of water will need to be manually emptied on a daily basis.
- Automation: Choose a model with a built-in humidistat. This allows the desired RH level to be set (eg 60%), and the unit will run automatically only when needed. This is more efficient and effective than running it on a timer.

Integrated dehumidification

Central ducted dehumidifiers can be installed either into the heat pump ducting or in a separate ducted system. This more expensive strategy works well in very large homes or spread-out floor plans.

Common questions and concerns: what about...

...just using my heat pump, isn't that dehumidifying?

Heat pumps don't dehumidify the air in the winter. This only happens incidentally in the summer. More efficient heat pumps dehumidify less than older heat pumps as manufacturers chase efficiency and better Energy Star ratings—dehumidification uses more energy and lowers the heat pump COP.

62 Success relies on correct selection and installation. See George Tsongas. (2025). Understanding Mold And Moisture Problems Inside Housing. ASHRAE Journal. May 2025.

6.4 Domestic hot water systems

After space heating, generating hot water is typically the single largest component of a New Zealand home's energy bill. Upgrading to an efficient, well-designed water heater is a key systems upgrade that delivers significant ongoing savings on power bills, especially for large households or others that use a lot of hot water.

The benefits are collective, not just individual. Upgrading the current stock of electric resistance hot water cylinders to far more efficient hot water heat pumps would reduce total national electricity consumption by 7%—enough to charge 1.4 million electric vehicles, without any additional generation.[63]

Most modern mains pressure hot water cylinders, including the storage tanks for many heat pump water heaters, are constructed from steel with a vitreous enamel lining (a glass-like coating). To protect the steel tank from corrosion through inevitable microscopic imperfections in this lining, a sacrificial anode is installed. This metal rod is designed to corrode instead of the tank itself. It is essential that this anode is inspected and replaced regularly, typically every three to five years, to prevent premature failure of the cylinder. Some cylinders have stainless steel tanks or electric anodes that do not need this maintenance.

Goal

Well-designed systems that produce and deliver hot water as efficiently as possible and which minimise both generation and distribution losses.

Challenges

There's a widespread reliance on inefficient direct electric resistance cylinders. Many homes also suffer from poor system design. Long waits for hot water at the tap waste water, energy and time.

Retrofit strategies

A high-performance domestic hot water system strategy has three parts: generating hot water efficiently, distributing it effectively and reducing overall demand.

6.4.1 High-efficiency generation with heat pump water heaters

Heat pump hot water heaters are the most efficient, widely available technology for generating hot water and are typically three to four times more efficient than a standard electric cylinder. However capital costs are higher than conventional hot water heaters and return may be extended for a small household. The noise generated by the heat pump needs to be considered when deciding on system type and location. There are two main types to choose between.

Integrated (aka monobloc) units combine the heat pump and the storage cylinder into a single appliance. This makes installation simpler and they are usually installed outside where the noise will not be heard inside the house. If installed inside, it must be in a space with adequate volume of air to draw heat from. The unit's operation will cool the air in that space, thereby increasing heating demand in winter but helping with cooling in summer. Best indoor options are a garage or a well-ventilated utility room. However ducted models with supply and exhaust air pathways do allow for locating the unit in an interior cupboard.

63 Bhawesh Singh. (2025). Hot Water Heat Pumps drive the electrification of NZ transport – without additional electricity generation. Stiebel Eltron NZ.

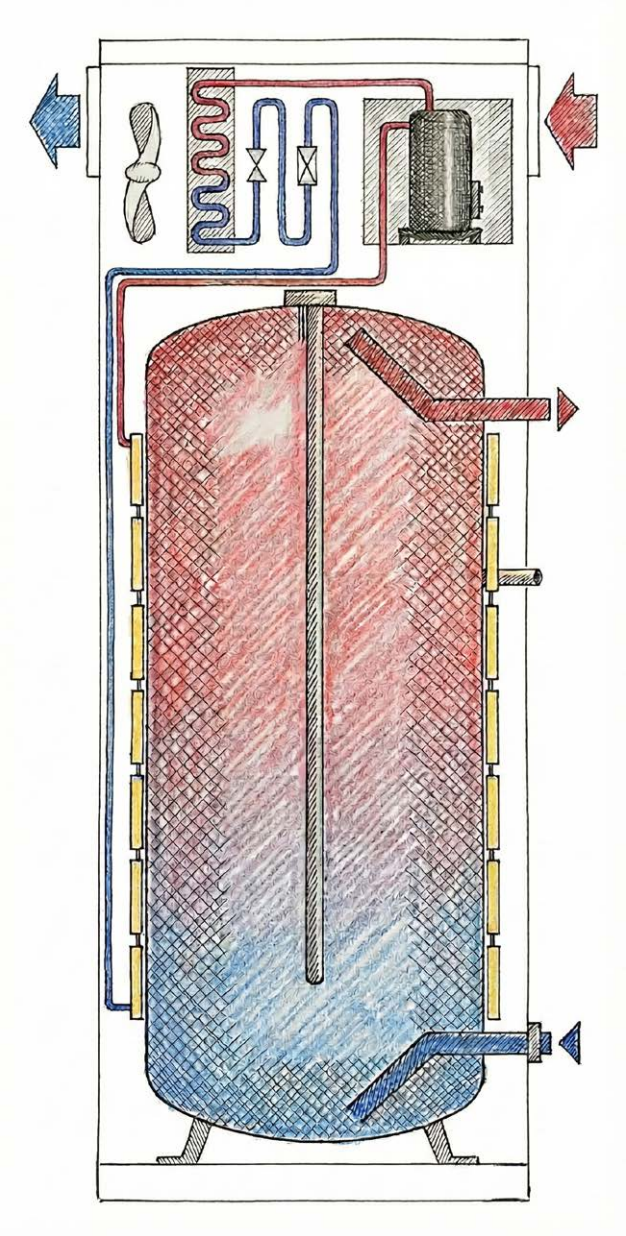


Figure 49: Monobloc heat pump water heater showing operation and anode which needs servicing in most cases.

Split systems separate the heat pump unit from the hot water cylinder. The heat pump goes outside, while the cylinder can be located inside the home. This provides flexibility for location but they are more expensive and the installation is more complex as it involves running refrigerant lines or hot water lines between the two components.

CO_2 hot water heat pumps are a type of split system: they generate the hot water in the outside box and then pump the hot water into a storage tank either outside or inside the home. These are often the best option with regard to energy efficiency and carbon emissions, as other refrigerants have higher greenhouse warming potential than CO_2.

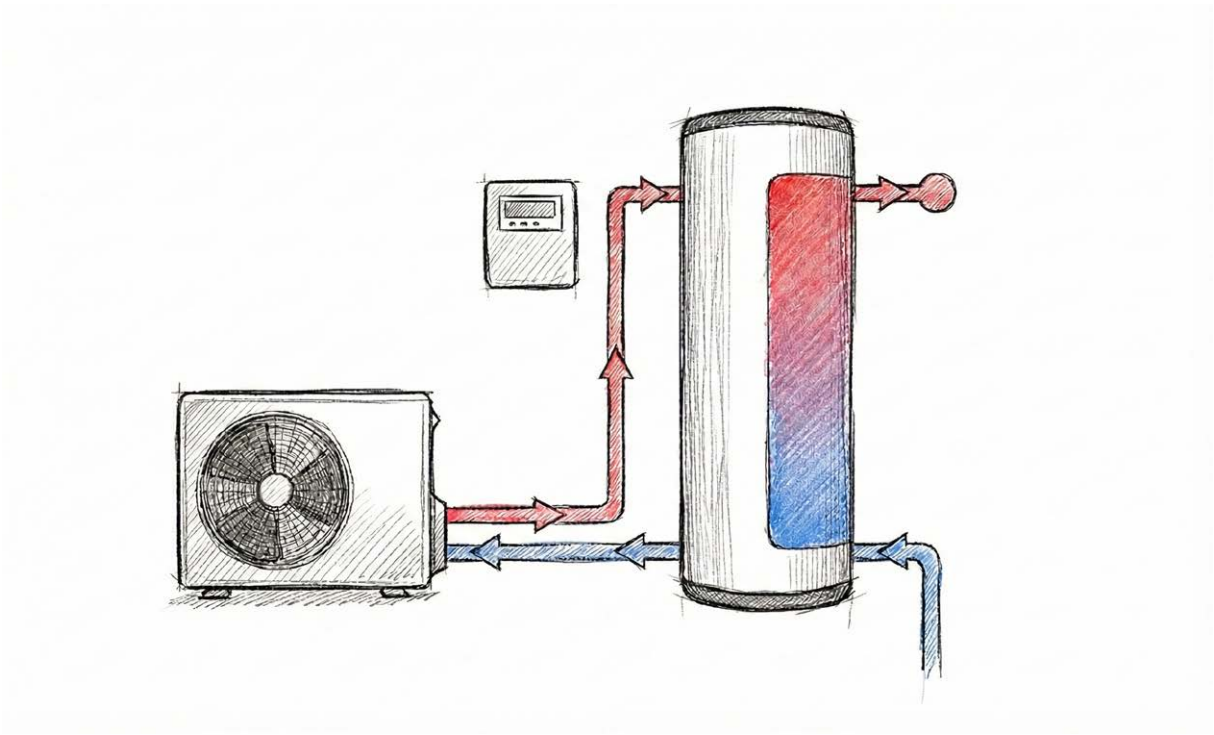


Figure 50: A split system, offering more flexibility with regard to location of hot water storage cylinder.

6.4.2 Reducing distribution losses with demand-controlled recirculation

In larger homes, the wait for hot water to travel from the cylinder to a distant tap wastes dozens of litres of water and the energy in the cooled-off water sitting in the pipes. A hot water recirculation loop solves this problem, but it must be designed correctly. It is a dedicated, fully insulated pipe that loops from the hot water cylinder to the furthest fixture and back.

It is very important that the recirculation pump is demand controlled. It must not be run continuously, which effectively turns the hot water pipes into expensive, inefficient radiators and wastes a lot of energy. A demand-controlled system is activated by a button near the tap or by a motion sensor. The pump runs briefly, bringing hot water to the fixture just before it is required and then shuts off.

6.4.3 Reducing demand with drain water heat recovery

Drain water heat recovery is a simple, passive technology that captures the heat from warm shower water going down the drain. A copper heat exchanger replaces a section of the main drainpipe from the shower. As warm water flows down the inside of the pipe, incoming cold mains water flows up through a coil on the outside, pre-warming it before it reaches the shower head. A thermostatic mixer automatically reduces the hot water flow to keep the water temperature constant. As a bonus, the water temperature doesn't change in the shower when the toilet is flushed.

The savings are greatest in homes with high shower usage. For the system to work effectively, a thermostatic mixing valve must be used at the shower to balance the pre-warmed cold water with the hot water from the cylinder. There are New Zealand made options as well as imported technology.

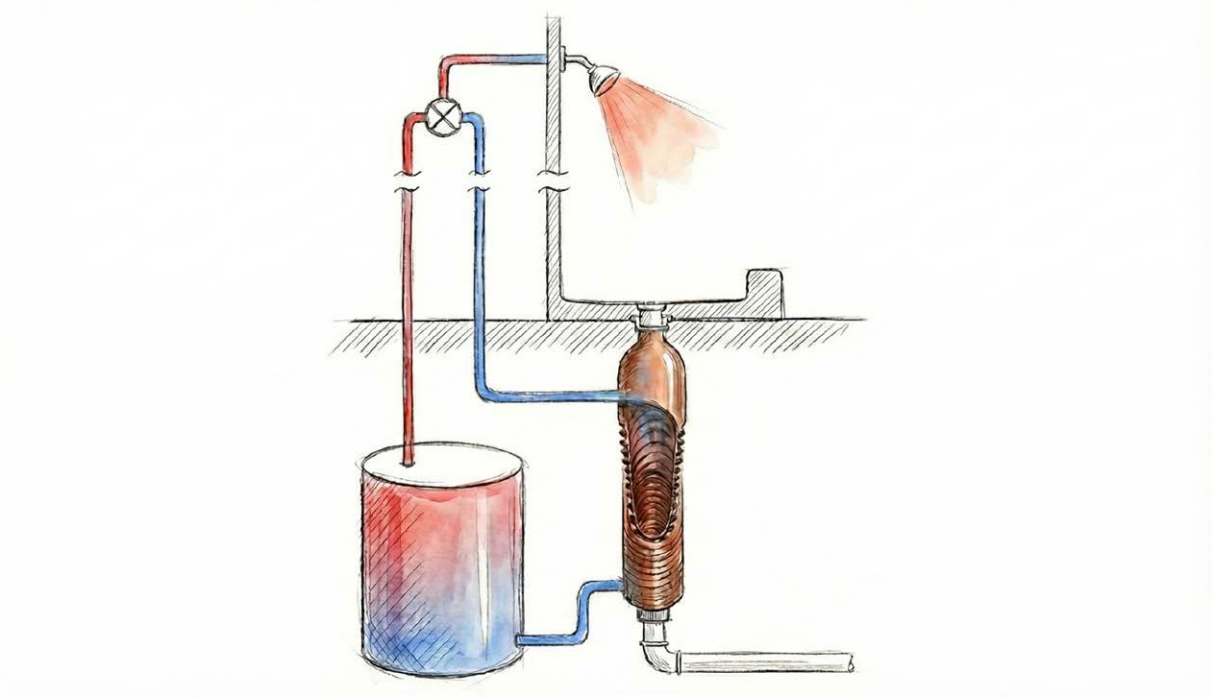


Figure 51: Drain water heat recovery uses the hot water flowing down the drain as you shower to preheat the cold shower water while you shower. Most drain water heat recovery units are installed vertically as shown but there are some that can be installed nearly horizontal as well (although performance is degraded compared with vertical installation).

Common questions and concerns: what about...

...solar hot water systems?

PV panels have become considerably cheaper and more efficient so combining these with a heat pump hot water system is almost always a more cost-effective and versatile solution. Systems can be designed to heat water while the onsite PV is generating electricity, thus producing the same outcome as a legacy solar hot water system: water heated directly from the electricity generated on the roof.

...continuous flow gas water heaters?

These don't have a place in a deep-retrofit context focused on reducing energy use and carbon emissions, as discussed in Chapter 4.

... electric instant hot water?

Instant hot water heating might seem like a good option for single-person households or others with very low or intermittent water use, for example a bathroom in a guest suite or a bach. However electric instant hot water heaters have extremely high power demands. They are more feasible if combined with a low-flow showerhead and a small local battery that can smooth out the spike in electricity demand.

...low flow showerhead and other ways to save on hot water?

Great idea. This and other tips can be found in the NZGBC Homestar design guide[64], which offers excellent advice on achieving hot water savings.

64 New Zealand Green Building Council. (2025). Homestar: A practical design guide to lower carbon, healthier homes.

6.5 Lighting, appliances and energy efficiency

Optimising the plug loads from lighting and appliances provides the final layer of efficiency once more energy intensive systems have been optimised.

Goal

Minimise all base electrical loads without compromising convenience or performance.

Challenges

Plug load typically accounts for a third of a household energy bill. Once heating, cooling and hot water heating has been significantly reduced, the remaining plug load will be approximately two-thirds of the energy bill. Replacing older, inefficient lighting and appliances will directly lead to ongoing energy savings.

Retrofit strategies

1. Switch to high-quality LED lighting. This can save 8% on the electricity bill and will pay off remarkably quickly. LEDs are available in a range of temperatures: choose according to lighting function and personal preference.
2. When replacing appliances, choose models with the best available official energy rating[65], especially for refrigerators/freezers. Chest freezers are more efficient than vertical freezers.
3. Heat pump clothes dryers use significantly less energy than traditional vented or condenser dryers.
4. Replace gas or conventional electric cooktops with induction cooktops. These are highly energy efficient and responsive and also improve indoor air quality. Some models have a high draw at start up and may require rewiring: consult with the electrician before finalising the purchasing decision.

Common questions and concerns: what about...

...solar PV and batteries?

On-site renewable energy generation is a recommended final step after the home's energy demand has been minimised. Reducing demand first makes any future solar and battery system smaller, more affordable and more effective.[66]

65 Details on the EECA-administered energy rating label scheme are available here.
66 ECCA. (2019). Energy Efficiency First

7 Case studies: Retrofit in practice

This section presents three successful deep energy retrofit projects completed in New Zealand. Each had a different construction typology and faced its own unique challenges. These case studies demonstrate how the workflow and technical guidance outlined in this handbook can be used to transform older, under-performing houses. It reinforces that every retrofit project is different and the best decisions respond carefully to individual circumstances and client goals. These very different houses have each been transformed into a healthy, comfortable and efficient modern home that perfectly suits their owner's aspirations.

7.1 Deep energy retrofit of a timber bungalow



Figure 52: Timber bungalow in Kaiwaka. Photo of post-retrofit home.

Project team

Architecture & Passive House Design Energy Architecture NZ Ltd

Structural Engineering Groove Design

Builder/owner Till Schlimme

Certifier Sustainable Engineering Ltd

This single-storey timber house in an eco-village on the Kaipara Harbour was built in 2008. The house was well-intentioned for its time, using natural materials like earth plaster and cypress cladding and above Building Code levels of insulation and double-glazing.

Problems Nonetheless, this was not a comfortable or healthy environment. The aluminium window frames were not thermally broken and excessive timber fractions compromised wall insulation performance. The home was draughty, it overheated in summer and was cold and damp in winter. A lack of effective ventilation led to mould in the bathroom, despite a wood-burning stove lit all winter.

Motivation The home's new owner is a master cabinetmaker with experience restoring historic buildings in Europe. Personally and professionally, he knew that a much higher level of comfort and health was achievable. His goal was to transform the house into a nice, healthy living environment by applying a rigorous, performance-first deep energy retrofit—all the while preserving the building's simple charm and layout.

The project aimed for EnerPHit certification. It focused on creating a continuous airtightness layer and insulating from the exterior. This strategy was key, as it allowed the owner to continue living in the house throughout the renovation and ensured no new weathertightness or condensation risks were introduced. The owner wanted a robust thermal upgrade, not a wholesale cosmetic renovation. He was happy that the before and after photos would look remarkably similar; even the windows' aluminium powder coating matches the colour of the original painted timber windows.

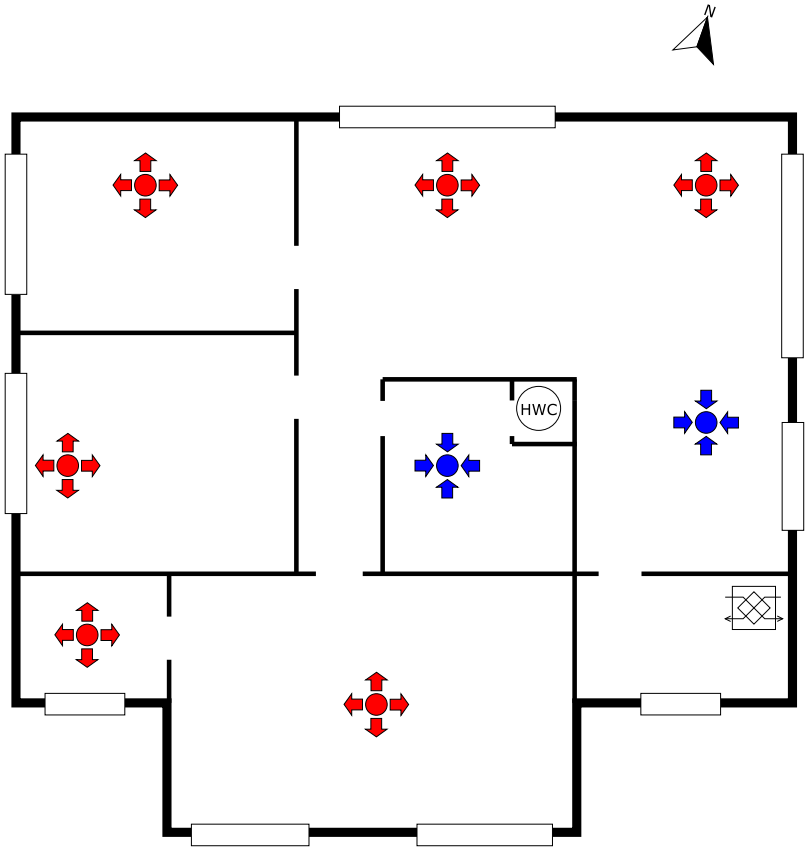


Figure 53: Cottage floorplan post-retrofit with ventilation system location and supply/extract ventilation from the MVHR.

7.1.1 Masterplan overview

Element-by-element retrofit strategies

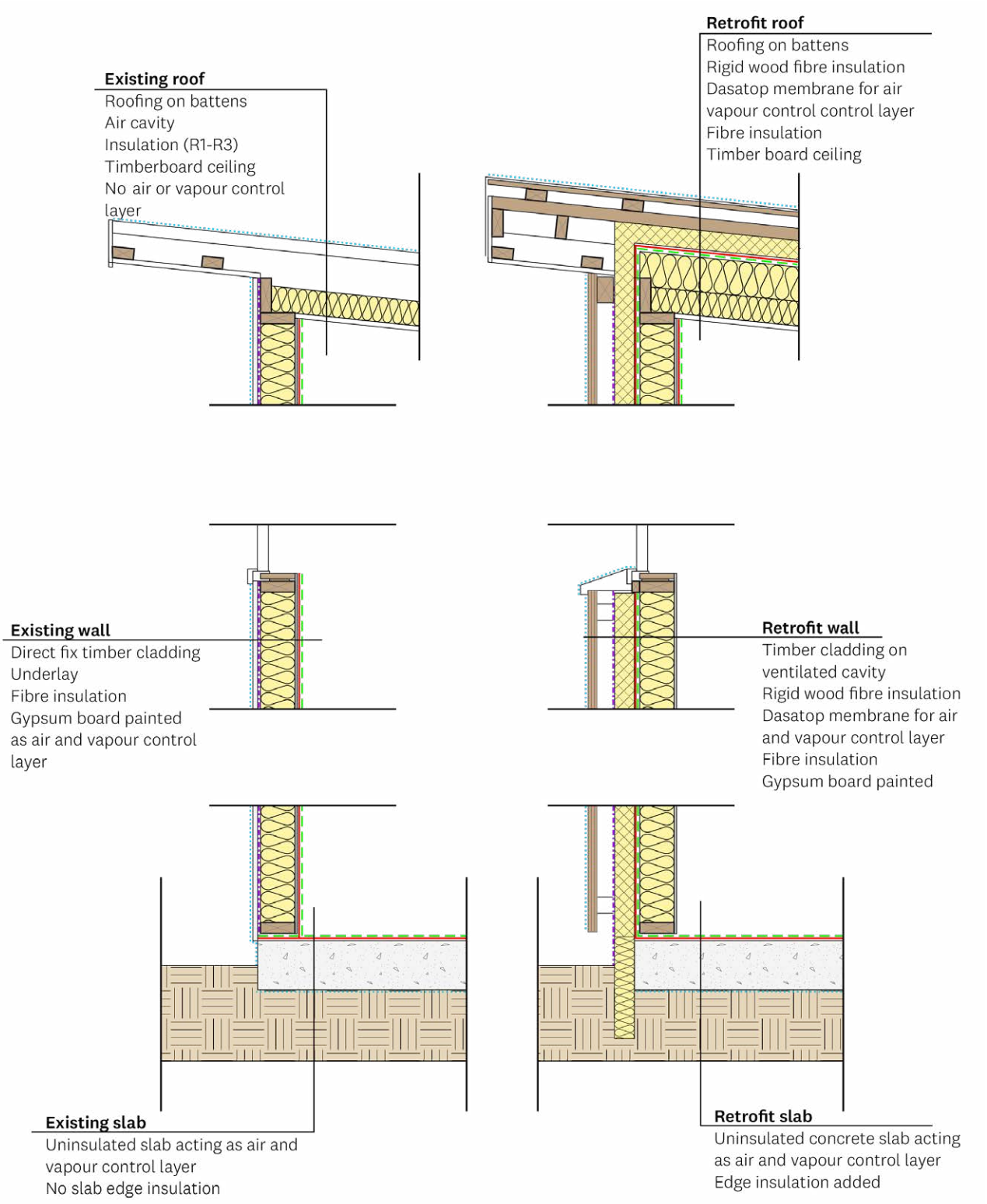


Figure 54: 2D cross-section of the entire building graphic showing before and after for the building's key elements.

Floors The existing concrete slab lacked insulation, creating a significant thermal bridge. This was addressed by excavating the perimeter of the slab and adding a continuous layer of exterior edge insulation as illustrated above and shown in the photo below. Installing insulation above the slab to further improve floor R-values was not necessary in this northern climate and would have been disruptive and expensive given the strategy was to work from the exterior.



Figure 55: Slab edge insulation retrofit. EPS foam to bottom of footing.

Walls The walls were upgraded entirely from the outside. The existing board-and-batten Lawson cypress cladding was carefully removed and set aside. A specialist retrofit airtightness membrane was installed over the original wall framing, creating a continuous air control layer. An 80mm wood fibre insulation board was then fixed (see below), followed by cavity battens and reinstatement of the original cladding.



Figure 56: Wood fibre insulation over the air control layer on the outside of the original studs.

Roof The roof was also upgraded from the exterior. An airtightness membrane was laid over the existing rafters and meticulously taped. A continuous layer of wood fibre insulation was then installed (see below), transforming this assembly into a thermal-bridge-free warm roof. Hygrothermal modelling using WUFI software was carried out on this assembly.



Figure 57: Wood fibre insulation over the air control layer on the outside of the original rafters and ceiling insulation.

Windows The original windows were a weak link with regard to thermal comfort and the efficiency of the building's envelope. High-performance timber/aluminium windows made in New Zealand were installed in the middle of the new, thicker wall assembly to minimise thermal bridging. The risk of overheating from the large west-facing windows is mitigated by shade from existing mature trees and newly installed external shutters.



Figure 58: Window installed before external wood fibre insulation is fixed.

7.1.2 Building systems upgrade

System	Before	After
Ventilation	Opening windows	Balanced mechanical ventilation with heat recovery (MVHR)
Heating	Cast iron wood-burning stove	Heat pump for heating and cooling
Hot Water	Wetback on wood stove with solar thermal panel	Existing solar thermal panel retained, with heat pump hot water system backup
Wastewater	Composting toilet	Indoor flushing toilet with vermicast-based blackwater and greywater system



Figure 59: MVHR installed in the kitchen storeroom. Note the attenuator splitter on the top right.



Figure 60: Ductwork for MVHR with false ceiling to be fitted below.



Figure 61: Heat pump outdoor unit for hot water on the left, which powers the existing hot water storage tank inside. Heat pump outdoor unit for heating/cooling on the right with indoor high wall unit in the lounge.

7.1.3 Performance and outcomes

This retrofit was outstanding: thanks to the owner-builder's commitment and his very high standard of detailing, the project went over and above the EnerPHit standard, achieving full Passive House certification. The owner is delighted with how warm and inviting the home feels, especially when he walks in after long hours working outside in the cooler months.

7.1.3.1 Metrics

	Pre-deep energy retrofit	Post-deep energy retrofit	Units
Heating Demand	118	16	kWh/m^2/year
Heating Load	74	10	W/m^2
Useful Floor Area (TFA)	72	91	m^2
Form Factor	3.2	3.9	
Air leakage at 50Pa	12	0.6	ACH/hour
Primary Energy Renewable	67	49	kWh/m^2/year

The pre-retrofit data was estimated; heating demand assumed the building was maintained at 20˚C throughout for the heating season.

7.1.3.2 Construction details (with average insulation values)

Roof	R7.1
80mm Gutex Woodfibre insulation / 225mm Terra Lana in skillion roof/sarking	
External walls	R4.7
80mm Gutex Woodfibre insulation / 140mm timber-framed wall insulated with Terra Lana / GIB	
Floor	R0.38 (neglecting benefit of ground)
Existing concrete slab with Cupolex pods and new concrete slab with 200mm continuous EPS all externally insulated with a vertical wing of EPS edge insulation	
Glass	R0.88
ThermaDura low-e argon double glazing 4-18-4	
Windows	R0.7
ThermaDura Designline 78 series	
Ventilation efficiency	81% including duct losses
Steibel Eltron LWZ 180 (Balance)	

7.1.3.3 Key lessons learned

An exterior retrofit is minimally disruptive. The owner remained living in the house throughout the entire retrofit process.

Hygrothermal modelling is essential for new assemblies. The use of a novel (for New Zealand) assembly of wood fibre insulation over an airtightness membrane was validated with hygrothermal modelling to ensure it was safe and durable in Northland's climate. This required higher ventilation rates than standard.

The common issue of finding space for ventilation ducting was solved by cleverly routing it through a pantry, kitchen cupboards and wardrobes.

Certification provides a clear target and verified outcome. The owner valued having a measurable goal to work toward and the quality assurance provided by blower door testing and the final certification. He believes this proven performance will add significant value when it is time to sell his home.

7.2 Case study: deep energy retrofit of a concrete block and membrane roof home



Figure 62: Executive home in Auckland's western beaches. Photo of post-retrofit home.

Project team

Architecture Sang Architects

Passive House Design Sustainable Engineering Ltd

Mechanical Design Edge Innovation Ltd

Builder Bruyere Ltd

Certifier PHI Darmstadt Germany

This project is notable for being New Zealand's first certified EnerPHit project. This ambitious, determined undertaking involved stripping a large, luxury house back to its concrete and timber shell and rebuilding it to achieve world-class performance.

Problems Despite only being built in 2008, the original house suffered from significant design flaws. Most critically, mould was discovered in the ceiling cavity of the cold roof assembly, under the concrete deck on the mid-level and behind the walls of the downstairs bedrooms. A hygrothermal analysis of the original plans had predicted exactly this outcome. This discovery spurred the owner's commitment to a full, certifiable deep energy retrofit that transformed the home over a three-year period.

Motivation The masterplan addressed the two fundamental weaknesses of the original design: the uninsulated concrete structure riddled with thermal bridges and the moisture-prone cold membrane roof. The solution was to wrap the entire shell of the building in a continuous, unbroken layer of exterior insulation. This exterior insulation strategy aimed to eliminate thermal bridges, keep the entire structural mass warm and dry within the thermal envelope and convert the problematic roof into a robust and durable warm roof assembly.

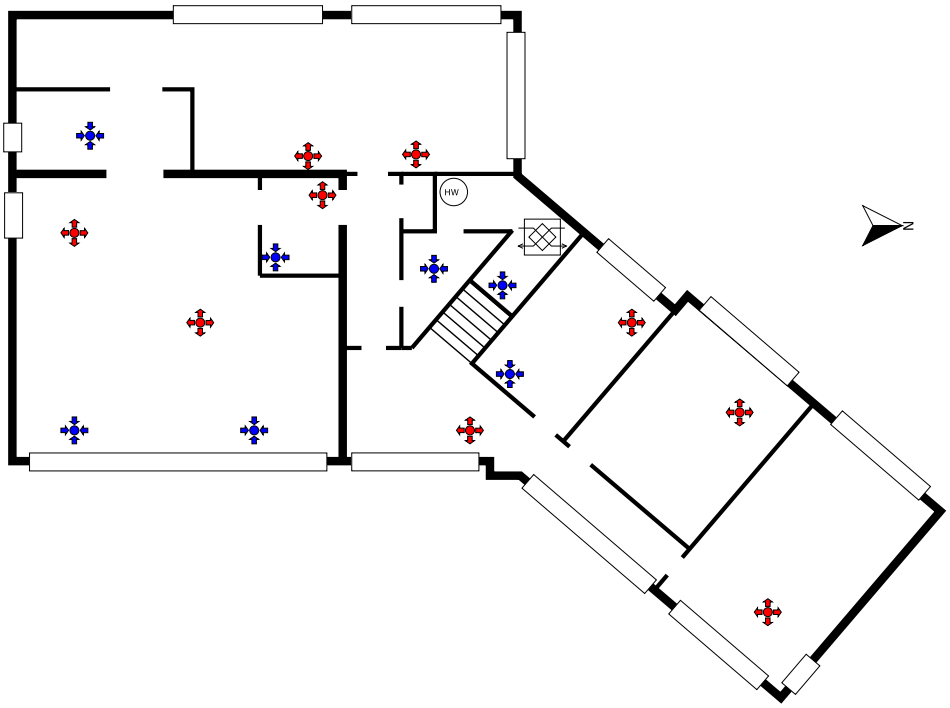


Figure 63: Ground floor post-retrofit . MVHR and hot water cylinder shown along with ventilation supply and extract terminals. The garage (lower left corner of the plan) is outside the thermal envelope but is ventilated at the same level as the rest of the home. Corresponding losses to the MVHR efficiency were accounted for in the energy model.

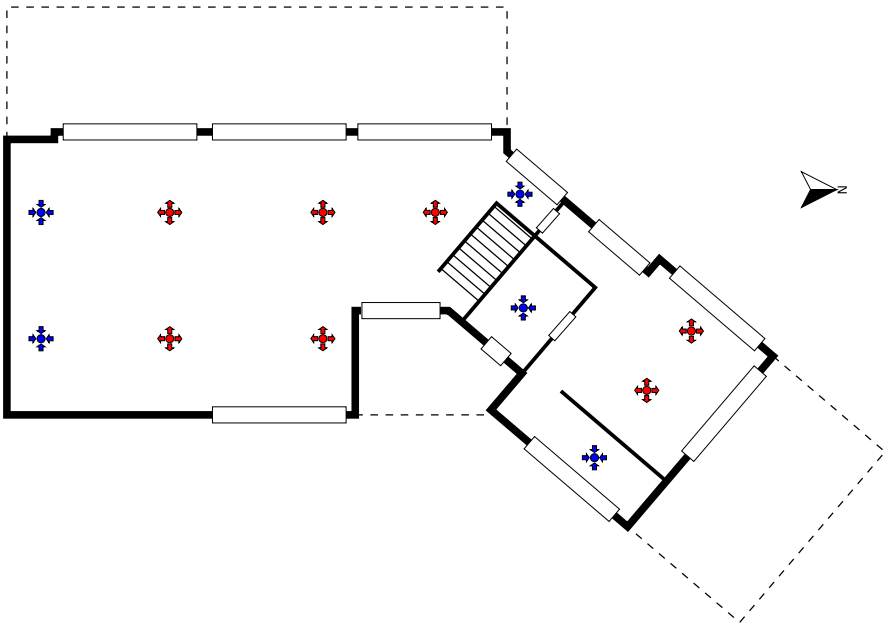


Figure 64: First floor post-retrofit showing ventilation supply/extract terminals.

7.2.1 Masterplan overview

Element-by-element retrofit strategies

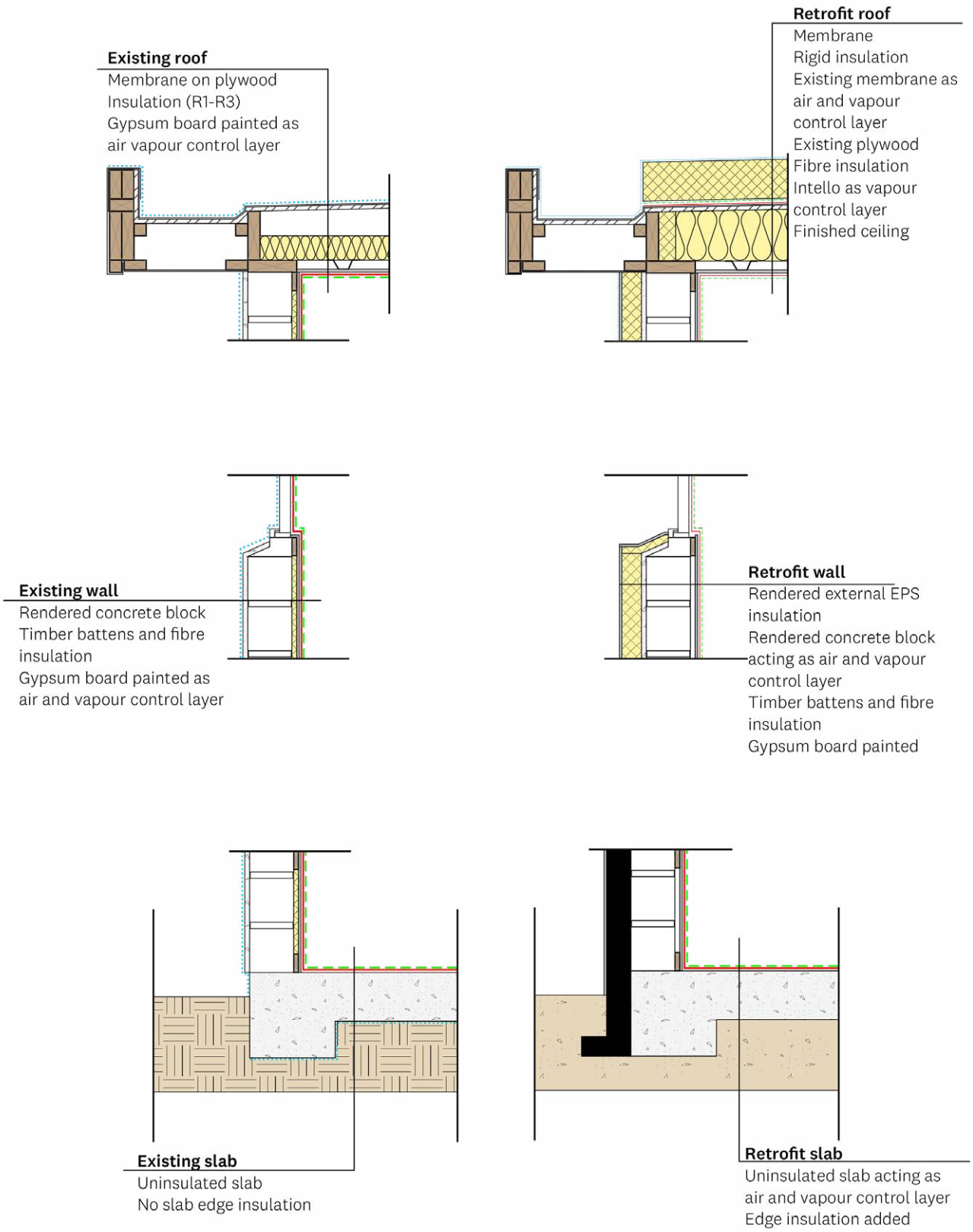


Figure 65: 2D cross-section of the entire building graphic showing before and after for the building's key elements.

Floors The existing slab had no underslab insulation and no edge insulation. Insulation could not be applied on top of the ground floor slab given the two-storey structure and low ceiling heights on the ground floor. Instead, the design focused on the critical thermal bridge at the slab edge. The perimeter of the building was excavated in order to install external wing insulation—a vertical layer of insulation against the slab edge extending 600 mm into the ground. This reduced perimeter heat loss, keeping the edge of the slab warmer and preventing the risk of mould developing at the floor-to-wall junction.

The area around the front door was problematic as installing wing insulation would have required a lot of damage to hard landscaping and extensive remediation. A thermal bridge model determined a smaller cut was acceptable. A neat slot was cut in the hardscaping to allow edge insulation only to be fitted to the slab in the vicinity of the entrance. This was sufficient to keep fRSI values in the safety zone. The primary concern was not thermal performance but ensuring the structure remained warm enough that mould could not develop.



Figure 66: 60mm rigid XPS foam insulation fixed to the edge of the existing slab. All construction photos supplied by Sang Architects and used with permission.

Walls The uninsulated concrete block walls were retrofitted entirely from the exterior. The existing plaster was repaired to act as the air control layer on the outside of the blockwork, followed by a thick, continuous layer of rigid insulation and StoTherm direct plaster system. This mitigated the significant thermal bridges created by the original materials and construction details.



Figure 67: Outside of existing render detailed as the air control layer in the external walls.



Figure 68: 100mm rigid EPS wall insulation fixed to the exterior of the concrete block wall assembly.

Roof The original cold membrane roof assembly was left as-is on top of the 19mm plywood deck as it remained in good condition. After stripping the underside of the roof back to its timber structure, all existing timber was sealed in epoxy paint as a best-practice mould encapsulation measure. A new, high-performance warm roof was then installed on top of the existing membrane. This involved laying a continuous thick layer of rigid insulation followed by a new waterproofing membrane. This keeps the entire roof structure warm and prevents moisture accumulation in the plywood from the warm air inside the home.

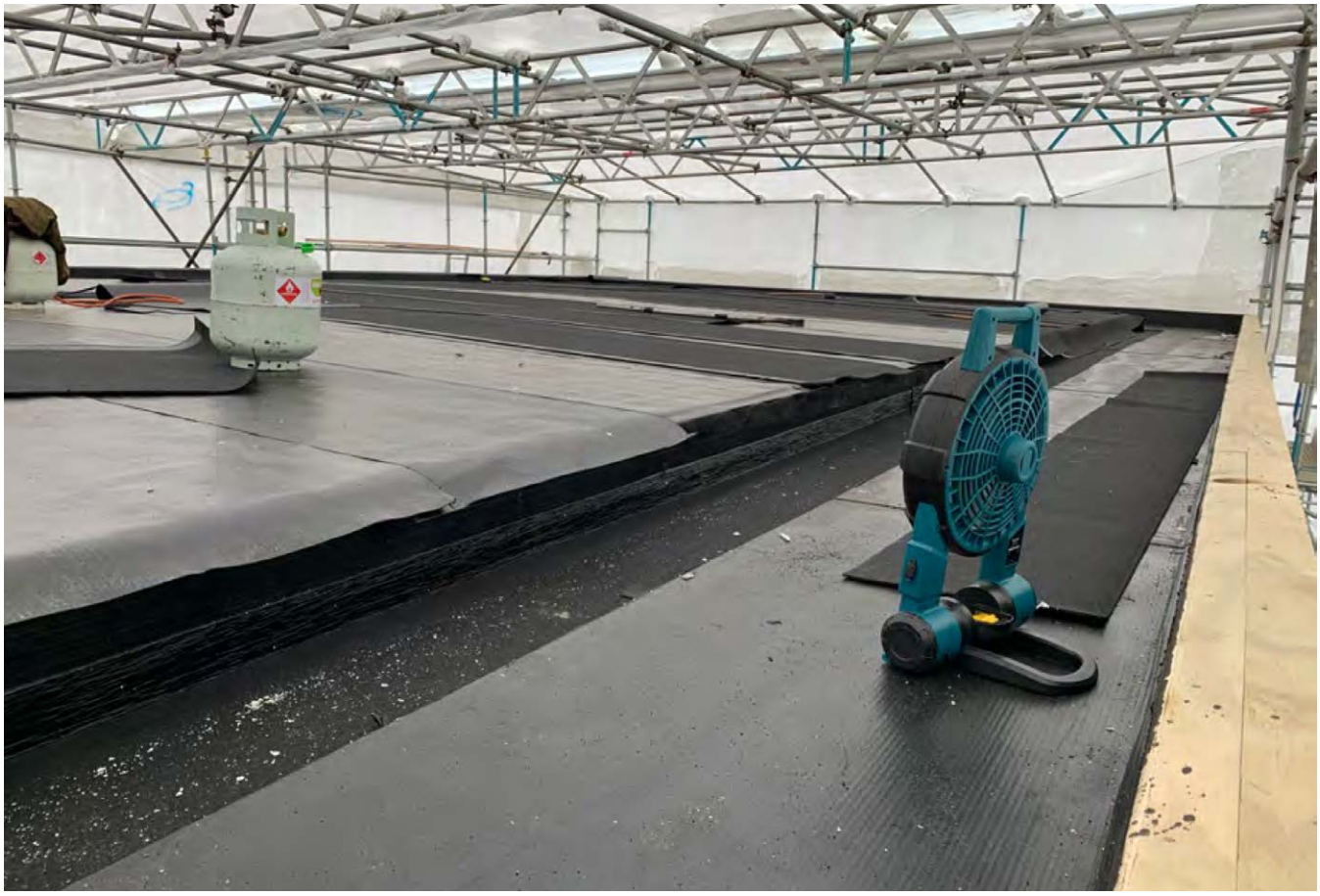


Figure 69: Building tented for roof renovation. The warm roof used existing cold membrane roof membrane as the air and vapour control in this assembly.

Junctions Minimising thermal bridges was a major focus and a challenge given the original drawings didn't always reflect the as-built reality discovered on site once construction was underway. Insulation details and thicknesses needed adjusting mid-construction as the team found they didn't have the space they expected to fit insulation, plus discovered thermal bridges not visible on the plans.

One significant challenge was the uninsulated concrete slab edges. Edge insulation was retrofitted and the small area of new concrete slab had underslab insulation.

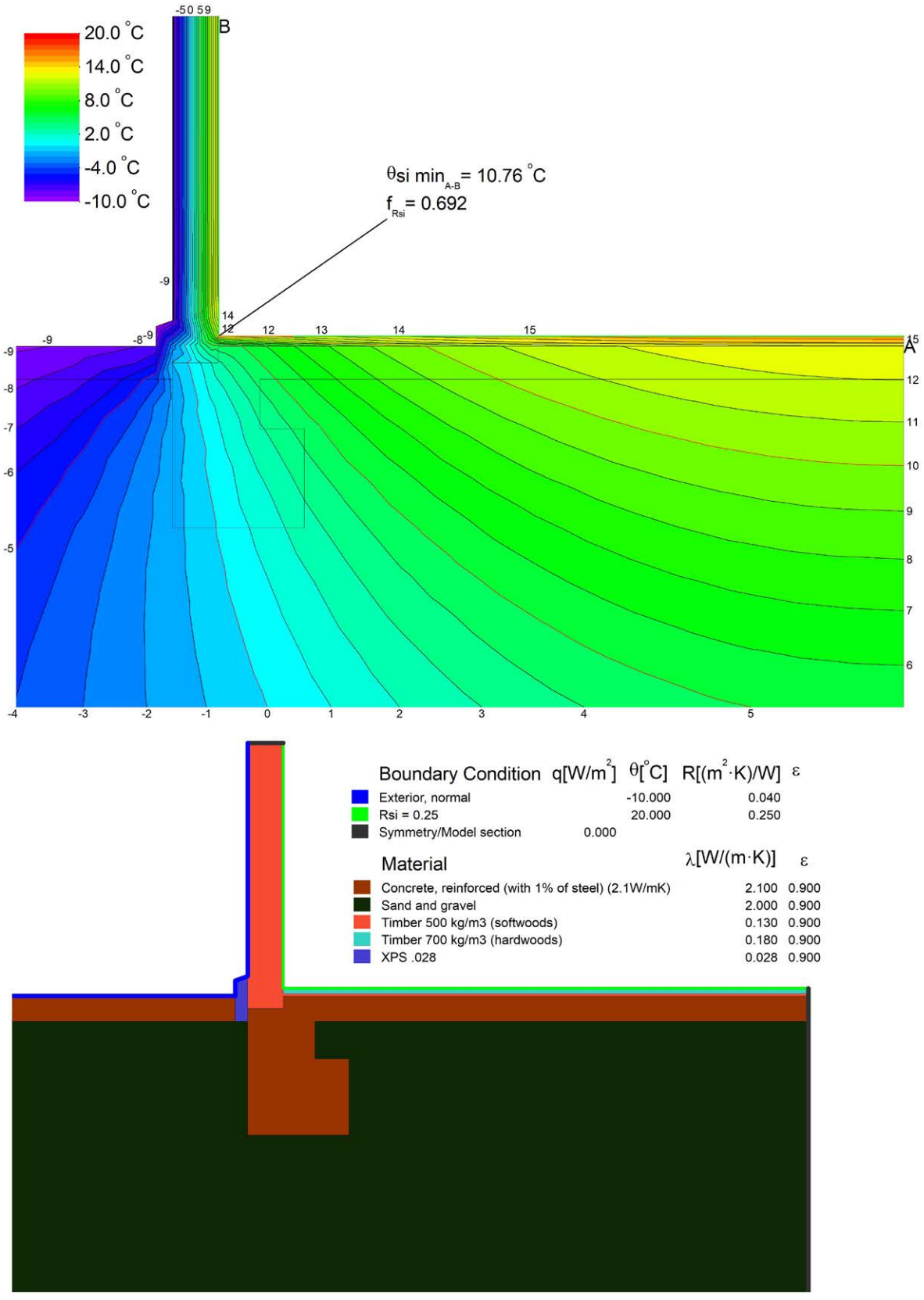


Figure 70: Slab edge insulation at paved areas. The remaining slab edge insulation went deeper into the ground but along paved areas this minimum depth was used to prevent having to rip out and re-pave.

7.2.2 Building systems upgrade

System	Before	After
Ventilation	Windows and glass louvres	Balanced mechanical ventilation with heat recovery (MVHR) and integrated central dehumidification.
Heating/ cooling	Wood fireplace, electric resistive heating	Concealed mini-split heat pumps provide active cooling and heating. Largely decorative wood stove, sealed with external air supply.
Hot water	Gas instantaneous	Heat pump hot water heater with demand-controlled recirculation loop with back-up systems for peak demand.



Figure 71: Mechanical room with hot water heat pump and solar hot water loop. The DHW system also includes a backup gas califont mounted on the exterior of the building, used during occupancy peaks. This all-in-one hot water heat pump has ducts to bring in outside air and return exhaust air to the exterior, allowing an interior installation.

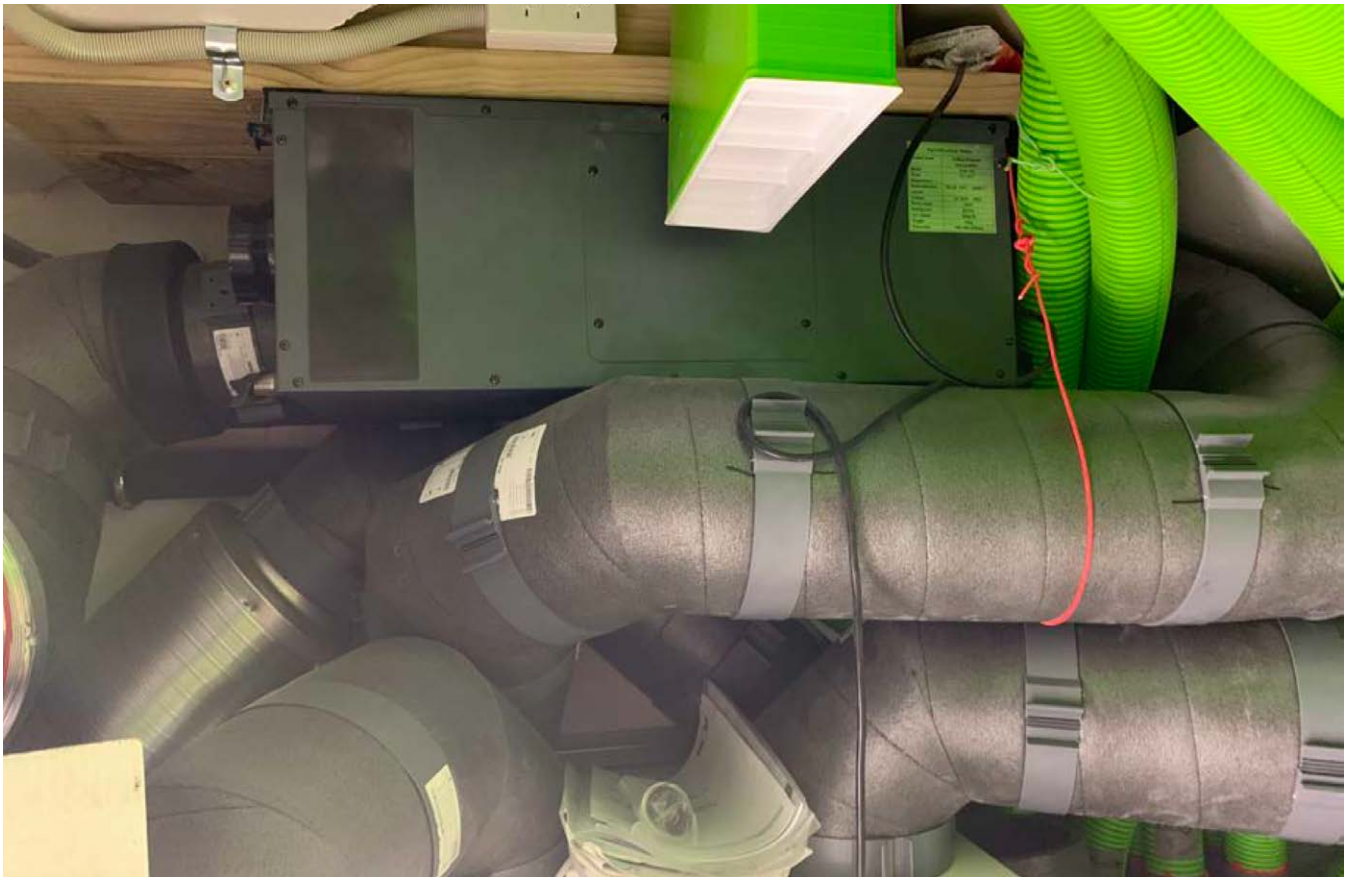


Figure 72: Dehumidifier installed above the MVHR and integrated into the ventilation system. This ensures the supply air has low humidity levels throughout the year.



Figure 73: Lounge with small, highly efficient wood burner. Not required for heating, it is rarely lit and generally when entertaining and the doors are open.

7.2.3 Performance and outcomes

The project achieved EnerPHit certification via the component method, a testament to the quality of the design and construction. The owners were delighted with the result.

7.2.3.1 Metrics

	Pre-deep energy retrofit	Post-deep energy retrofit	Units
Heating demand	213	27	kWh/m^2/year
Heating load	80	17	W/m^2
Useful floor area (TFA)	190*	221	m^2
Form factor	4.0*	3.7	
Air leakage at 50Pa	12*	1.0	ACH/hour
Primary energy renewable	180	60	kWh/m^2/year

* These pre-retrofit data points were estimated. Heating demand assumed the building was maintained at 20˚C throughout for the heating season.

7.2.3.2Construction details (with average insulation values)

Roof	R6.4
Nuralite warm roof 170mm of PIR on timber deck. Ceilings to decks insulated internally with 80mm Kingspan Kooltherm K10 board	
External walls	R3.8
StoTherm+ (100mm of graphite infused EPS outside the concrete block)	
Floor	R0.2 (neglecting benefit of ground)
Uninsulated slab on ground with edge and wing insulation retrofitted. New slab section insulated 50mm XPS.	
Glass	R1.0
Glass Team Cool-Lite SKN176 (4:/16/4 90% Ar)	
Windows	R0.9
SmartWin (SEDA)	
Ventilation efficiency	75% including duct losses
Wolf CWL-2-400	

7.2.3.3 Key lessons learned

Resolving concrete thermal bridges is non-negotiable given their poor energy performance and the likelihood of mould developing inside the building structure. Keeping the entire mass of the building warm eliminates the risk of internal condensation, along with condensation and mould at junctions like midfloors.

Expect surprises and respond in a methodical way. Discovering unexpected thermal bridges once deconstruction was underway added complexity. The changes this forced to insulation levels were made in collaboration with the energy modeller, who checked the implications of variations and confirmed acceptable solutions. The discipline imposed by working toward certified performance targets ensured such changes were checked and taken into account. It was sobering to realise the extent of additional heat loss in the pre-retrofit building, beyond what could be predicted based on analysis of the original construction drawings.

Cold membrane roofs with fibre insulation below them are a high-risk assembly in New Zealand. This project confirmed the predicted moisture risk of a traditional cold membrane roof and underscored that conversion to a warm roof is the most durable, low-risk solution for any low-slope roof retrofit.

Airtightness requires meticulous attention to penetrations. Even in a full renovation, achieving a high level of airtightness is a challenge. A significant portion of the remaining air leakage in this project was attributed to penetrations for the direct extract kitchen rangehood, fireplace and five lift-slide doors.

Active cooling is essential for highly glazed, high-mass homes. Despite a robust strategy to reduce solar heat gain with external shading and specialised low-SHGC glazing, the massive west-facing glazed areas meant that active cooling was still required for summer comfort. This highlights the importance of using predictive energy modelling to get a realistic understanding of overheating risk, especially when multi-million-dollar views dictate large glazing areas on high-risk orientations.

Video of the project is available at the end of this case study.

7.3 Case study: deep energy retrofit of two-storey timber-framed state house



Figure 74: Timber-framed two-storey duplex, a former state house. Damaged by an internal fire prior to the deep energy retrofit. Photo is pre-retrofit.

Project team

Architecture & Passive House design Robertson Architects

Builder QualMax Construction

EnerPHit certifier[67] Sustainable Engineering Ltd

This duplex was originally built in 1942 with timber framing, some brick veneer on the ground floor, a weatherboard-clad upper storey and minimal (if any) insulation. It is a very recognisable example of a state housing typology (New Zealand State House Plan 7E-115), which had been subject to some alterations during its decades in private ownership.

It suffered from the typical performance problems of mid-century housing: draughty, cold and damp in winter and expensive to heat. The owner-architect wanted to demonstrate that this common typology was suited to a systematic deep retrofit, transforming the 80-year-old structure into a healthy, comfortable and highly efficient home.

> "While uninsulated, the original state houses were a well-considered design for their time and easily retrofitted. This plan has a compact form, shared party wall, suspended timber floor and well-considered window area/placements. This one had a good orientation for solar gain."
> Murray Robertson, owner and architect

67 Project had not completed the certification process at time of publication.

Motivation The vision was to execute a methodical deep retrofit process based on predictive energy modelling that tested and validated every key decision. The masterplan prioritised an internal retrofit strategy, which would preserve the original weatherboard exterior while creating a new, continuous high-performance thermal and airtight envelope on the inside of the existing structure. This was an easy choice as a fire had destroyed the internal linings but left the structure and exterior elements intact. It meant working from the interior was practical and less expensive than the alternative.

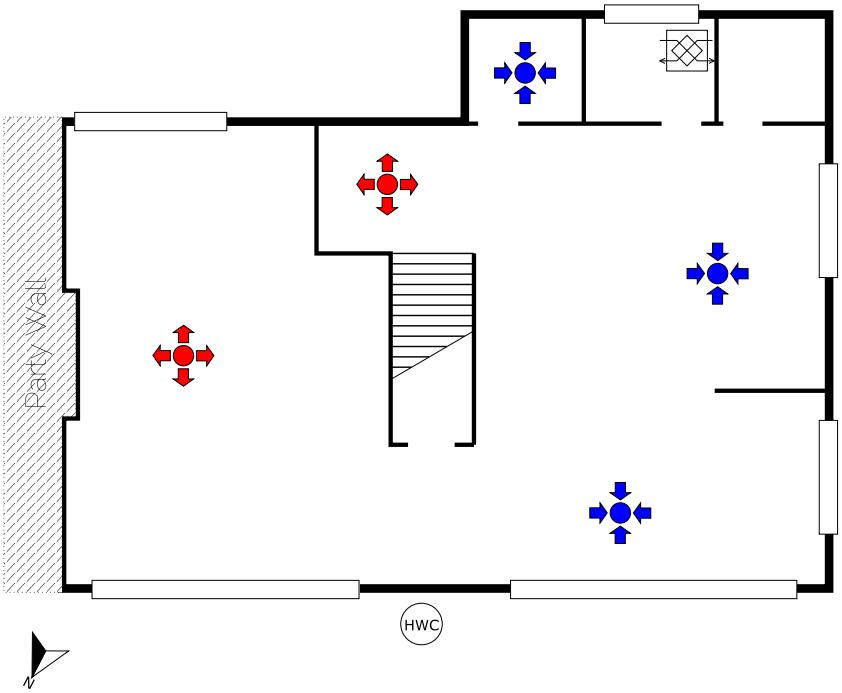


Figure 75: Ground level floorplan with MVHR location, hot water cylinder and ventilation supply/extract terminal locations.

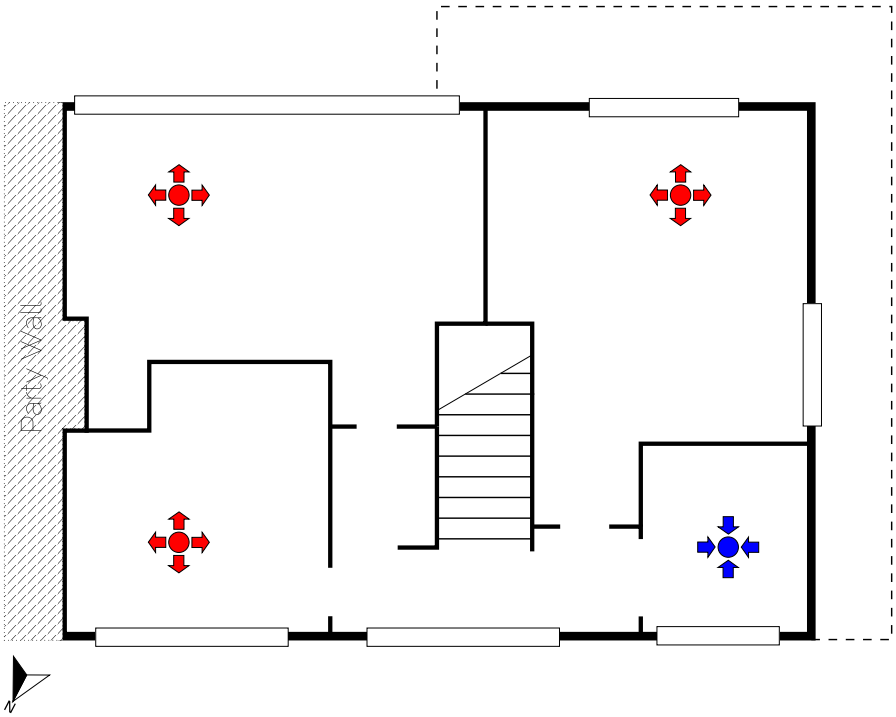


Figure 76: First floor plan with ventilation supply/extract locations.

7.3.1 Masterplan overview

Element-by-element retrofit strategies

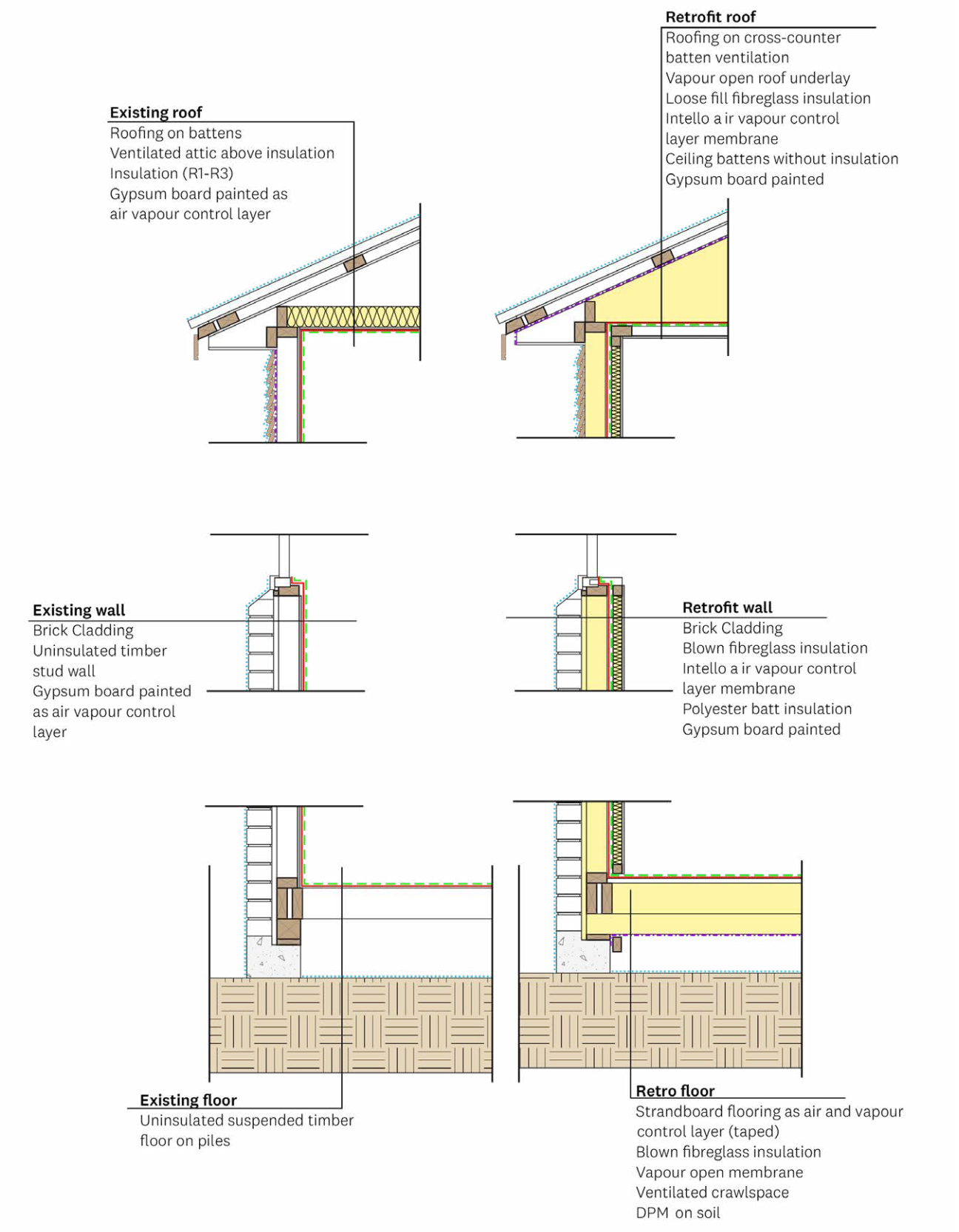


Figure 77: 2D cross-section of the entire building graphic showing before and after for the building's key elements

Floors During demolition, the contractors discovered an uninsulated concrete slab hidden below the flooring, where a laundry and porch had once stood. This issue was solved by fitting rigid foam insulation on top of the concrete. The remainder of the timber framed floor was insulated from below with blown fibreglass insulation as planned.



Figure 78: New strandboard flooring over the timber joists. This serves as the air and vapour control layer and is shown taped for airtightness.



Figure 79: Bare original floor joists with additional new joists on ground floor on left. Right photo shows the floor from beneath with insulation blown through holes in the vapour open membrane under the new strandboard flooring.

Walls The walls were upgraded entirely from the inside. The original exterior building wrap was found to be in very good condition behind the timber cladding—but not installed behind the brick. Existing interior linings were removed and the empty stud cavities were filled with dense-pack insulation blown through penetrations in the continuous air and vapour control membrane installed on the inside face of the original studs. Hygrothermal modelling verified that this assembly would be safe and durable, with the analysis showing that running the mechanical ventilation at a slightly higher rate would ensure the wall could always dry effectively. A service cavity was created before new interior linings were installed.



Figure 80: Windows installed and empty stud cavities with original brick revealed. Note new roof trusses as the fire destroyed the original roof.



Figure 81: Loose fill fibreglass insulation blown behind the vapour retarder air control membrane. Note membrane air and vapour control layer fitted to ceiling also. This is upstairs and the original flooring was retained.



Figure 82: Service cavity batt insulation installed (left) and then finished with plasterboard (right).



Figure 83: At the midfloor the existing timber floorboards were cut back to allow the air control layer to run continuously up the inside of the external walls. This was a clever solution for the airtightness but did cause issues with the timber floorboards subsequently moving. Retrofits often require custom solutions to details like this.

Roof The existing truss roof was upgraded from above. The first step was to create a continuous air control layer at the ceiling line, sealing all penetrations. Next a deep layer of new insulation was installed, ensuring all gaps were filled while maintaining clear ventilation paths in the attic space.



Figure 84: Roof membrane installed with ventilation above the membrane (cross-counter battens under metal roofing) to allow insulation to be in contact with the membrane.



Figure 85: Roof insulation is loose fill fibreglass blown into truss space over an air and vapour control membrane.

Windows High-performance, triple-glazed uPVC window units were specified for the entire house. These were carefully installed and meticulously taped to the new internal air control layer to ensure a continuous airtight connection.



Figure 86: New uPVC windows were installed throughout. The two sections on the right are fixed and the last is a tilt-turn unit shown tilted. Operable windows are considerably more expensive than fixed and should be specified with due consideration.

7.3.2 Building systems upgrade

System	Before	After
Ventilation	Windows	Balanced mechanical ventilation with heat recovery (MVHR)
Heating	Inefficient resistive electric heaters	Small, right-sized high-wall heat pump
Hot Water	Old electric resistance cylinder	Heat pump hot water heater



Figure 87: The MVHR unit installation.



Figure 88: Heat pump hot water all-in-one tank and compressor. Above is the heating/cooling heat pump outdoor unit with a typical high-wall indoor unit in the lounge.

7.3.3 Performance and outcomes

The project successfully transformed a typical cold state house into a certified high-performance home, which met the rigorous EnerPHit standard.

7.3.3.1 Metrics

	Pre-deep energy retrofit	Post-deep energy retrofit	Units
Heating demand	413*	16	kWh/m^2/year
Heating load	138*	13	W/m^2
Useful floor area (TFA)	90	90	m^2
Form factor	3.0	3.0	
Air leakage at 50Pa	12*	1.0	ACH/hour
Primary Energy Renewable	427	50	kWh/m^2/year

*Estimated assuming the building was heated to 20˚C at all times.

7.3.3.2 Construction details (with average insulation values)

Roof	R8.1
400mm of Knauf Supafil at 12 kg/m3 (0.043), Pro Clima Intello, 50mm timber battens without insulation, 13mm gypsum plasterboard	
External walls	R3.3 weatherboard, R4.3 brick
Existing weatherboards and underlay, 100mm of Knauf Supafil at 32 kg/m3 (0.032), Pro Clima Intello, 45mm Knauf R1.3 glass fibre batt (0.035), 10mm gypsum plasterboard	
Floor	R5.8 not including benefit of the ground
New strandboard subfloor, 125mm of Knauf Supafil at 32 kg/m3 (0.032) between joists, 100mm of Knauf Supafil at 32 kg/m3 (0.032) between bearers, Solitex Extasana membrane, crawlspace DPC	
Glass	R1.56 (g-value 0.49)
Clear/LightBridge/LightBridge (Planibel AS) Triple 4/14/4/14/4 (clear outside)	
Windows	R0.88 including installation losses
Starke uPVC	
Ventilation efficiency	79% including duct losses
Zehnder ComfoAir 180	

7.3.3.3 Key lessons learned

This project demonstrated the considerable value of a structured 10-step workflow that spanned from initial research and modelling through to final verification.[68] This process-driven approach is essential for managing the complexities and risks of a deep retrofit.

Retrofits always uncover surprises and budgeting for contingencies is crucial. Finding the old, unlevelled concrete laundry slab required the team to adapt the design on the fly.

Modelling and verifying high-risk (or simply novel) assemblies is needed. The internal wall insulation strategy was only approved after detailed hygrothermal analysis. This confirmed the wall assembly would be safe from moisture and therefore durable, so long as the ventilation rate was increased. This change from 0.3 to 0.5 ACH couldn't be predicted or quantified without undertaking the WUFI simulation.

A well-briefed team is essential. Getting the entire construction team aligned on the "why" of the project from the beginning is critical. Many of the techniques for airtightness and thermal-bridge-free construction are new to tradespeople, so clear communication and a collaborative approach are necessary.

68 Murray Robertson. (2023). State House to Passive House – Deep Retrofit Workflow in 10 Steps. *Robertson Architects.* June 5 2023.

8 Further Resources

Links to online technical drawings library, tools and resources

High-Performance Construction Details Handbook. Includes detailed thermal modelling of common and high-performance construction details. Provides numbers for the benefit of recessing windows. https://passivehouse.nz/hpcd-handbook/

Passive House for New Zealand – The warm, healthy homes we need. Short layperson's guide to the Passive House standard and the first 26 projects built and certified in New Zealand. https://sustainableengineering.co.nz/library/ph4nzwarmhealthyhomes/

Homestar Design Guide. Excellent guide to the NZGBC Homestar program and how to apply the Homestar design process to new homes. https://nzgbc.org.nz/homestar-design-guide

NZS 4246:2016 Energy efficiency – Installing bulk thermal insulation in residential buildings. This standard needs updating and an insulation quality grading system but is a good solid start. It is cited in the Residential Tenancies Regulations 2019 for healthy homes and is a Building Code compliance document for new buildings. It has been sponsored for free access by MBIE. https://www.standards.govt.nz/shop/NZS-42462016.

OutPHit. This European programme has great resources for retrofit at scale. Much of the technical data is summarised here: Jan Steiger (2024). D4.6 Deep renovation guidelines. Passive House Institute.

9 Homeowners guide to a deep energy retrofit

A deep energy retrofit is a well-planned, systematic upgrade of your home that takes into account your particular goals and priorities. It considers the opportunities and constraints specific to your house: the climate, its orientation, shading and local planning regulations. It's the opposite of a shallow, one-size-fits-all approach.

Deep energy retrofits offer big benefits in multiple ways. There's immediate benefit for the occupants. The process transforms a cold, draughty, damp house into a home that is healthy, comfortable and will last longer with less maintenance. The bill for heating and cooling is dramatically reduced.

Deep energy retrofits are the ultimate in green building. From a sustainability point of view, it's better to fix what we have rather than knockdown and rebuild. Deep energy retrofits at scale would powerfully benefit the environment and our country's goal to reduce greenhouse gas emissions and mitigate the impacts of climate change.

Deep vs shallow (or, planned vs ad hoc)

So far New Zealand's approach to improving housing stock has been generic solutions that are usually focused on a single goal or intervention. Government incentives to install extra insulation is a good example. But buildings are systems, full of interconnected parts and systems. Changing how one thing works has knock-on effects and not all are beneficial. For example, retrofitting insulation into wall cavities will keep the house warmer in winter but unless it's well planned, it could lead to mould and eventually rot in the framing in some circumstances.

Generic solutions aren't a good idea when it comes to retrofitting housing for better health, comfort and energy-efficiency. It's also not advisable to generalise based on the age or style of the house because there are too many individual variables. It's vital we don't rely on overseas retrofit guides, from far away countries that use different construction methods and materials. Deep energy retrofits have to rely on New Zealand-specific knowledge and expertise.

Although Passive House (aka Passivhaus) was developed in Europe, it's an independent performance standard, so can and has been successfully used all around the world. Most people associate it with new buildings but there is a specific Passive House Institute certification called EnerPHit for retrofits. It's not essential to seek certification for a deep energy retrofit but the EnerPHit model provides a very helpful framework with several options for meeting the targets. It recognises that retrofitting is harder than a new build, because significant factors like building orientation or a concrete foundation are already set.

Search the internet for "EnerPHit projects NZ" to learn more

A deep energy retrofit follows a detailed plan that avoids risk and delivers the most value for money spent. It doesn't have to happen all at once: the plan could extend over a decade or more, taking into account the circumstances of your family, your budget and your specific home.

A thought experiment

Think for a moment about what you really like about your current home—and what you wish you could change. Now imagine arriving at a future version of your home, where a deep energy retrofit has been carried out.

You walk in the door and it's good to be home. The air is fresh and clean, there's no mustiness or damp. You close the door and it's quiet and peaceful inside: the noise from traffic or neighbours recedes. The power bill has arrived and you're amazed again at how much money you're saving even while the house has never been so comfortable to live in.

Waking up on a winter's morning, the windows are dry: no more mopping condensation off the sills. It's a healthy, comfortable temperature in the kids' bedrooms, the same as the rest of the house. You've slept well, helped by the excellent indoor air quality; it's easier to get out of bed and there's no need to put off going to the bathroom because it's so cold. You realise you haven't been sick once yet this winter and your youngest hasn't needed their asthma inhaler for a while.

Reading the news headlines over breakfast reminds you that the choices you made have a wider impact. Your family is thriving but the country is doing better too. News articles talk about the rapid shift away from residential gas connections and how the risk of rolling blackouts has faded. Some expensive new electricity generation projects have been shelved because the spikes in winter power demand have flattened out. Commentators are saying that widespread improvements in household energy efficiency is a major factor. New Zealand is back on track for meeting its 2050 climate change mitigation goals.

All of this is possible.

Different pathways, same goal

Every deep energy retrofit is an individual strategy for your home. There are two pathways to get there: step-by-step or all-at-once. Which is best depends on your circumstances.

Step-by-step

Your analysis and strategy is figured out at the beginning and then actual construction work happens in distinct phases. It might take a few years to work through the phases, or a decade or even longer. This is generally the most cost-effective way to tackle a deep-energy retrofit because a phase usually starts when a building component has reached the end of its life. You're already faced with the cost of replacing the roof or your windows, so it's more feasible to choose better quality and more energy efficient or healthy new components.

You don't get all the benefits all at once, but you don't have to fund it all in one hit either.

All-at-once

Starting with the same analysis and strategy, your family goes all in. You'll have to move out for a bit while all the upgrades are carried out during a single construction process. People are more likely to choose this option if they've bought a dilapidated do-up or were planning a major renovation anyway, such as adding an extension or moving walls around.

Your home will literally be transformed but the entire budget is needed now. Some building components will be replaced before they have worn out, but they may be re-purposed in your renovation or find new life in another project.

Read more about these two pathways, including example scenarios, in Chapter 1 of Deep Energy Retrofit for New Zealand

A masterplan is always the first step

It's not a deep energy retrofit if it doesn't start with some solid analysis about the current state of your house and the development of a detailed strategy for integrating all the changes to building components and systems. The masterplan is developed by a suitably experienced professional. This person may be an architect or architectural designer, a builder, an engineer or a certified Passive House professional. Your specific circumstances, requirements and budget will very much shape the plan.

The masterplan also considers the risk profile of each specific project. Blown-in wall insulation might have been a great move for a friend's house–but this solution might be high risk for you because your home is made from different materials in a different era. This example shows the value of having expert, independent advice at the masterplan stage.

Without a masterplan, changes will amount to a series of shallow retrofits and money and opportunities will be wasted. Starting with a strategy ensures every dollar spent contributes towards the final goal. Every step builds on the previous work and provides scaffolding for the next phase. For example, well thermally insulated windows are installed in a specific way that means they can be reused in a few years when the house is reclad and wall insulation is added.

A masterplan helps avoid the lock-in effect. That's a way of describing the trap where cheap upfront choices become expensive long-term problems. Say you need to replace the windows in your house because the uninsulated aluminium frames are at the end of their life. You opt for double-glazed windows but the frames aren't properly thermally broken (that means heat moves through them and condensation will almost certainly form in winter) and the glass coating and spacers are mediocre. This choice locks in less comfort and higher heating bills for the entire lifetime of those windows, making it harder to justify earlier replacement with well-insulated glazing.

It's like buying a washing machine with a two star energy rating because it's a few hundred dollars cheaper than a five star model. You pay less upfront but you keep paying for that decision with higher water and energy bills. Your operational costs (and carbon emissions) are *locked in*.

9.3.1 The four key stages

The deep energy retrofit workflow follows four key stages, regardless of whether the construction work is staged or done all at once.

1. **Assessment and Masterplan (The 'look and plan' stage)**: A professional assesses your home's condition (from its insulation levels to potential hazards like asbestos), identifies constraints and opportunities and works with you to create a personalised high-level roadmap.
2. **Integrated Design (The 'draw and document' stage)**: The masterplan is turned into detailed, buildable instructions—architectural drawings for submission to council and from which a builder or quantity surveyor will cost the project. This is where specific products are chosen and critical junctions are designed to ensure the different components all work together over time.

3. **Quality Construction (The 'build and check' stage)**: Construction begins, carried out by a well-briefed team of builders and sub-contractors who are comfortable with new, improved ways of doing things.
4. **Handover and Education (The 'finish and educate' stage)**: The project is completed, and your design/build team walk you through care and maintenance of your new high-performance home and its systems.

While the NZ Building Code says a building consent is not required when 'replacing like-with-like', a deep energy retrofit very often falls outside of that exemption because the replacements have different functional properties or change the way building systems interact.

For more information, see Chapter 4 of Deep Energy Retrofit for New Zealand – Residential

9.1 The balanced approach: what to upgrade and when

You might have heard debate about 'fabric first' or 'systems first' as competing approaches to retrofitting homes. For a deep energy retrofit, you actually need both. They aren't competing ideas, but rather two halves of a whole. The best first step, however, depends on your priorities and budget.

- Upgrading your fabric means improving the building envelope to substantially lower heating and cooling costs.
- Upgrading your systems means switching to more efficient mechanical systems and appliances, for instance switching off gas and installing a heat pump for space and water heating.

If your primary goal is to quickly improve your family's health and comfort, starting with systems can provide the biggest immediate benefit while you plan for the fabric upgrades.

- **Ventilation** Every home needs an ongoing exchange of fresh air to keep indoor air healthy and to avoid a damp, unhealthy living environment. This is best achieved with continuous mechanical ventilation, which can be as basic as replacing old bathroom extract fans. A balanced mechanical ventilation with heat recovery (MVHR) system is the gold standard. It provides a continuous supply of fresh, filtered air to every room, removes stale damp air and there's only a tiny impact on heating or cooling bills.
- **Heating and hot water** Switching to a high-efficiency heat pump for both space heating and hot water provides immediate, affordable warmth and is a critical step in decarbonising your home. This single system upgrade can often reduce energy demand by 30-40% while maintaining the same level of comfort.

However, a deep energy retrofit is only complete when you pair these system upgrades with an upgraded building fabric. The building fabric or envelope is improved by employing four vital control layers that manage the movement of water, air, vapour and thermal (energy eg heat). A quality building envelope means an efficient building, which requires much smaller heating, cooling and ventilation systems. They are cheaper to buy and much cheaper to operate over their decades of use.

For more information about building control layers, see Section 3.6 of *Deep Energy Retrofit for New Zealand* – Residential

9.1.1 When to upgrade the fabric

The most cost-effective time to upgrade your home's fabric—its insulation, windows and airtightness—is when maintenance or replacement of components is due. Your masterplan ensures these opportunities are anticipated and a plan is in place ready to put into action.

- Re-roof: Substantially increase ceiling insulation, install a proper air control layer at the ceiling line and make sure the roof space is properly ventilated.
- Replace windows: Now's the time to install modern, high-performance double or triple-glazed units with thermally-broken frames and a low-e coating. Ensure they are installed so they can make use of past or future improvements to wall performance.
- Re-clad: Add a continuous layer of insulation on the outside of the wall and a robust air and water control layer. Working from the exterior is one of the most effective ways to improve building durability (preventing leaks and damp or mould) and improve energy efficiency.
- Renovate internally: A kitchen or bathroom renovation or moving internal walls provides access to the wall cavities, providing a chance to improve insulation and air sealing in that part of the house.

9.2 Assembling your team and ensuring quality

A deep energy retrofit is a team sport. Choosing the right players is essential for success.

9.2.1 Who you'll need

- A designer or architect: Look for a professional with proven, specific experience in deep energy retrofits. Ask to see examples of their work and talk to their previous clients.
- An energy advisor or modeller: This expert uses software like PHPP or ECCHO to guide your masterplan, verifying that the design will achieve your goals before a single dollar is spent on construction.
- A builder and sub trades: You need a construction team that understands the need for attention to detail. The quality of installation, especially for insulation and air sealing, is even more important than the quality of the products themselves.
- A project manager or retrofit supervisor to co-ordinate the entire process to ensure nothing is missed. This might be one of the above experts, in which case formally assign that responsibility, as it's not always included in the scope of works.

PROJECT TEAM DIRECTORY & CHECKLIST

Deep Energy Retrofit Roles, Responsibilities & Contacts

Project Address: .....

Date Started: .....

Retrofit Pathway: ☐ Step-by-Step ☐ All-at-Once

Masterplan Lead: .....

1. DESIGN & PERFORMANCE MODELING

DONE	ROLE & REQUIREMENTS	APPOINTED PROFESSIONAL / COMPANY	CONTACT INFO (PHONE / EMAIL)
☐	**Architect / Architectural Designer** Proven deep energy retrofit experience	Name / Business...	Phone / Email...
☐	**Energy Advisor / Modeller** PHPP or ECCHO software experience	Name / Business...	Phone / Email...

2. CONSTRUCTION & MANAGEMENT

☐	**Main Builder / General Contractor** Airtightness & insulation detailing focus	Name / Business...	Phone / Email...
☐	**Project Manager / Retrofit Supervisor** Formally assigned quality coordination	Name / Business...	Phone / Email...

3. SPECIALIST SUB-TRADES

☐	**Ventilation Specialist (MVHR)** Ducting design & balanced airflow setup	Name / Business...	Phone / Email...
☐	**Window Installer / Glazier** Experience with windows & flashing systems used	Name / Business...	Phone / Email...
☐	**Insulation & Air Sealing Installer** Airtight membrane & cavity insulation	Name / Business...	Phone / Email...
☐	**Electrician / HVAC Installer** Heat pump space & water heating systems	Name / Business...	Phone / Email...

MASTERPLAN VERIFICATION & NOTES

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.....

.....

.....

☐ Masterplan Completed ☐ Building Code Exemption / Consent Verified ☐ Team Briefing Held

A successful deep energy retrofit relies on a well-coordinated team where everyone understands their role. Sections 14B to 14G of the Building Act 2004 sets out clear legal responsibilities for each party involved in a building project, ensuring accountability and quality from the design phase through to the final construction. For a homeowner, understanding these roles helps you ensure your project stays on track and achieves its high-performance goals.

Here's who is responsible for what in your deep energy retrofit:

- **You, the owner:** You are ultimately responsible for the entire project. This means you must secure the necessary building consents (or make sure they are done) and ensure the final built work matches the high-performance plans you have approved.
- **The designer:** This is the professional, such as an architect or architectural designer, who creates the masterplan for your retrofit. Their key responsibility is to design a project that not only meets the Building Code but (if built as designed) will also deliver the warmth, health and energy efficiency you're targeting. If they are not also carrying out energy modelling, they should work closely with the person that is.
- **The builder:** The builder and their subcontractors are responsible for the physical construction work. In a deep energy retrofit, their most critical job is to follow the designer's plans precisely, as even small deviations in installing insulation or airtightness layers or substitution of products can significantly undermine your home's final performance.
- **The building consent authority:** This is your local council. They are responsible for reviewing your designer's plans to confirm they comply with the Building Code before issuing a building consent. They will also conduct inspections at key stages of the project to check that the work on site is following those approved plans.
- **Product manufacturers and suppliers:** These companies are responsible for ensuring the performance claims they make about their products, such as insulation or windows, are accurate. They must provide clear instructions so that when their products are installed in your home as specified, they deliver the thermal performance required for a successful retrofit.

9.2.2 Trust but verify

Quality shouldn't be assumed, rather independently measure and verify that you're getting what you paid for. The most fundamental quality assurance mechanism for a deep energy retrofit is committing to a recognised certification standard, such as EnerPHit or Homestar. Without a clear set of defined targets, it is common for projects to suffer from well-intentioned shortcuts, often added during the construction phase. These ad-hoc changes or compromises can quickly degrade the building's thermal envelope, resulting in sub-par performance that fails to deliver on the initial investment.

Targeting a certification standard from the outset of the project means every design decision and construction detail is scrutinised against a rigorous, objective benchmark. Within this overarching framework, some specific diagnostic tools will verify the physical work. The blower door test, for example, is a critical physical check run during and towards the end of construction to measure the building's actual airtightness.

Taken together, the certification standard and targeted physical testing provide clear, objective data on how well the work was executed, ensuring the home actually delivers the superior health, comfort, and efficiency that was designed.

9.3 Getting started

The first step is often the hardest. The journey to a high-performance home begins with the decision to make a comprehensive plan.

9.3.1 Finding your opportunity

The most affordable time to start your deep retrofit journey is when you are already planning a renovation or need to replace a major building component. By integrating high-performance upgrades into work that is already required, the additional cost is minimised while the benefits of the upgrade are maximised.

9.3.2 Financing your project

As deep retrofits become more common, new financing options are emerging.[69] Talk to your existing mortgage provider about green home loan top ups or personal loans and look around for better offers.

9.3.3 Your next steps

Feeling inspired but not sure where to begin? Here is a simple checklist.

1. **Find the right professional** While very few New Zealand designers or builders currently have extensive experience with deep energy retrofits, this is changing quickly. An accredited Passive House Institute Retrofit Expert, a certified Passive House tradesperson, or a Certified Passive House designer or consultant will all have useful skills.
2. **Ask for a masterplan** before you do anything else, invest in a comprehensive plan. It is the single best investment you will make in your project.
3. **Discuss the right first step** work with your designer to decide on the best first move for your family's priorities, your home's condition, and your budget.

69 Major banks offer low-interest or interest-free top-up loans for energy-efficient upgrades-



EECA ENERGY EFFICIENCY & CONSERVATION AUTHORITY
TE TARI TIAKI PŪNGAO

NZGBC NEW ZEALAND GREEN BUILDING COUNCIL
TE KAUNIHERA HANGANGA TAUTAIAO