Thermal bridging in timber-framed walls

BRANZ Webinar July 2021

Verney Ryan and Guy Penny, Beacon Pathway Inc

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Creating homes and neighbourhoods that work
well into the future and don't cost the Earth

Project background

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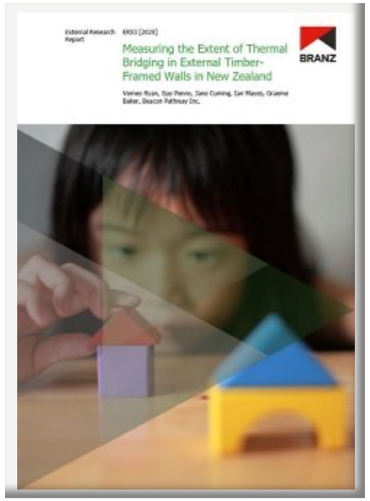
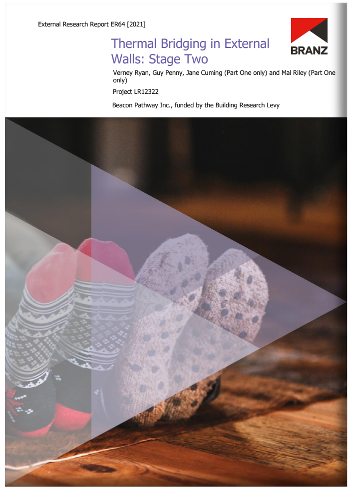
Aim is to deliver insights into:

- The scale of the issue of percentages of framing in New Zealand residential construction
- The effect that high percentages of framing, thermal bridging and weak points have on as-built R-values
- The causes/reasons why high percentages of framing might be occurring – working with frame and truss
- Exploring pragmatic and buildable solutions



Report ER53



Report ER64

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Thermal bridging

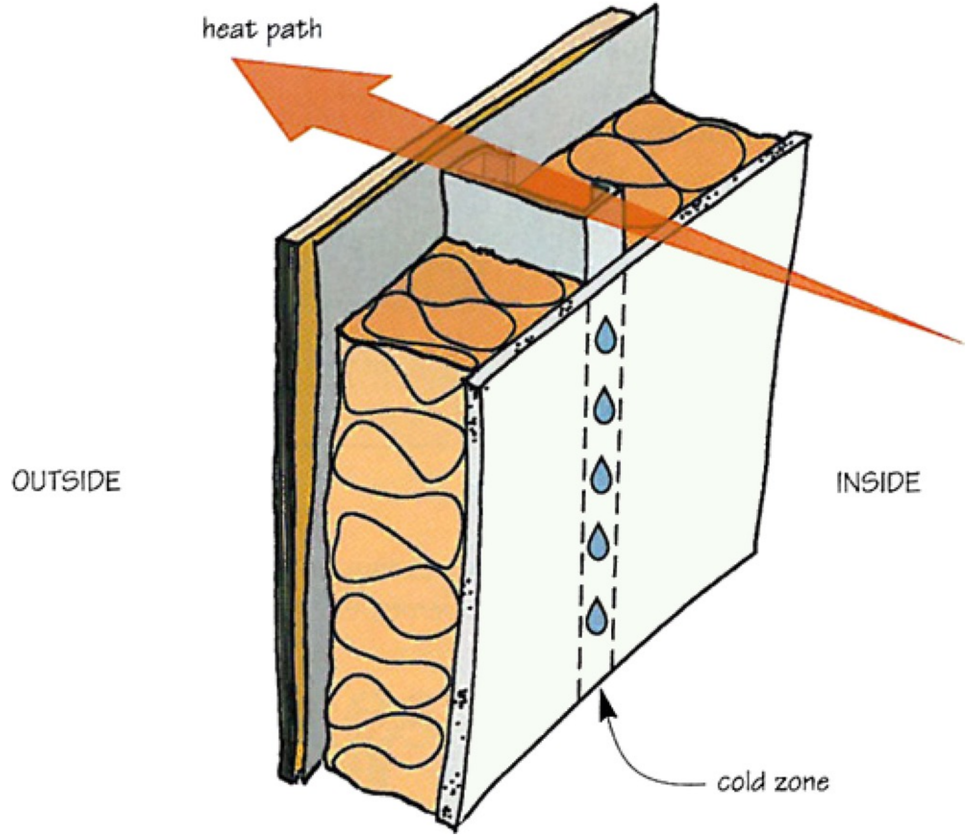


Image source: Build magazine *Condensation and thermal bridges*
Malcolm Cunningham, 1 April 2005, Build 87

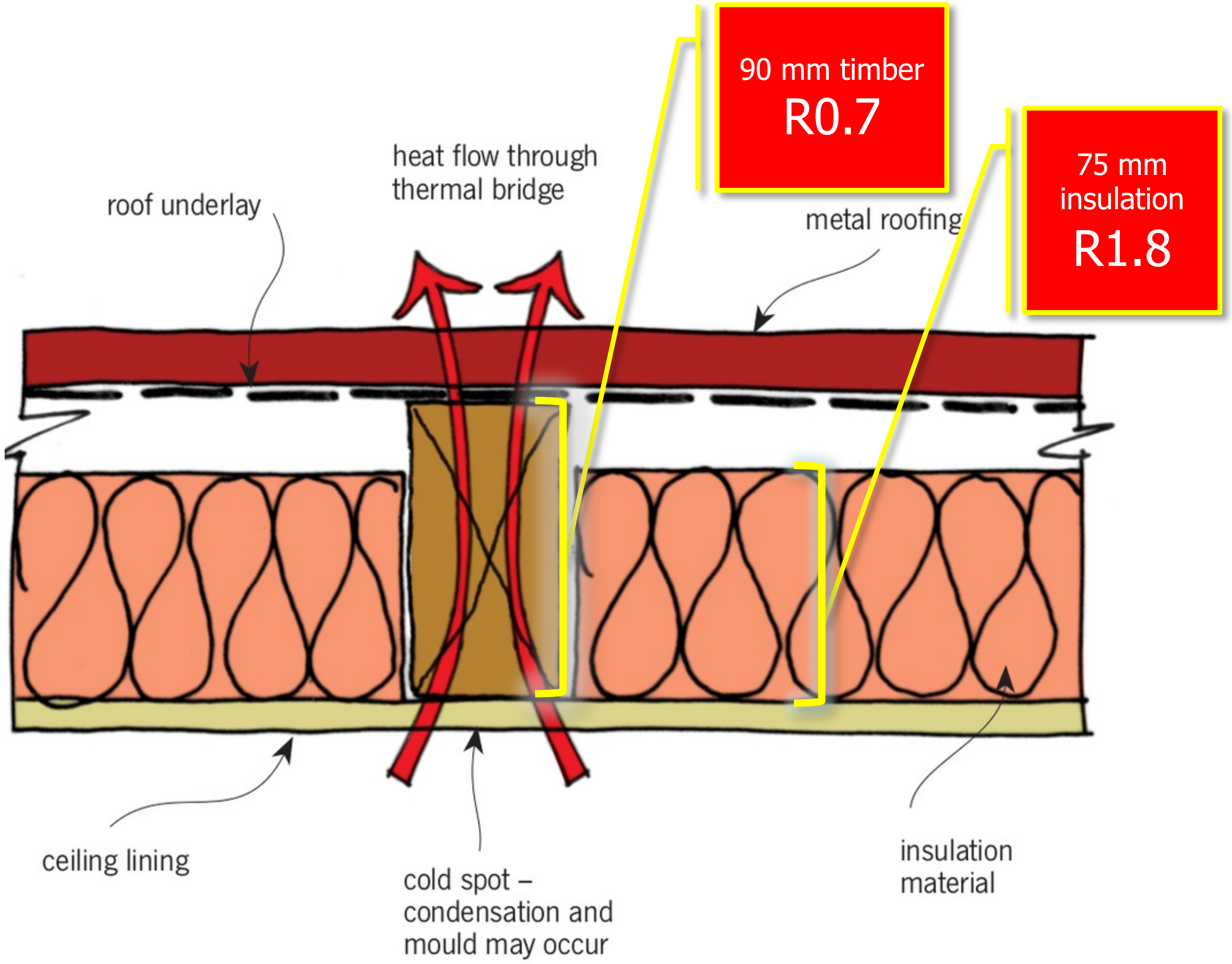
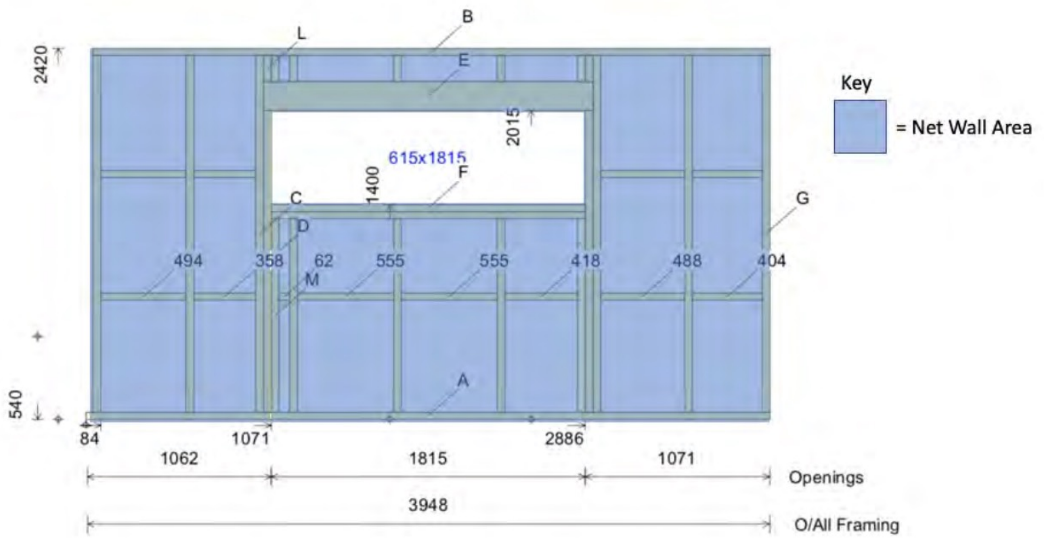


Image source: Build magazine *Aggravated thermal bridging*
Malcolm Cunningham, 1 December 2011, Build 127

Methodology

- Case study approach – 47 newly constructed houses from Auckland, Christchurch, Wellington and Hamilton
- Utilised combination of frame and truss elevations and wall panel layouts alongside site data collection
- Range of typologies, 1–3 storeys, variety of different builders, companies, range of different cladding types



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Frame and truss
Delivering 95%+ of all houses

Image source: https://www.thomsonsitm.co.nz/UserFiles/ThomsonsITM/Image/Frames%20and%20Truss/Generated/thomsons_itm_pre_nail_frames_and_truss_gallery_new09_midsize.jpg

Results

47 dwellings
71 separate building levels
1,103 individual wall panels
Thousands of sticks of timber

Headline results

- The average percentage of timber framing compared to the area of the wall is **34%**
- **Lowest 24% – highest 57%** (by level)
- Range of drivers – structure and weathertightness, cladding requirements, design
- Little additional framing added on site – average across house level = 2%
- There are some significant uninsulated areas – average 3% but up to 10% (area by level)

17% framing (net wall area)

25% framing (net wall area)

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30% framing (net wall area)

55% framing (net wall area)

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Key observations

- **34%** average wall framing … higher than **14–20%** framing content generally assumed by regulators and industry
- Unlikely to be getting expected performance across the whole wall
  - Construction R-values across whole wall area lower than expected
  - Thermal bridging and framing versus insulation as well as insulation installation
- Some distinct weak points and blind spots - midfloors, corner junctions, internal wall junctions, uninsulatable areas
- Areas of framing highest in those cold damp condensation-prone areas – bathrooms, laundries, ‘back of your south-facing cupboard’

NZS 4218:2009 Definition for framed walls

"This includes studs, dwangs, top plates, and bottom plates, but ***excludes*** lintels, additional studs that support lintels, and additional studs at corners and junctions"

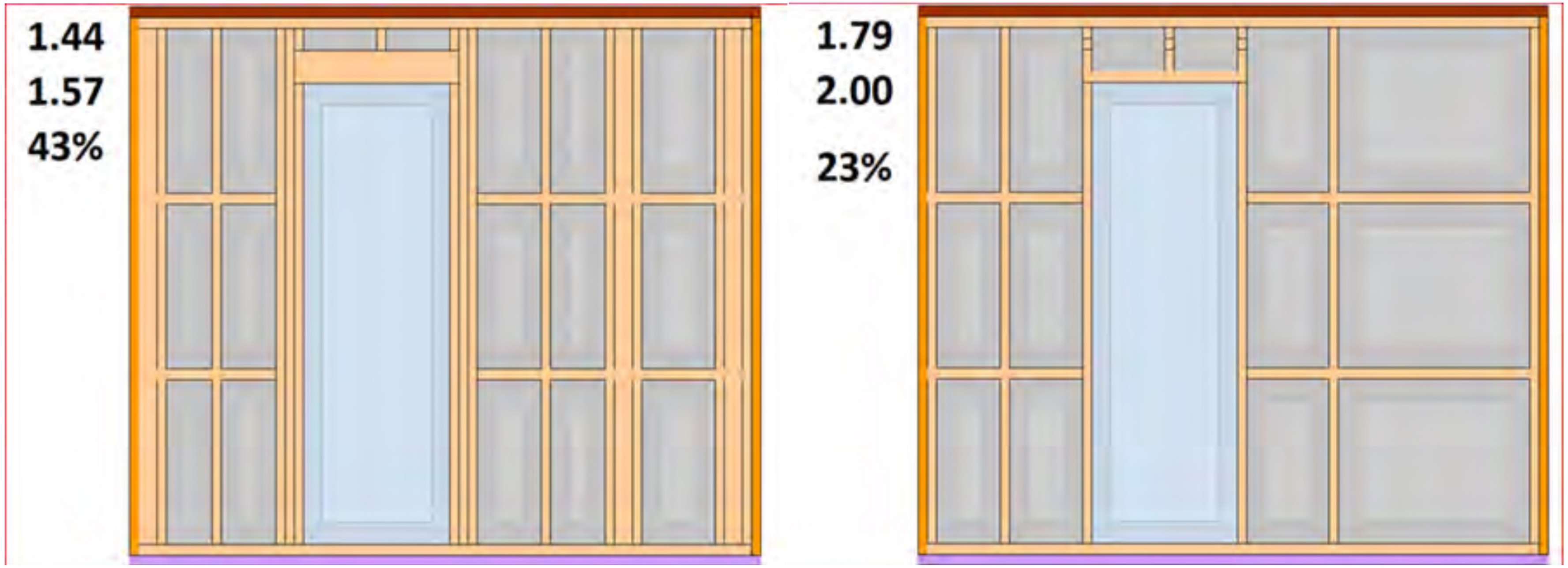

Figure 8: Actual timber framing (left) compared to allowable definitions under NZS 4218 (right)

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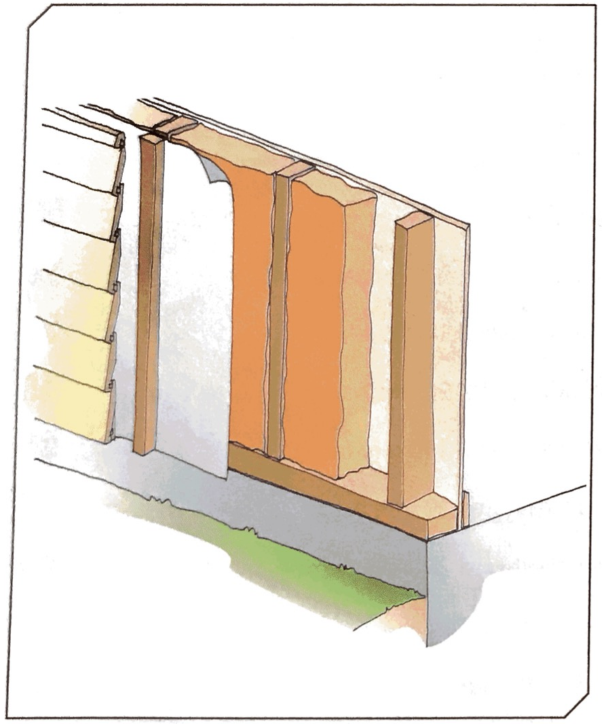
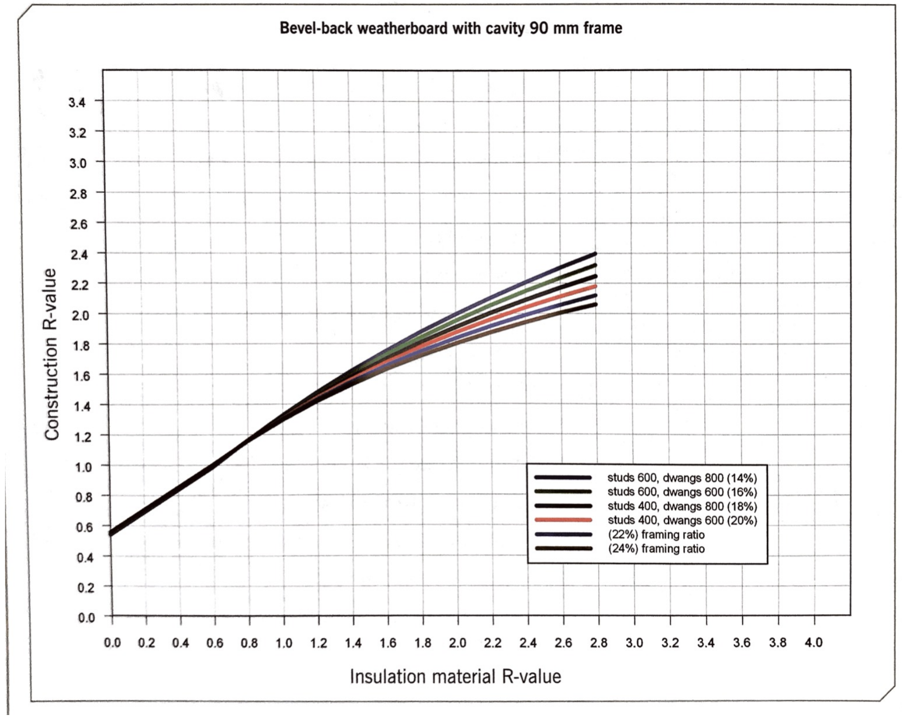
Every picture tells a story

Wall | **Bevel-back Weatherboard** | **Timber framed – cavity** 90 mm frame



Framing timber spacing	Insulation material R-value					
	1.8	2.0	2.2	2.4	2.6	2.8
	Total construction R-value					
studs 600, dwangs 800 (14%)	1.8	1.9	2.1	2.2	2.3	2.3
studs 600, dwangs 600 (16%)	1.8	1.9	2.0	2.1	2.2	2.3
studs 400, dwangs 800 (18%)	1.8	1.9	2.0	2.0	2.1	2.2
studs 400, dwangs 600 (20%)	1.7	1.8	1.9	2.0	2.1	2.1
(22%) framing ratio	1.7	1.8	1.9	1.9	2.0	2.1
(24%) framing ratio	1.7	1.8	1.9	1.9	2.0	2.0

1. All insulants should be placed against wall underlay
2. R-2.8 is the highest practicable R-value of common insulation materials that can be used with 90 mm studs



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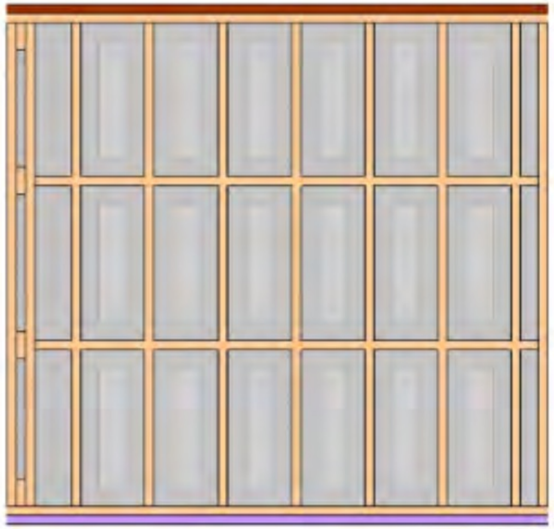
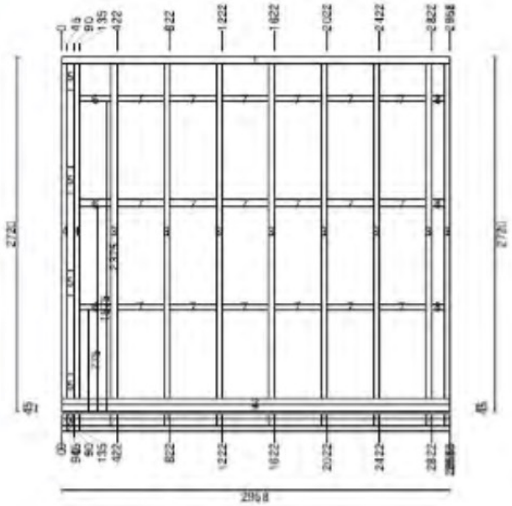
1.75
2.06

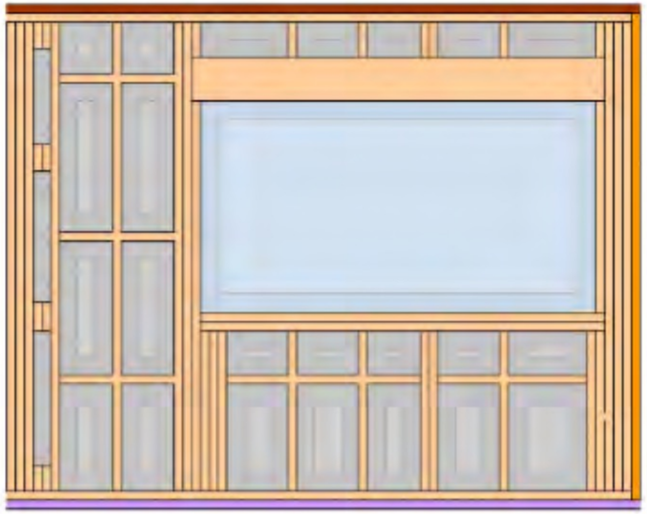


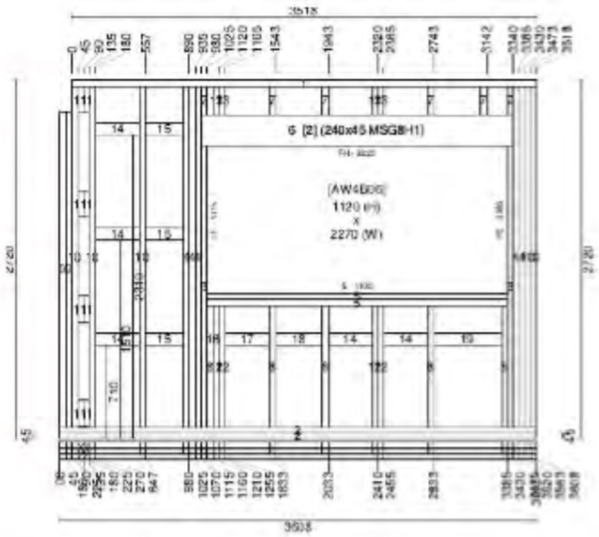


Area type: South West Living
Studs: 400mm centres
Nogs: 800mm centres

Net Wall Area:	7.1m^2
Framing %:	28.69%
Framing Area:	2.05m^2
Uninsulated Area	0.3m^2
R-Value with 2.0 insulation	1.75
R-Value with 2.8 insulation	2.06

1.39
1.51





Area type: North West Kitchen
Studs: 400mm centres
Nogs: 800mm centres

Net Wall Area:	6.2m^2
Framing %:	51.49%
Framing Area:	3.19m^2
Uninsulated Area	0.03m^2
R-Value with 2.0 insulation	1.39
R-Value with 2.8 insulation	1.51

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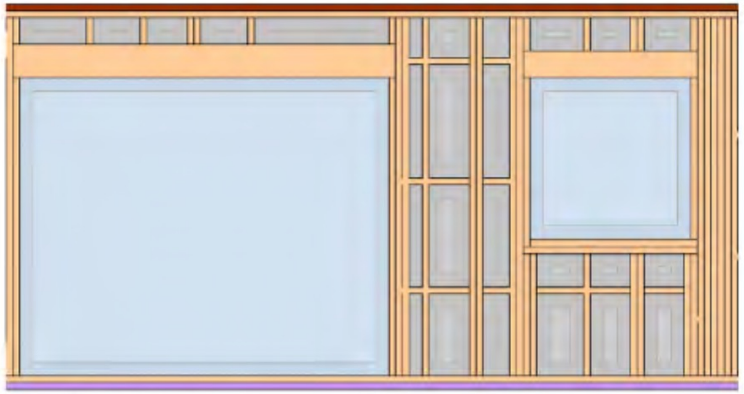
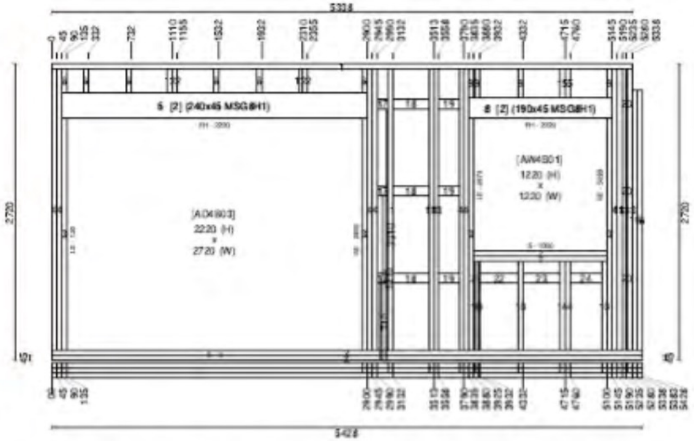
1.21
1.29

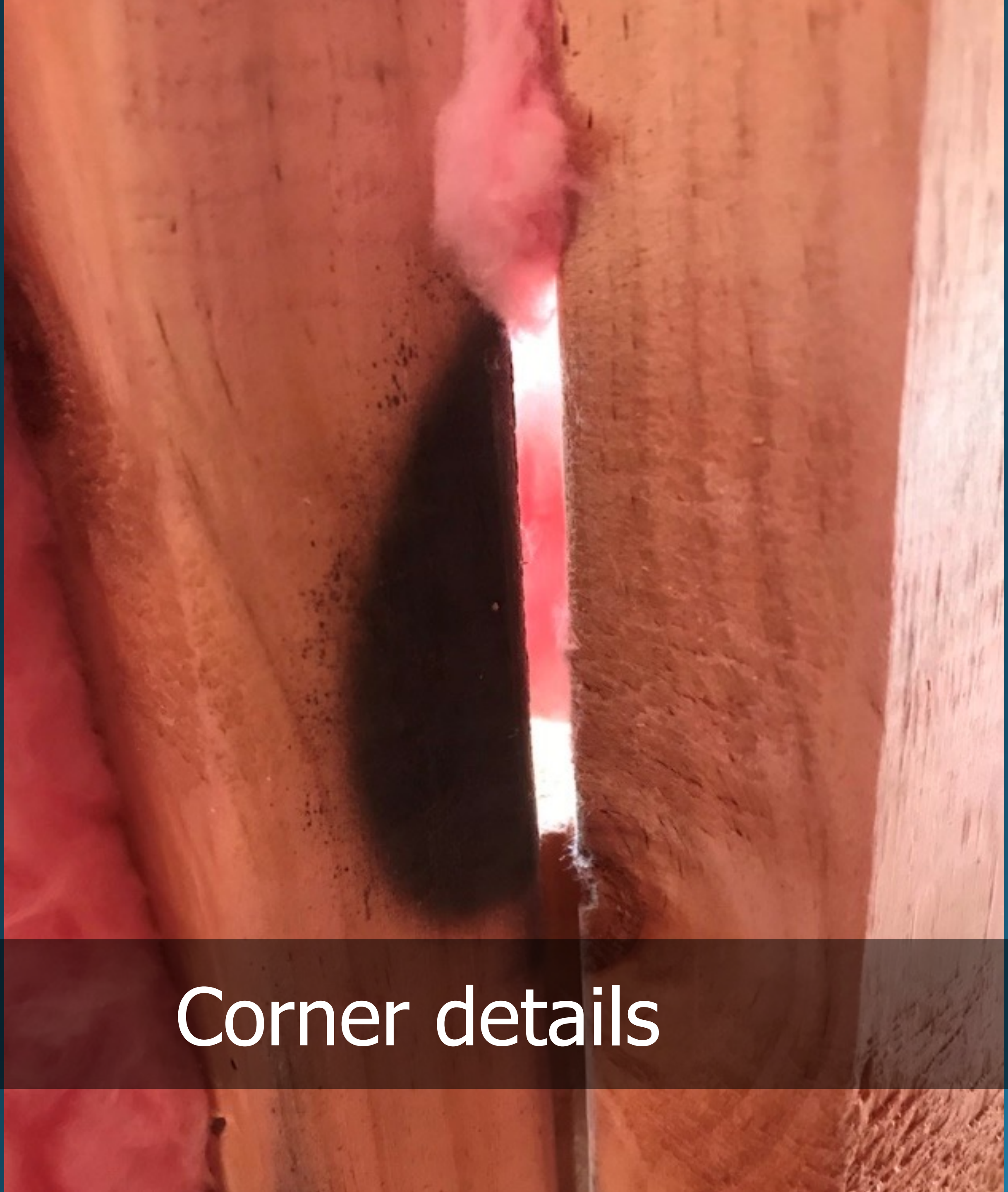


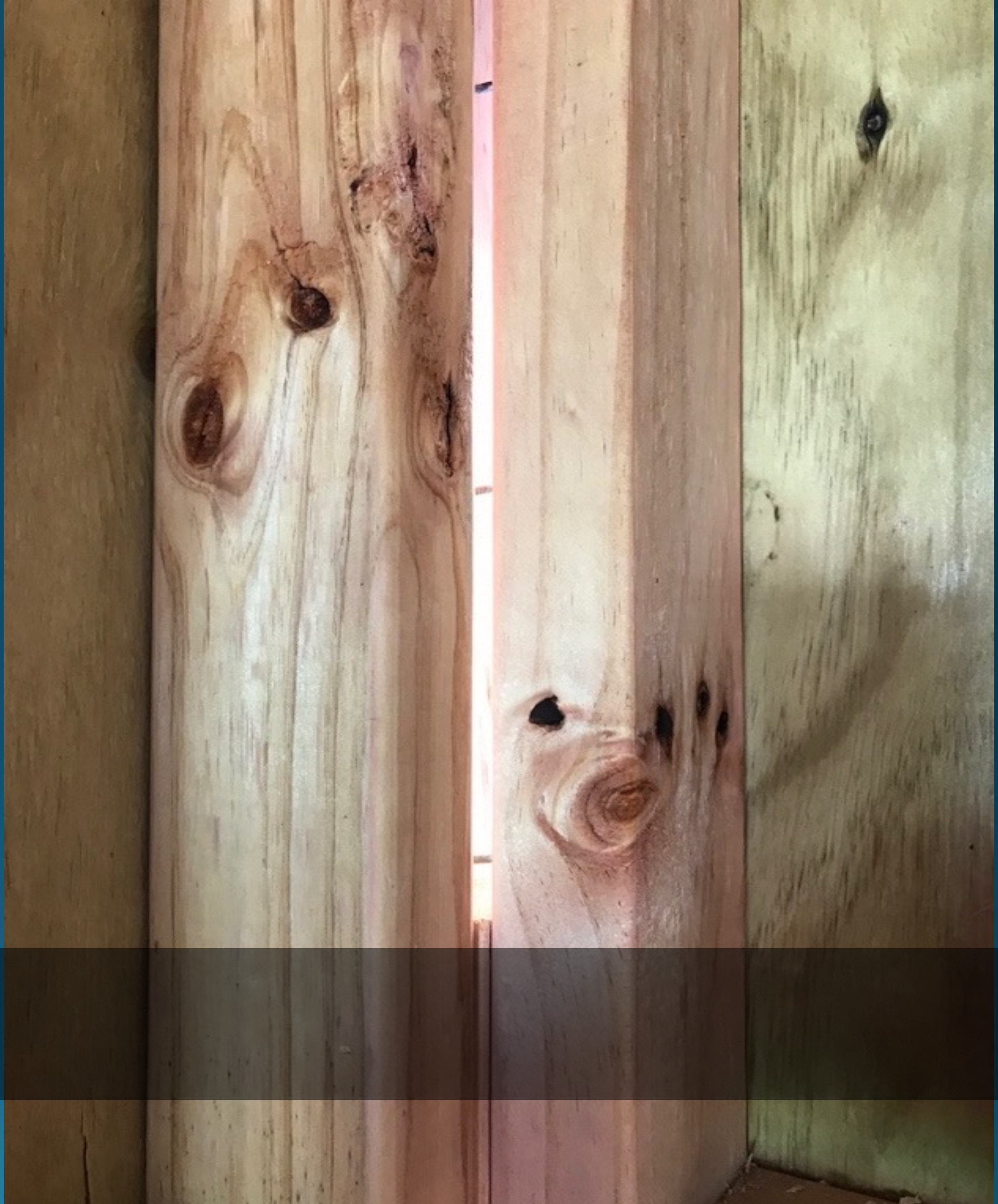


Area type: South East Living
Studs: 400mm centres
Nogs: 800mm centres
Net Wall Area: 5.6m²
Framing %: 57.99%
Framing Area: 3.25m²
Uninsulated Area 0.m²
R-Value with 2.0 insulation 1.21
R-Value with 2.8 insulation 1.29

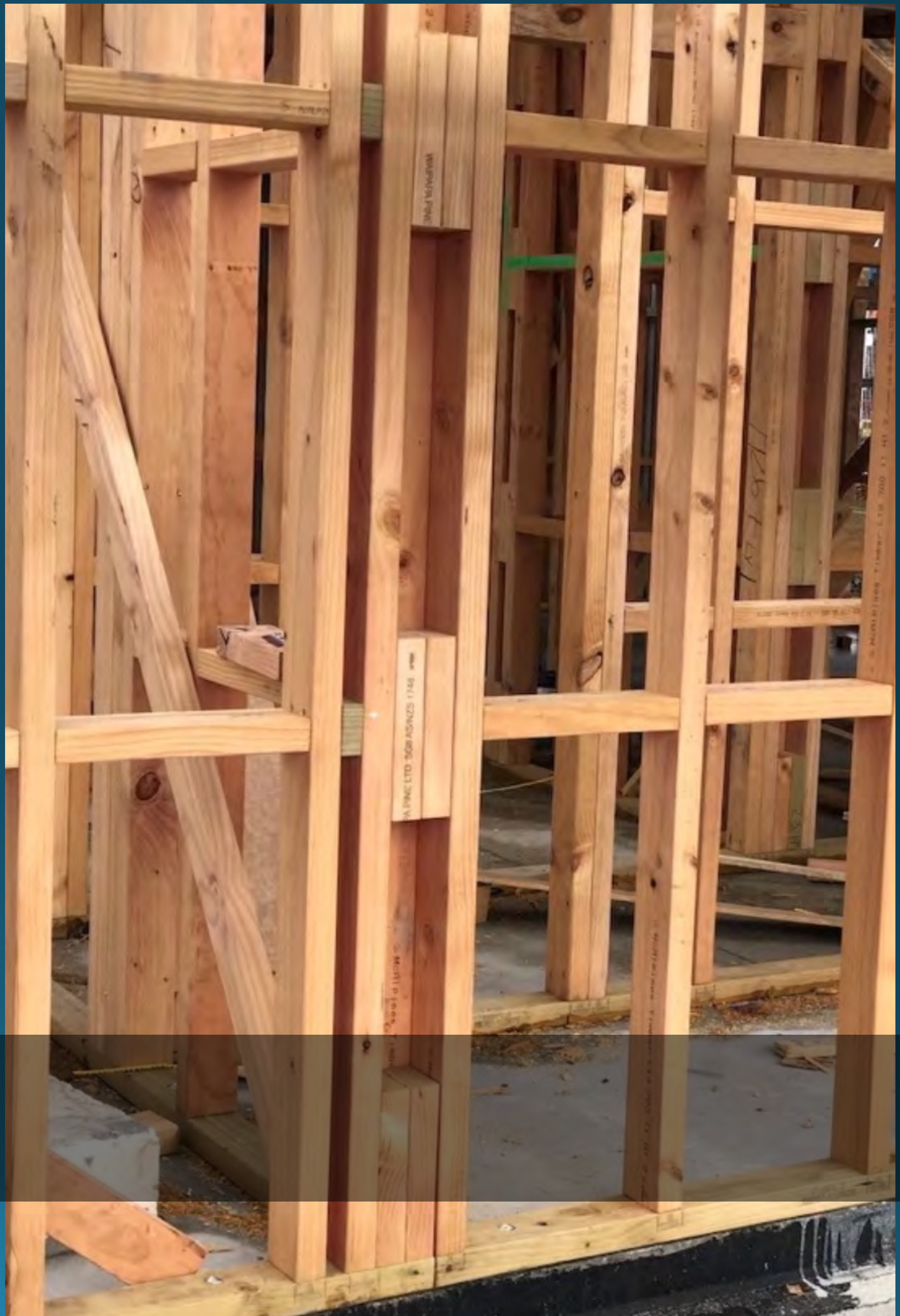

Weak points & blind spots

Uninsulated midfloor framing





Corner details



Internal wall junctions

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Weak points and blind spots

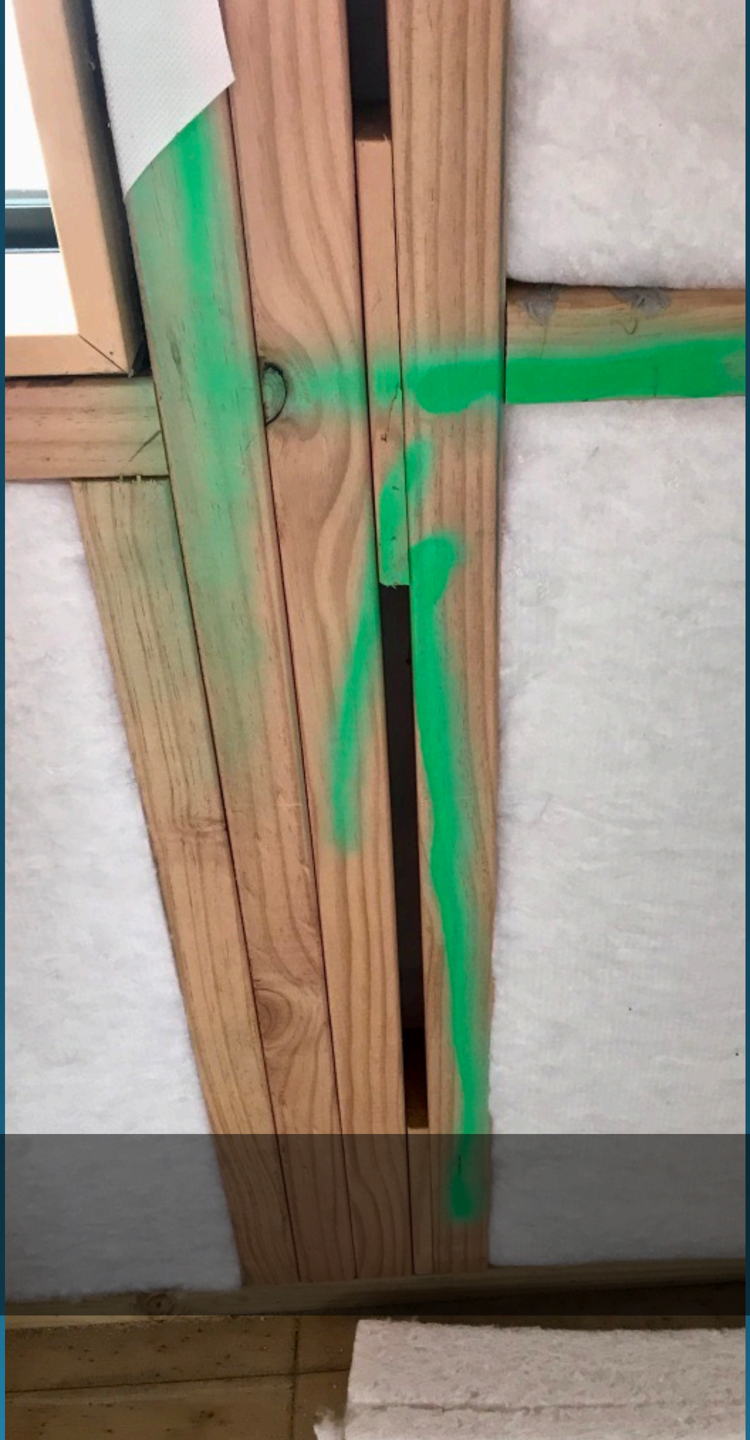
Weak points and blind spots

How do these affect performance?

High concentrations of framing

Near solid corners [redacted]

Stairwell blocking for handrails



Uninsulatable voids

But wait … there’s more

What are the drivers of these percentages of framing?

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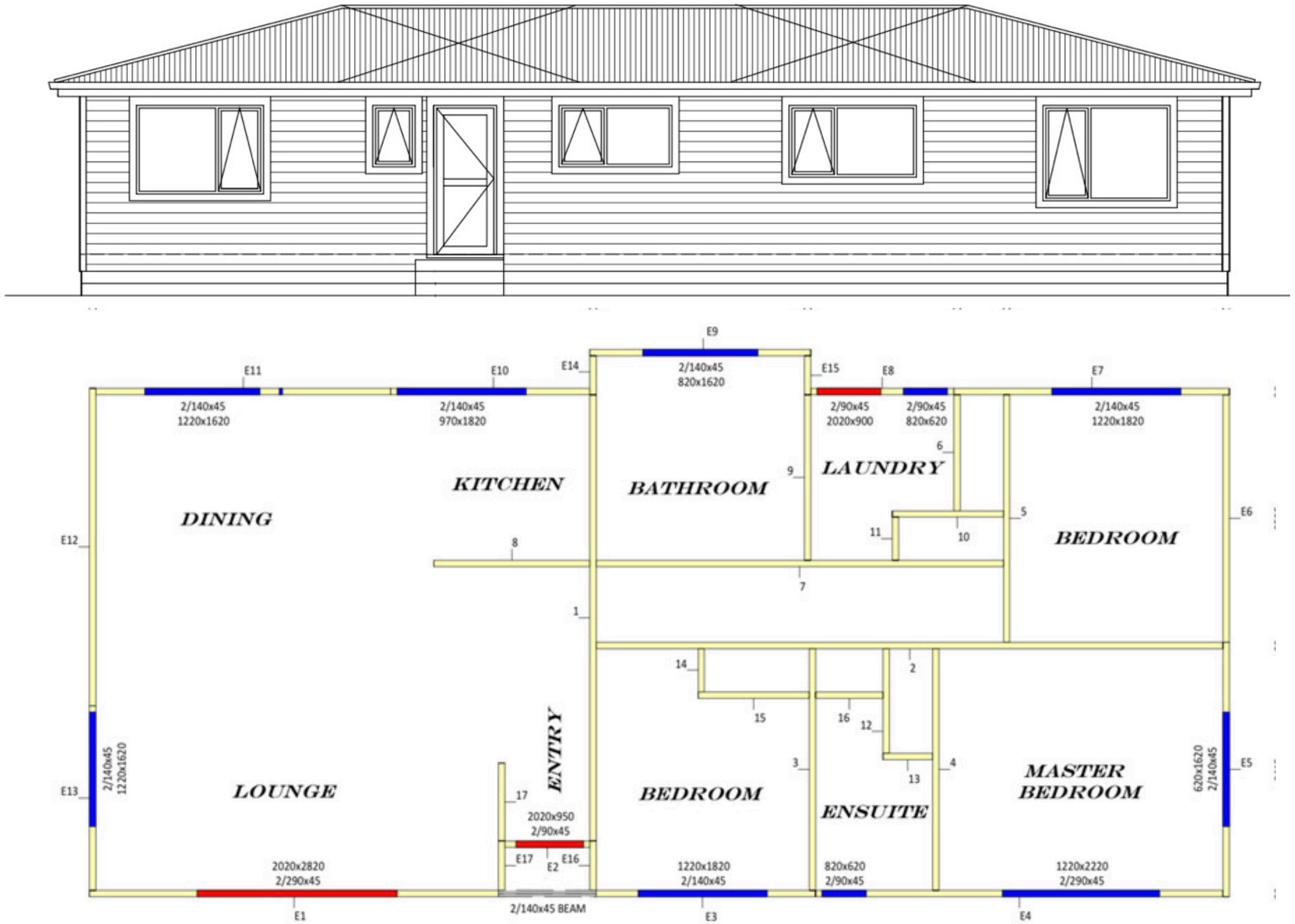
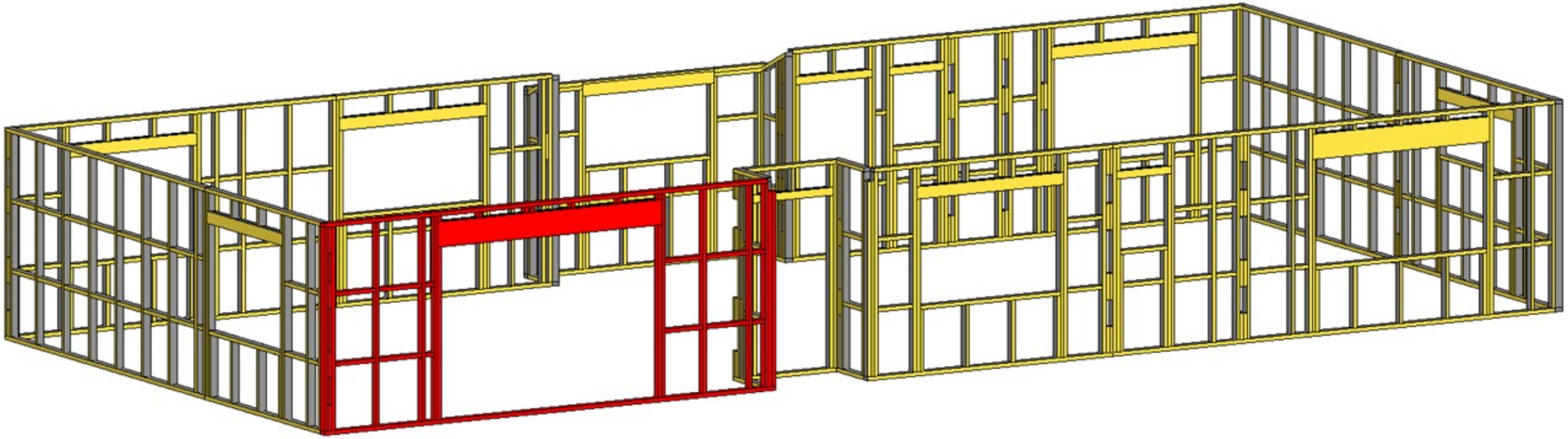
Exploring framing

A modest 3-bedroom house plan

- 25° degree hipped roof
- Light roof cladding
- 2.4 m walls
- No internal garage
- 16.1 m x 7.2 m
- Less than 120 m^2



Typical scenario showing studs at 600 mm centres and nogs at 800 mm



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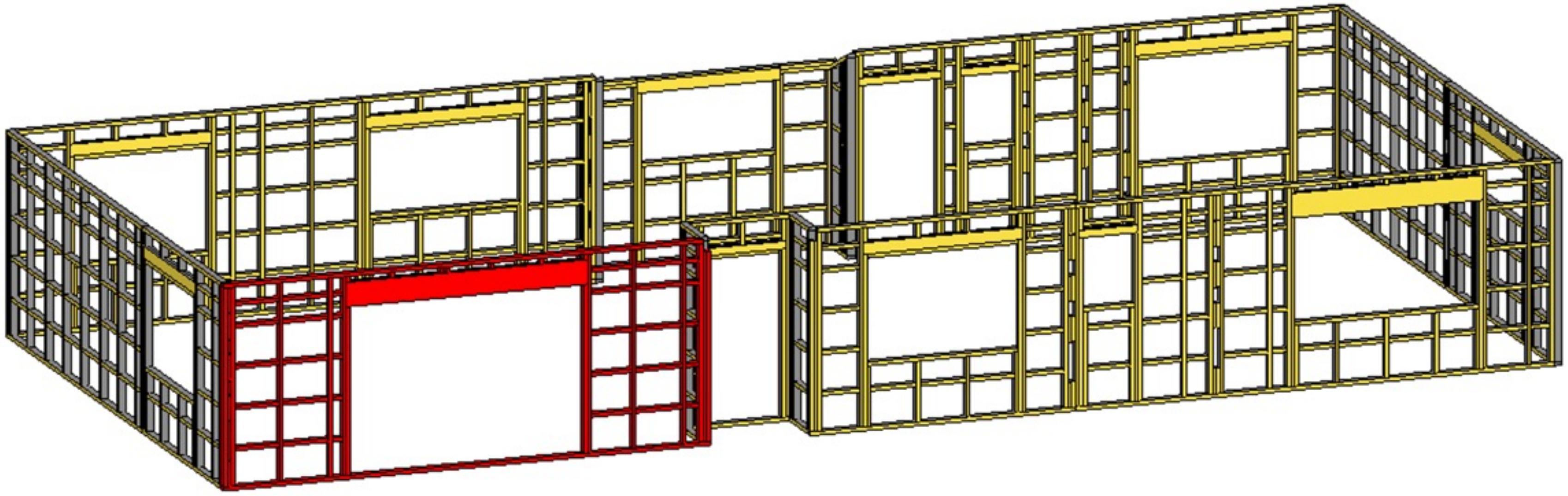
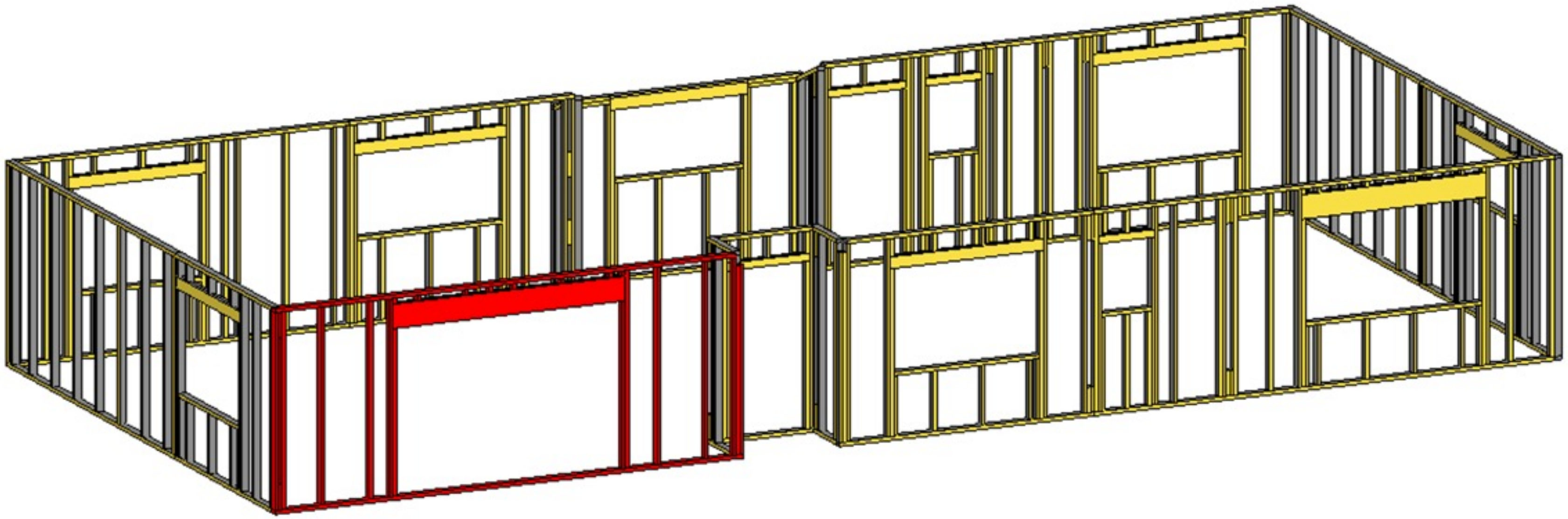
Scenario showing studs at 600 mm centres and nogs at 480 mm maximum for vertical shiplap cladding



Studs at 600 mm centres set out for rigid air barrier (RAB) and no nogs

Note: this would be problematic for fabricator delivery



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What we found

- Framing is primarily determined by structure and weathertightness but also influenced by cladding choices, fixing requirements, technical literature (e.g. fire and bracing), *some* builder/designer preference
- There is little ‘unnecessary’ or ‘excessive’ framing
- Percentages of framing higher than assumed even on a modest house
  - 90 x 45 mm framing at 600 mm centres ranged from **27%** to **35%** by volume with different cladding scenarios
  - 90 x 45 mm framing at 400 mm centres ranged from **31%** to **37%** by volume with different cladding scenarios

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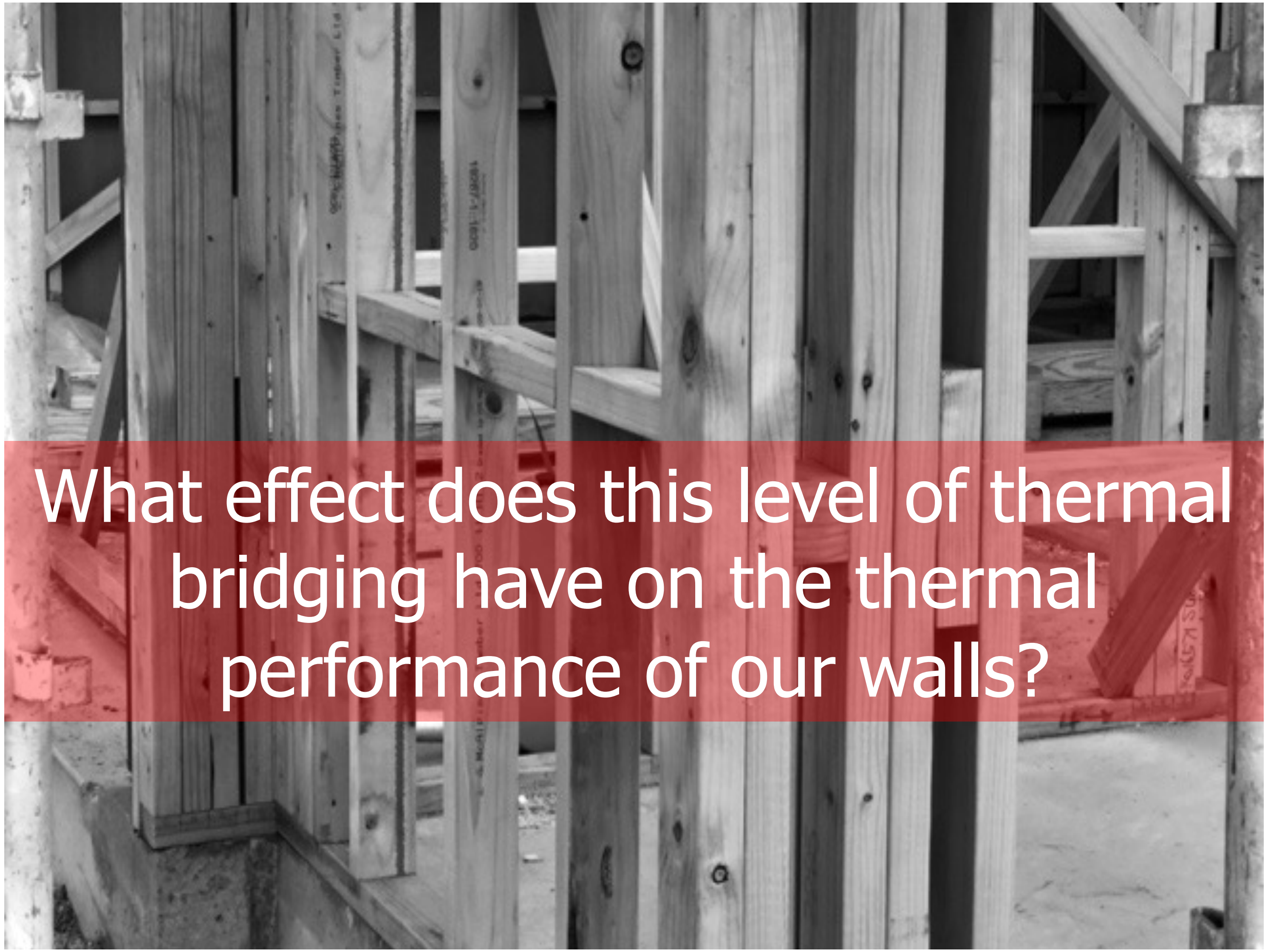
"Despite the skills of an experienced detailer working to optimise framing…

…on a simple single-storey house …

…it was a **significant challenge** even to get **below a percentage of framing of 27%.**"



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What are the construction (or system) R-values of walls of new-build residential buildings?

Guy Penny *PhD*

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How are walls of new-build residential properties performing (thermally)? Can we (easily) improve the thermal performance of walls?

To answer these questions, we selected 5 of the 47 surveyed properties and calculated their **whole-wall construction R-Values** (as-built) and modelled the following variables:

Treatment 1.	3 different levels of **insulation** (R2.0, R2.2, and R2.8)
Treatment 2.	With and without the effects of **weakpoints**
Treatment 3.	With **framing at 25%**

The 5 properties are located in Auckland (2), Wellington (1) and Christchurch (2)

- 3 x single level, 2 x double level
- 3 – 4 bedroom
- Framing percentages range from 26 - 36%
- Floor area range from 110 – 145m^2

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What is Construction (or System) R-value?

- The R-value of an assembly (or a system) made up of different materials
  - Includes the R-values of all the individual materials in the system
  - To calculate the construction R-Value of a wall we include all the different materials e.g. wall lining, framing, insulation, building wrap, ventilation cavity, cladding, air gaps

What area of a wall does Construction R-Value apply to?

- NZS 4218:2009: (NZ Standard for Thermal Insulation – Housing and Small Buildings)
  - Construction R-value for walls is defined as the R-value of a **typical area** of the wall, excluding the effects of openings or corners
  - To show compliance - the **typical area** must be R1.9 (Zone 1 and 2) or R2.0 (Zone 3)
    - the R-value of light timber framed walls shall be no less than R1.5 (E3/AS1)
- **This Research:**
  - We're interested in the construction R-value of the **whole–wall area** (net wall area = openings excluded)
  - Although openings are excluded, **the effects on whole-wall R-value due to timber framing** associated with openings and corners **are included in our calculations**

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Treatment 1: **As – Built**

How are these walls performing as-built? What is the effect of different insulation levels?

- Modelled whole–wall construction R-values with R2.0, R2.2 and R2.8 insulation

Treatment 2: **With Weakpoints Resolved**

What effect will resolving 6 common weakpoints have on whole-wall construction R-values?

- As above with weakpoints resolved
  - 5 weak-points (bundled): external corners, internal corners, wall junctions, mid-floor, top plate
  - Floor slab edge modelled separately

Treatment 3: **With 25% framing**

What effect will limiting the framing to 25% have on whole-wall construction R-values?

- Repeat Treatment 1 and 2 with 25% Framing

To calculate whole-wall construction R-values we used:

- A R-Value Calculator

  Passive House Academy of NZ ISO 6946 U-Value calculator

- Applied PSI values to all framing associated with edges, corners and openings
- The modelling methodology and results were peer reviewed by BRANZ

U-Value and Total Thermal Resistance of a Building Element in Accordance with ISO 6946

Project:

Component Nr.	Component Label

Internal Surface Resistance R_{si}: 0.13 m²K/W

	Range 1	Range 2	Range 3	Thickness d in mm	Thermal Conductivity λ in W/(mK) Range 1	Range 2	Range 3
1.	Insulation	Timber	block	45	0.045	0.130	0.130
2.	Insulation	timber	air	45	0.045	0.130	0.240
3.	plasterboard			10	0.220		
4.							
5.							
6.							
7.							
8.							
9.							

Thickness of Component: **100 mm**

Thermal Resistance of Unheated Space (e.g. Roof Space) R_u:

Area Ratio: 69% | 28.0% | 2.9%

External Surface Resistance R_{se}: 0.13 m²K/W

Results

As-built whole-wall R-values

Insulation	As-built with all 6 weak points present	As-built with 5 weak points resolved Floor slab edge remains uninsulated	As-built with floor slab edge insulated	As-built with all 6 weak points resolved
R2.0	1.26	1.39	1.70	1.95
R2.2	1.30	1.44	1.81	2.06
R2.8	1.40	1.57	2.02	2.35

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Results

As-built whole-wall R-values

Insulation	As-built with all 6 weak points present	As-built with 5 weak points resolved Floor slab edge remains uninsulated	As-built with floor slab edge insulated	As-built with all 6 weak points resolved
R2.0	1.26	1.39	1.70	1.95
R2.2	1.30	1.44	1.81	2.06
R2.8	1.40	1.57	2.02	2.35

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Results

25% framing whole-wall R-values

Insulation	As-built with all 6 weak points present	25% framing with all 6 weak points present	25% framing with 5 weak points resolved	25% framing with floor slab edge insulated	25% framing with all 6 weak points resolved
R2.0	1.26	1.33	1.48	1.84	2.15
R2.2	1.30	1.38	1.55	1.97	2.29
R2.8	1.40	1.53	1.73	2.30	2.74

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Results

Wall construction R-values average of 5 houses (Auckland, Wellington Christchurch)

3 x single level   2 x two levels   Net wall timber percentage 26-36%   Floor area 110-145 m^2

Insulation	As-built with all 6 weak points present	As-built with 5 weak points resolved Floor slab edge remains uninsulated	As-built with floor slab edge insulated	As-built with all 6 weak points resolved	25% framing with all 6 Weak points present	25% framing with 5 weak points resolved	25% framing with floor slab edge insulated	25% framing with all 6 weak points resolved
R2.0	1.26	1.39	1.70	1.95	1.33	1.48	1.84	2.15
R2.2	1.30	1.44	1.81	2.06	1.38	1.55	1.97	2.29
R2.8	1.40	1.57	2.02	2.35	1.53	1.73	2.30	2.74

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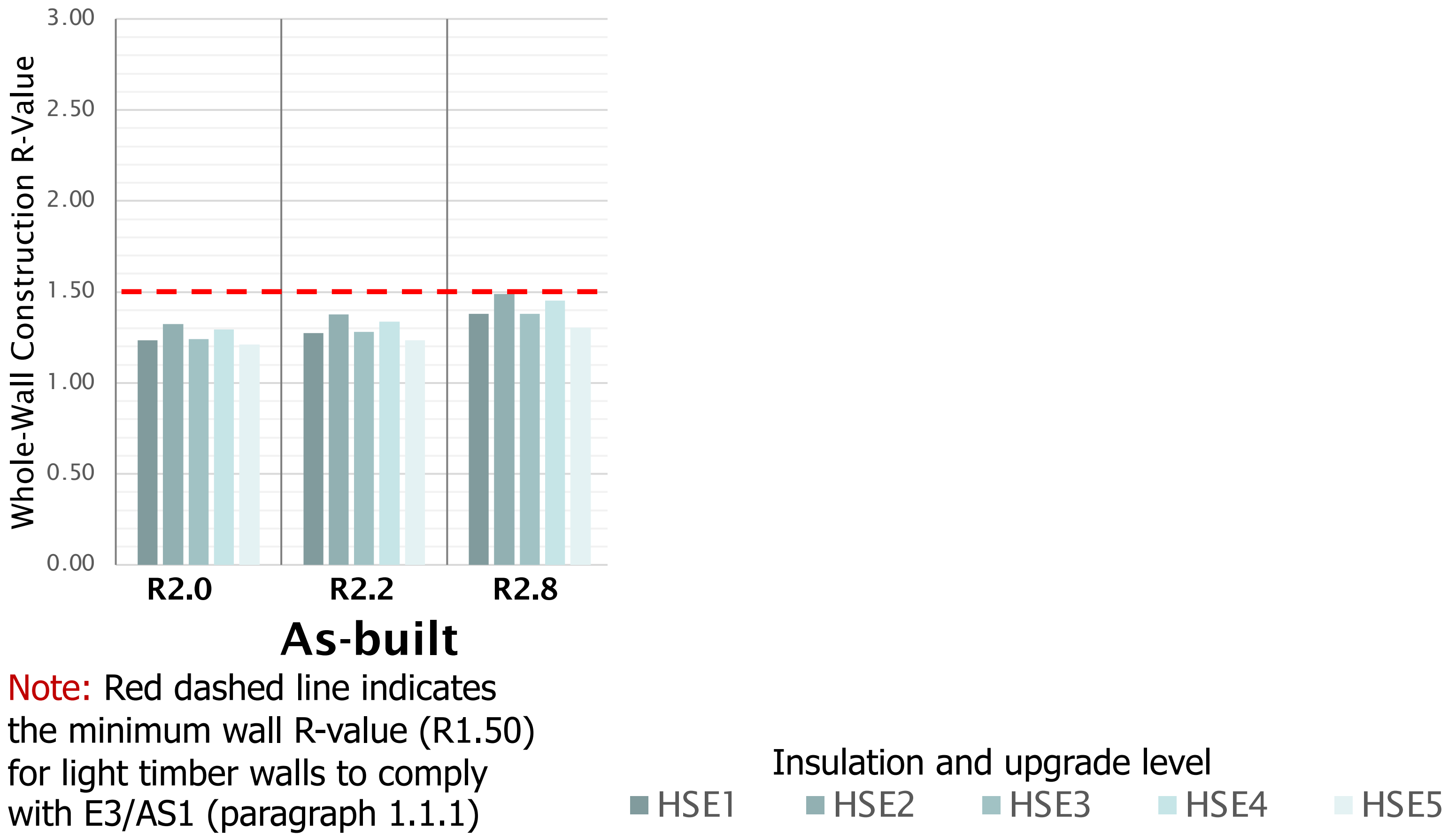
Results

Figure 1: Whole - Wall Construction R-values with Different Insulation and Upgrade Levels (with AS-BUILT Framing Percent)



Note: Red dashed line indicates the minimum wall R-value (R1.50) for light timber walls to comply with E3/AS1 (paragraph 1.1.1)

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Results

1. As-built walls of typical timber construction achieve a **whole wall construction R-value** of between **R1.26 - R1.4**

2. If floor-slab edge is effectively insulated, walls achieve between R1.70 – R2.0 (~ 30% - 40% increase)

3. If 5 common weak-points are resolved, walls achieve between R1.39 - R1.47 (~15% increase)

4. If all 6 weak-points are resolved, walls achieve between R1.95 – R2.35 (~ 55% - 68% increase)

5. Reducing framing to 25% of net wall area, increases R-values by 5-10% (R2.0), 6-12% (R2.2), 9-16% (R2.8)

6. **Actual whole wall construction R-values will be less** than reported here as we have not accounted for losses from poorly fitted insulation or air movement through the wall.

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Conclusions

1. New-build dwellings are not consistently achieving good wall system R-values across the whole-wall

2. Many parts of the wall are (well) below R1.5
   This does **not** satisfy the requirement stated in E3/AS1 – paragraph 1.1.1

1.1 Thermal resistance

1.1.1 *R-values* for walls, roofs and ceilings shall be no less than:

a) For light timber frame wall or other framed wall *constructions* with cavities, 1.5.

3. To achieve whole-wall construction R-values > R2.0 *within the same/typical approach to wall design*, several different interventions can be applied:

- **Weakpoints:** Must have effective floor-slab edge insulation (minimise other weakpoints)
- **Framing %:** Reduce the amount of framing where possible
- **Insulation:** Must be a minimum of R2.5 (ideally R2.8) and well-fitted
- **Openings:** Minimise number and size

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Conclusions.....continued

- Ultimately, **thermal bridging** through timber framing is still not addressed by this approach and will continue to be a source of heat loss and potential location of condensation and mould.
- **If we are to build healthy, energy efficient houses, actual whole-wall construction R-values must be considerably higher than what we have found in this research (>R3.0?)**
- **To do this we must address thermal bridging in walls**

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These are issues of real significance
We need a collaborative approach to explore solutions
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Advanced *framing and insulation* solutions





Zero Energy House – zeroenergyhouse.co.nz

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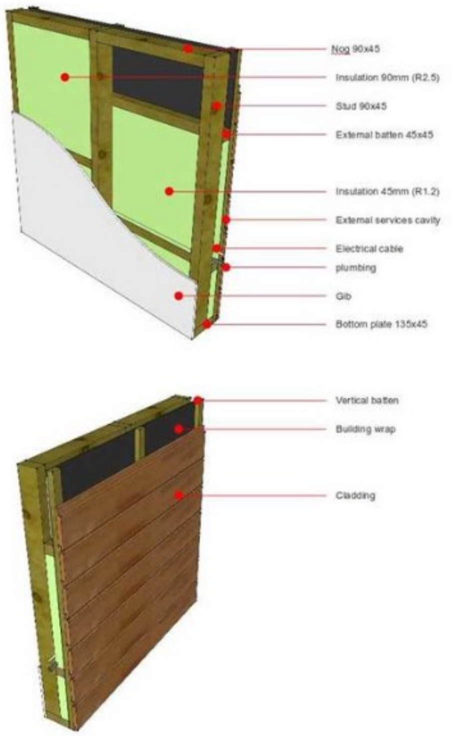
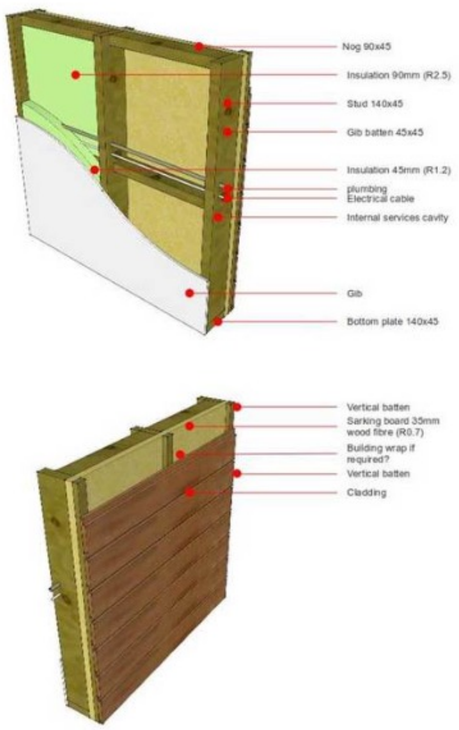
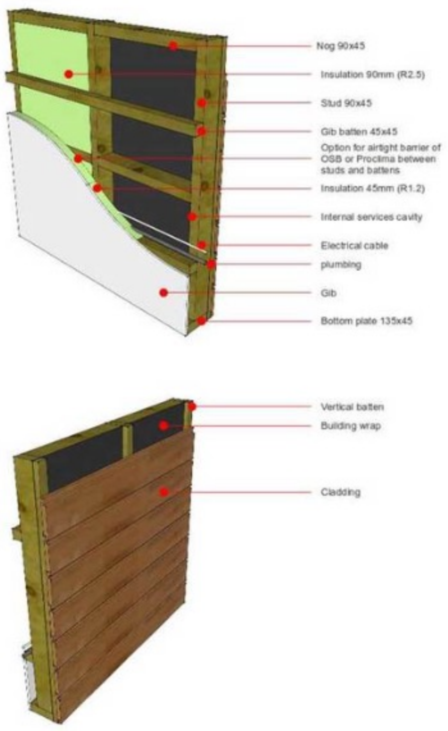


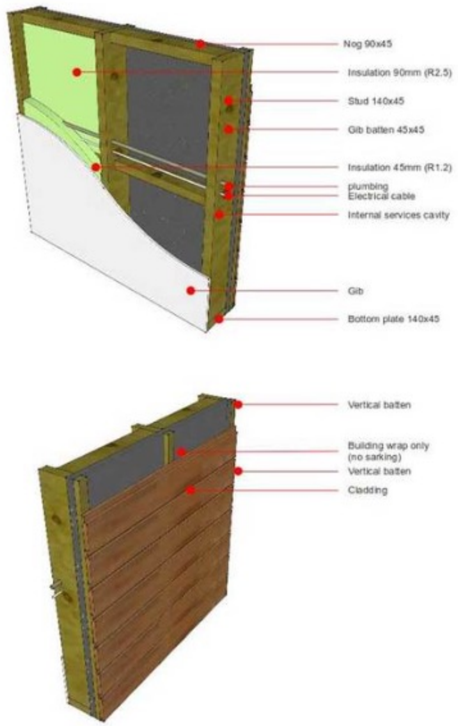
External battening, 90mm stud, no nogs.



140mm studs, 90 nogs, external 35mm insulated sarking board.

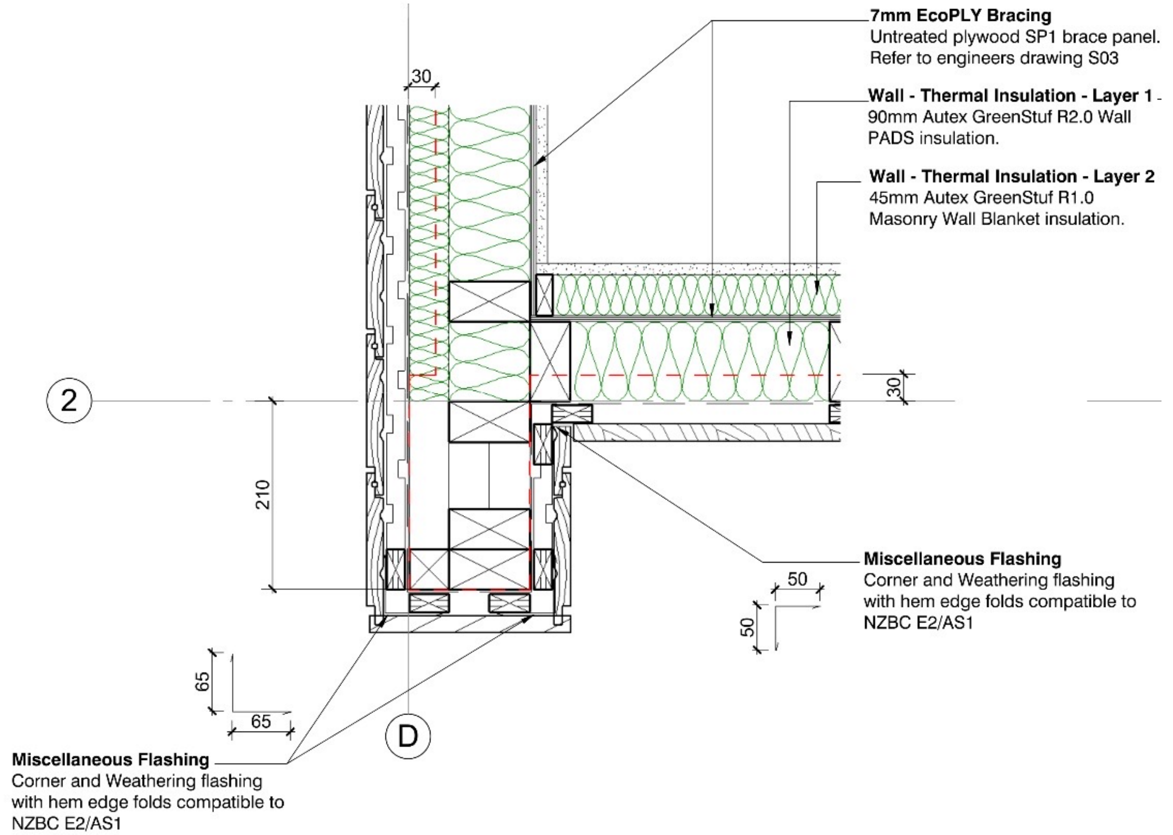


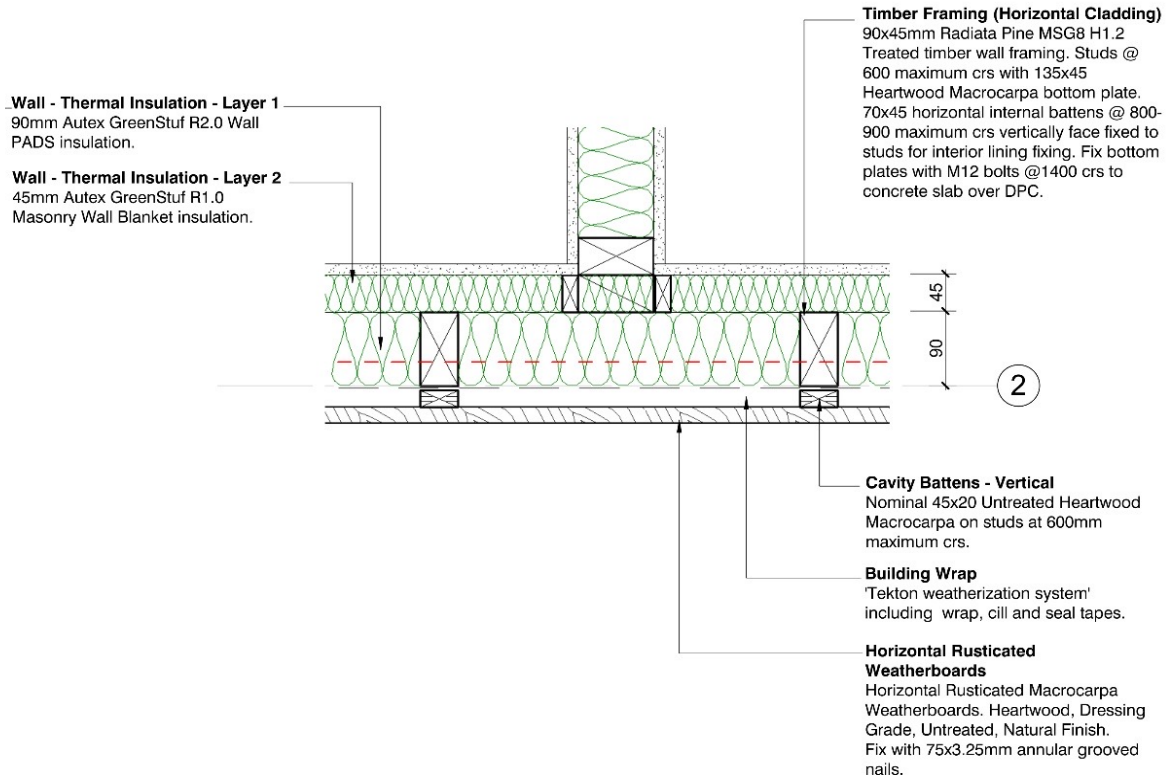
Internal battening, 90mm stud, 90mm nogs.



140mm studs, 90 nogs.

Zero Energy House – zeroenergyhouse.co.nz





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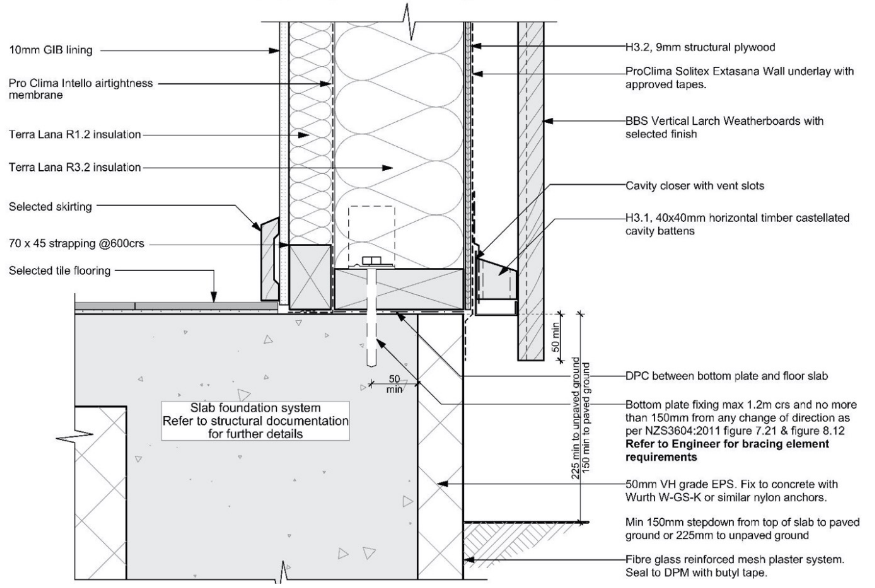
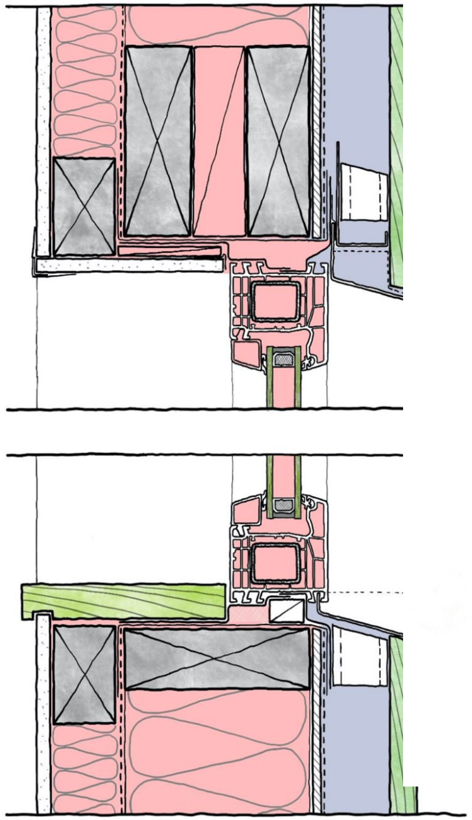
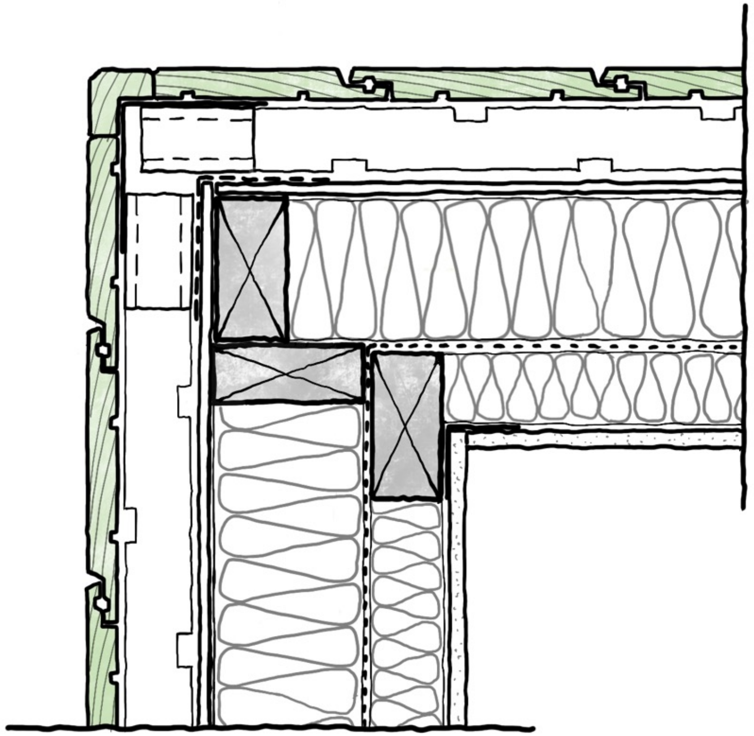
Advanced framing and insulation solutions

SuperWall / SuperWindow







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High-performance details

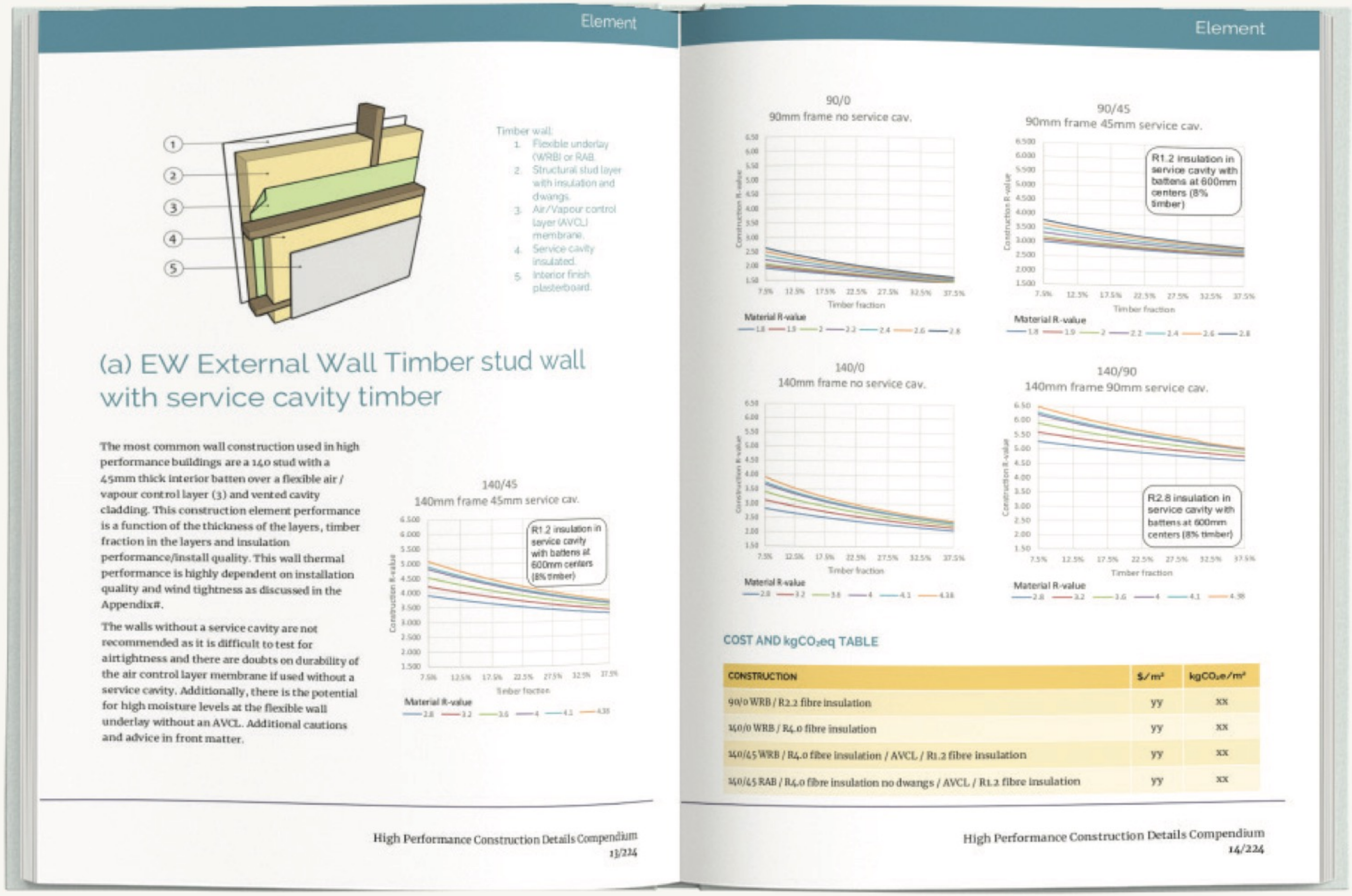
For more information see:

- Jason Quinn and Elrond Burrell
  High-performance details
  Build 182
  1 February 2021

- BRANZ External Research Report ER61

detail and make-up

thermal performance



description and cautions

cost and carbon table

High-performance details

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- Jason Quinn and Elrond Burrell
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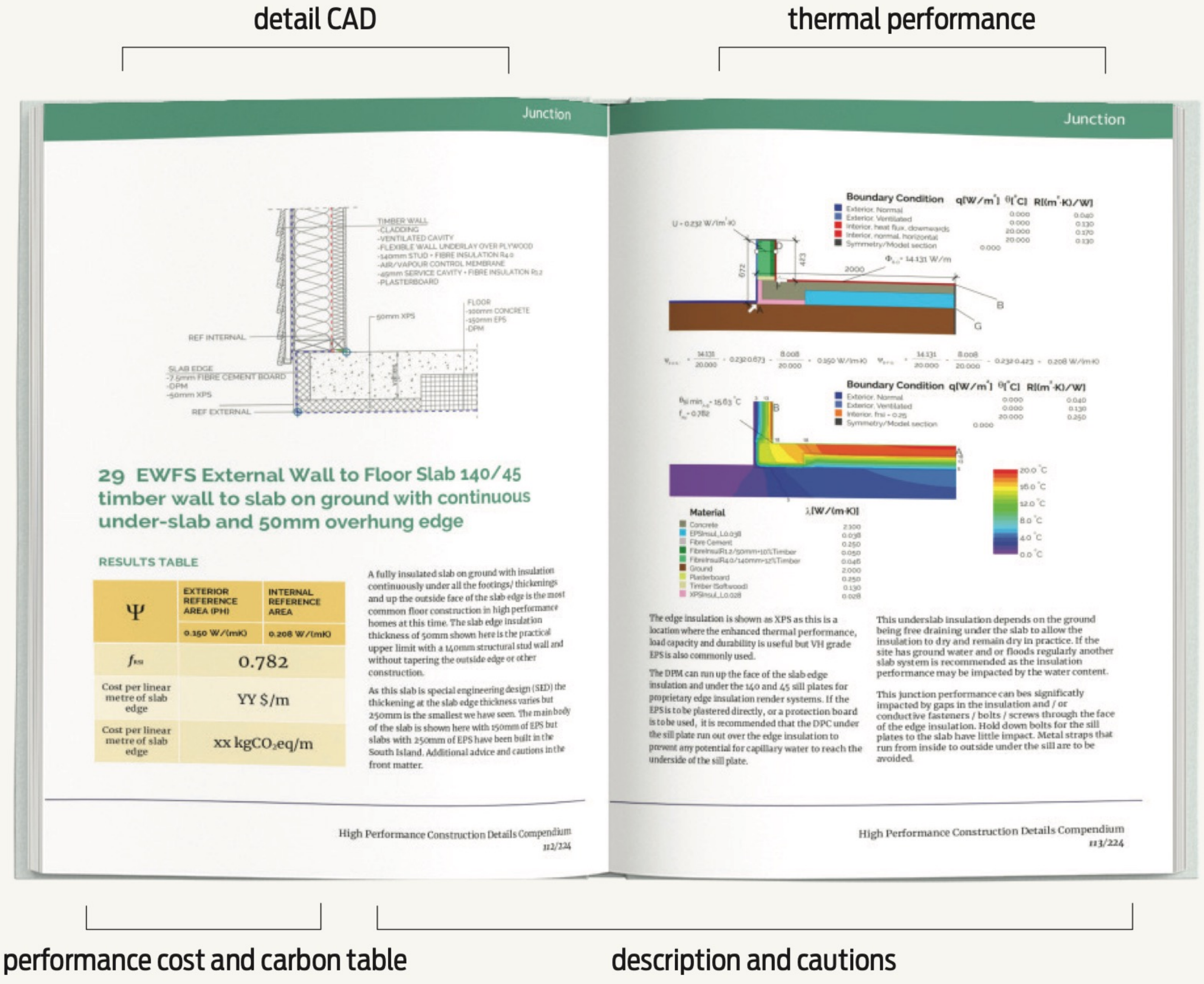
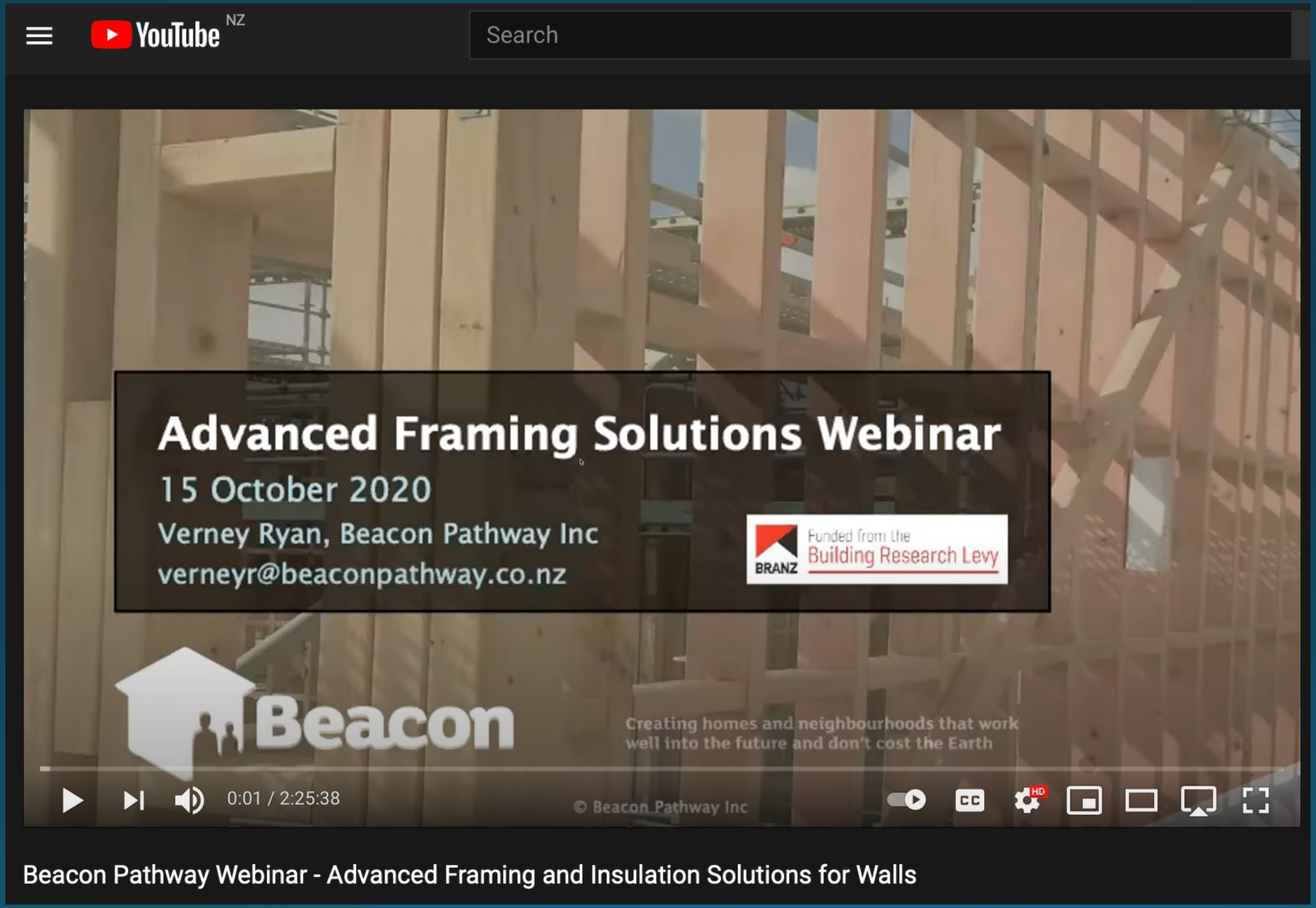


Wall solutions webinar video available



https://youtu.be/_altm5o6jcA

Future pathways

- Many advanced **framing and insulation** solutions are pragmatic and buildable using familiar approaches
- Scope to develop these further as Alternative and Acceptable Solutions
- Collaborative 'whole of sector' approach required – industry, government, research, education, training

Image source: https://www.thomsonsitm.co.nz/UserFiles/ThomsonsITM/Image/Frames%20and%20Truss/Generated/thomsons_itm_pre_nail_frames_and_truss_gallery_new09_midsize.jpg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