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The Carbon Challenge - Science and solutions

Live webinar series

Webinar 4

Webinar 4

Final in a series of four webinars

About us

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Greg Burn

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Questions

There will be a separate question and answer session from 1.30–2.30pm following this webinar

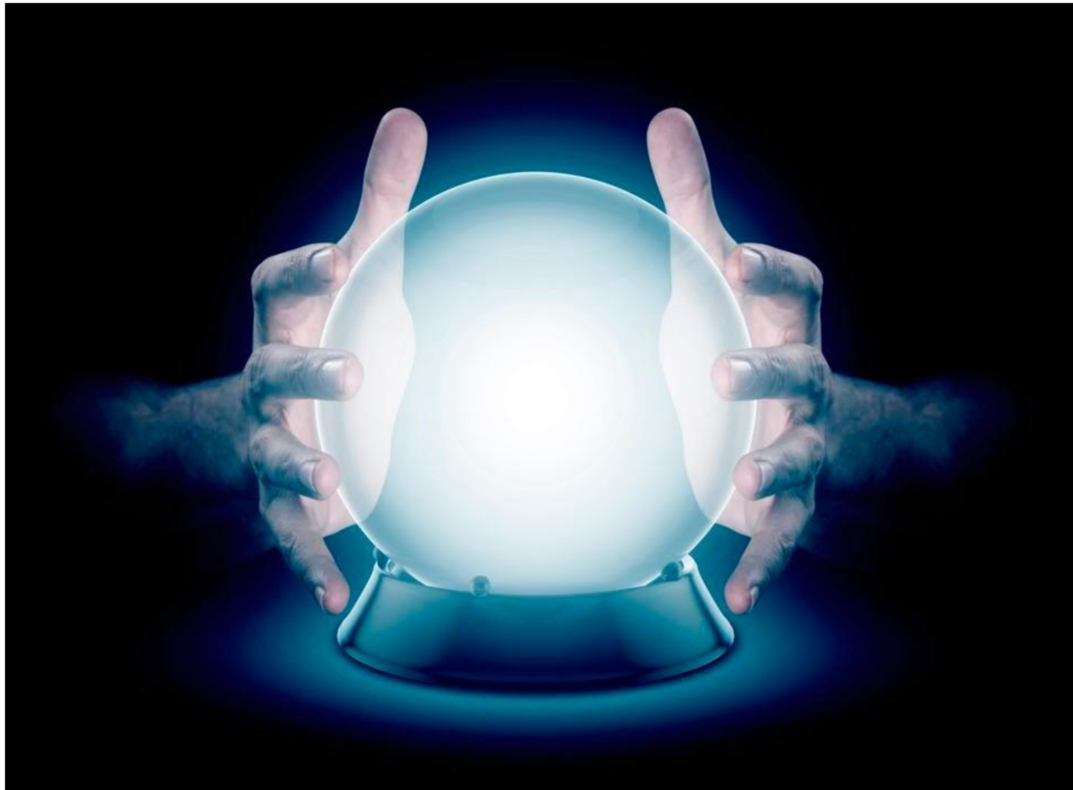
Programme

- Design and build a low-carbon dwelling

Webinar content

- Research/modelling/science based
- Primary focus on volume residential
- Continually evolving situation
- Realism – carbon emissions reduction represents a challenge to the industry

- We have left it really late – we need to act now!!



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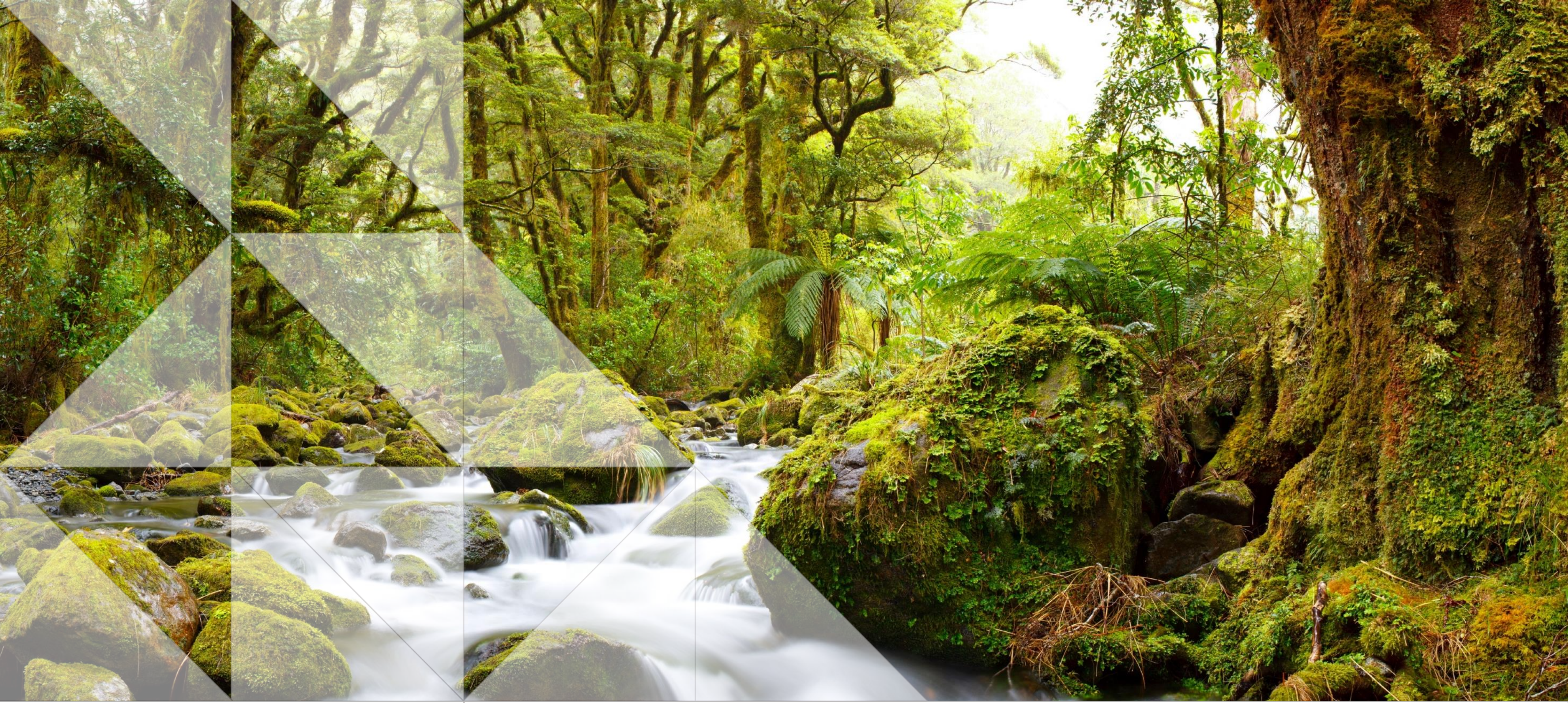

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Design and build a low-carbon dwelling

Design simulation exercise – purpose

Seeking the answer to:

- What 'rules of thumb', if followed in design, can help to lower the carbon footprint of our houses?
- What magnitude of carbon reduction could be expected compared to business-as-usual?

Intended as a starting point
Not exhaustive – there are other opportunities to reduce carbon

No substitute for assessing specific designs through the design/build process (and post occupancy) in a specific location

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Scope

Focus on stand-alone housing

Scope includes embodied and operational carbon emissions

Variables assessed:

- Construction R-values
- Ground floor construction
- House shape (area/perimeter ratio)
- Window to wall ratio
- House orientation and distribution of windows
- House size

Method

Using a simple box model to represent a house:

1. Change value of each strategy within a specified range
   e.g. shape = area/perimeter ratio = 2.1 to 3.1
2. Calculate the building carbon footprint based on:
   - Whole-of-life embodied carbon
   - Operational carbon from heating
   - Operational carbon from cooling
   - Plug loads and hot water
3. Determine range of resulting carbon footprints for each strategy to determine 'rule of thumb' optimums
4. Cumulatively apply these optimums to a simplified reference house
5. Calculate total carbon reduction compared to the reference house

Excludes: water use

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Weblink to methodology report: Methodology report

Test findings against alternative scenarios

Future climate
- 2050 climate files
- Expect lower heating requirement, higher cooling requirement

Relaxed heating/cooling schedules
- Minimum temperature 18°C but maximum increased to 27°C
- Active heating/cooling only from 7am to 11pm
- Expect lower heating and cooling requirement

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Reference house

Real house:

- 156 m² gross floor area (excluding garage)
- 4 bedrooms
- 2 bathrooms
- WWR 25%
- Carpeted floor slab
- Assume 34% framing ratio

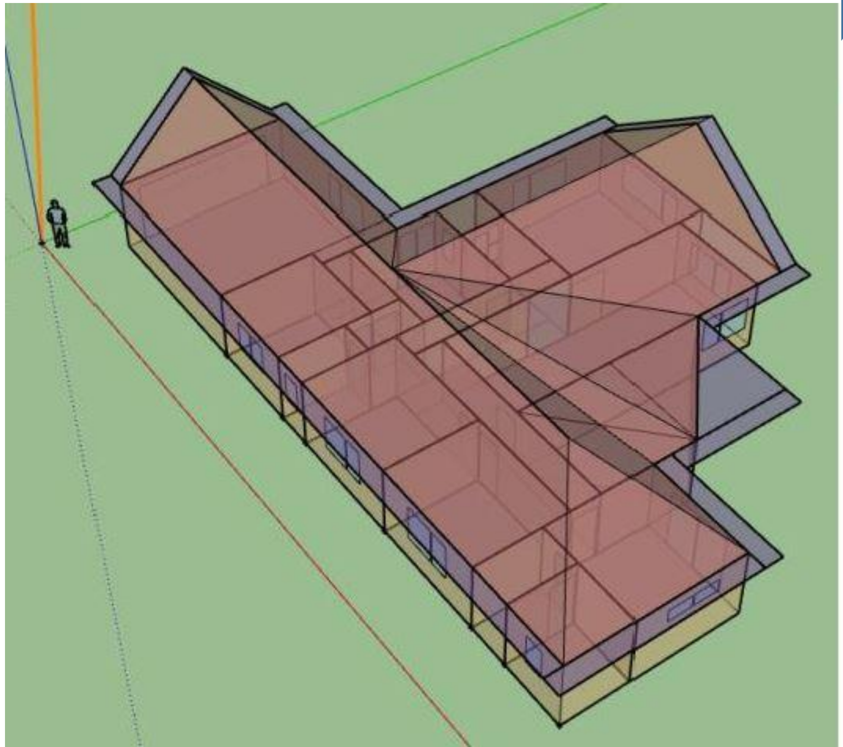
Simplified box model house:

- Same area
- Same WWR
- 0.36 ach
- 5 occupants

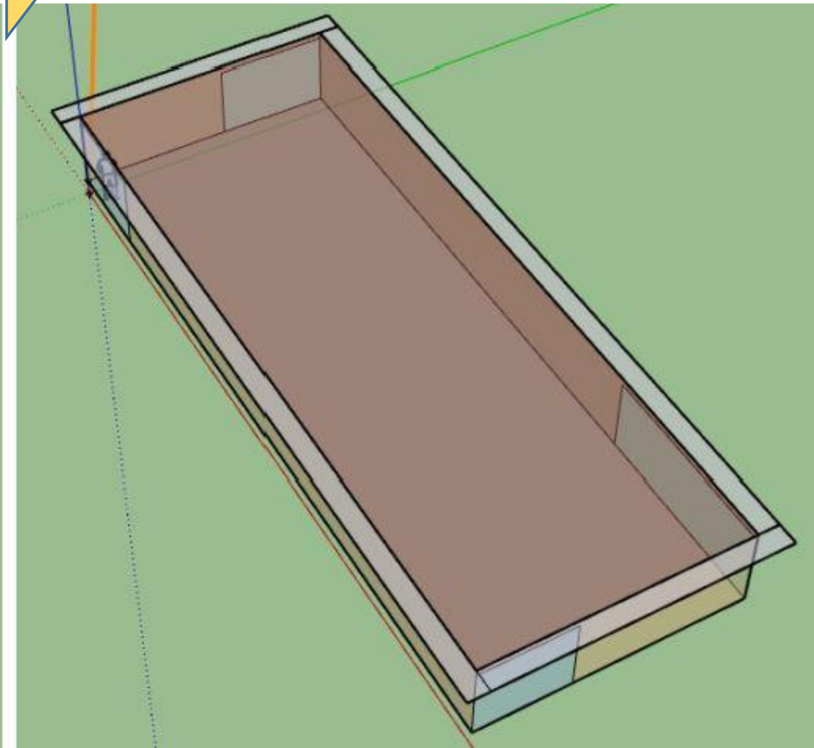
Baseline assumption for a warm, dry, healthy home:

- Indoor temperature maintained at 18–25°C 24/7
- Not how houses are typically operated currently!
- Means simulated energy use is higher

Real house

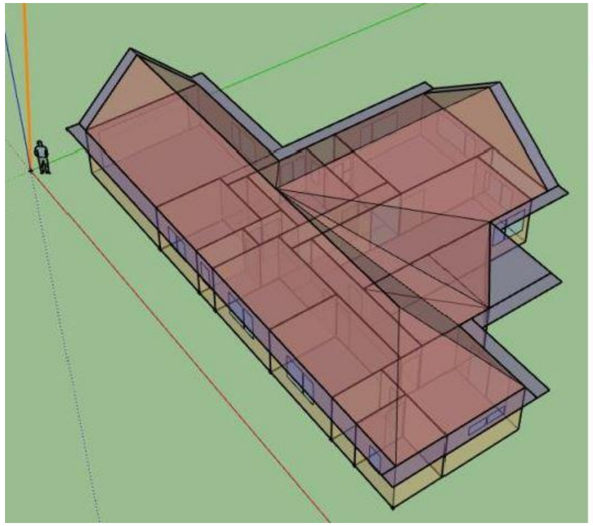


Simplified box model house

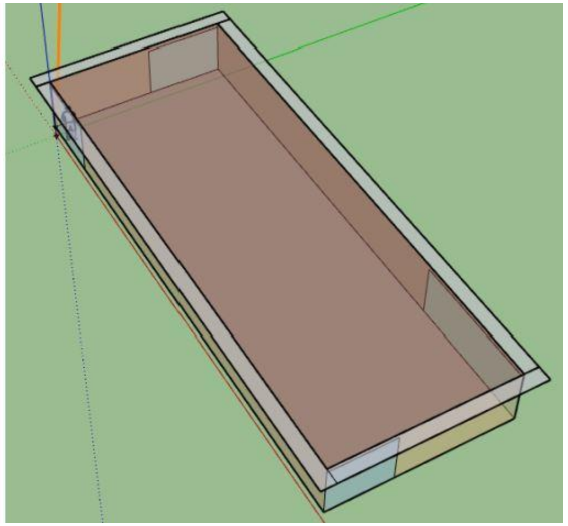


Simulated energy use comparison

Real house



Simplified box model house



Simulated energy use (excluding hot water):

Climate zone	% difference
1	4
2	6
3	12
4	9
5	8
6	11

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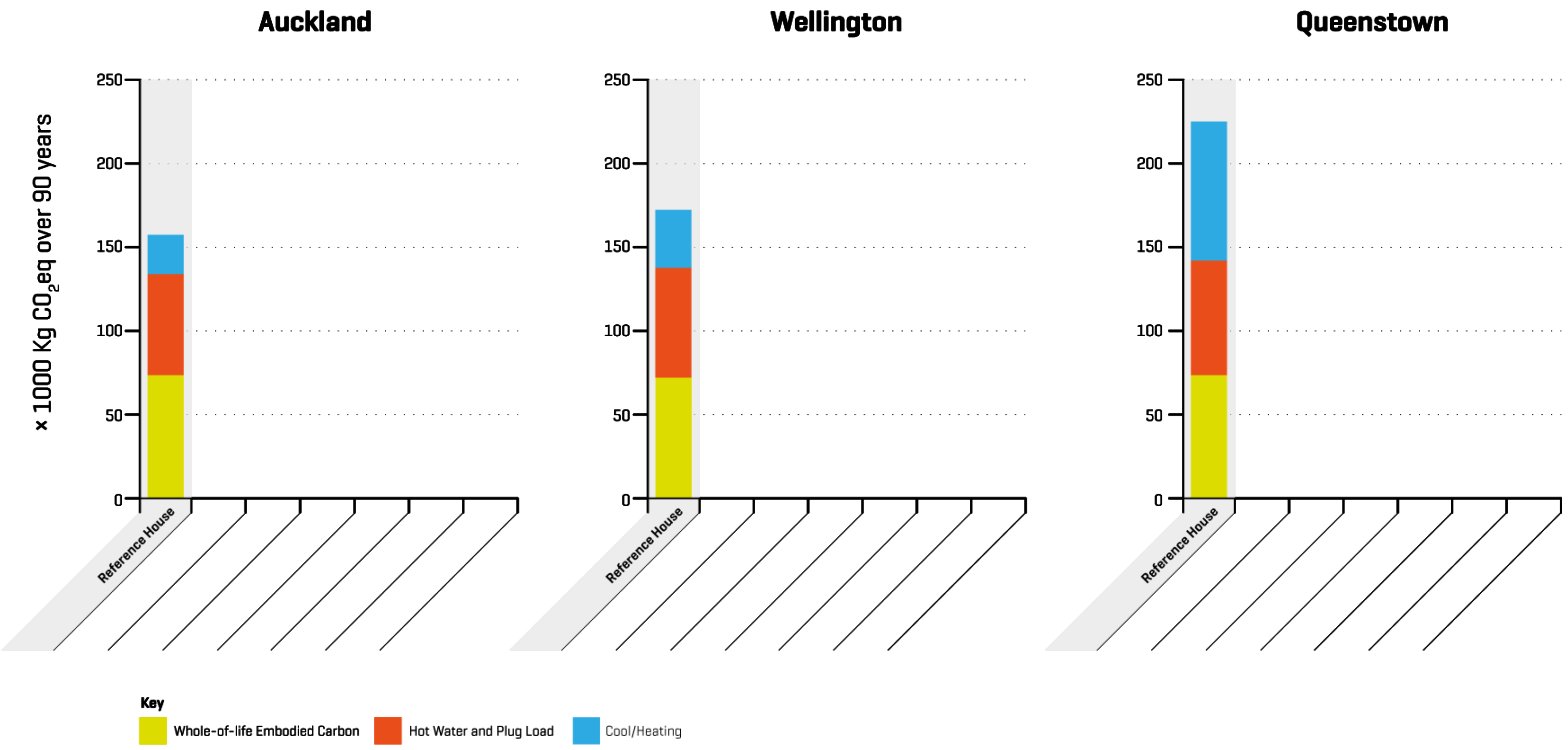
Reference house



Optimisation strategy 1: Increase construction R-values – summary

MODEL

Building element	Climate zone					
	1	2	3	4	5	6
Roof	R5.0	R5.4	R6.0	R6.6	R7.0	R7.4
Walls	R2.4	R2.6	R2.8	R3.2	R3.5	R3.8
Floor (slab on ground)	R1.9	R2.2	R2.5	R2.8	R3.2	R3.6
Windows	R0.39	R0.42	R0.45	R0.49	R0.55	R0.62

H1/AS1

Building element	Construction R-values ($m^2 \cdot K/W$)[1]					
	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5	Climate zone 6
Roof[2]	R6.6	R6.6	R6.6	R6.6	R6.6	R6.6
Wall	R2.0	R2.0	R2.0	R2.0	R2.0	R2.0
Floor *Slab-on-ground* floors	R1.5	R1.5	R1.5	R1.5	R1.6	R1.7
Floors other than *slab-on-ground*	R2.5	R2.5	R2.5	R2.8	R3.0	R3.0
Windows and doors[3]	R0.46[3]	R0.46[3]	R0.46	R0.46	R0.50	R0.50
Skylights	R0.46	R0.46	R0.54	R0.54	R0.62	R0.62

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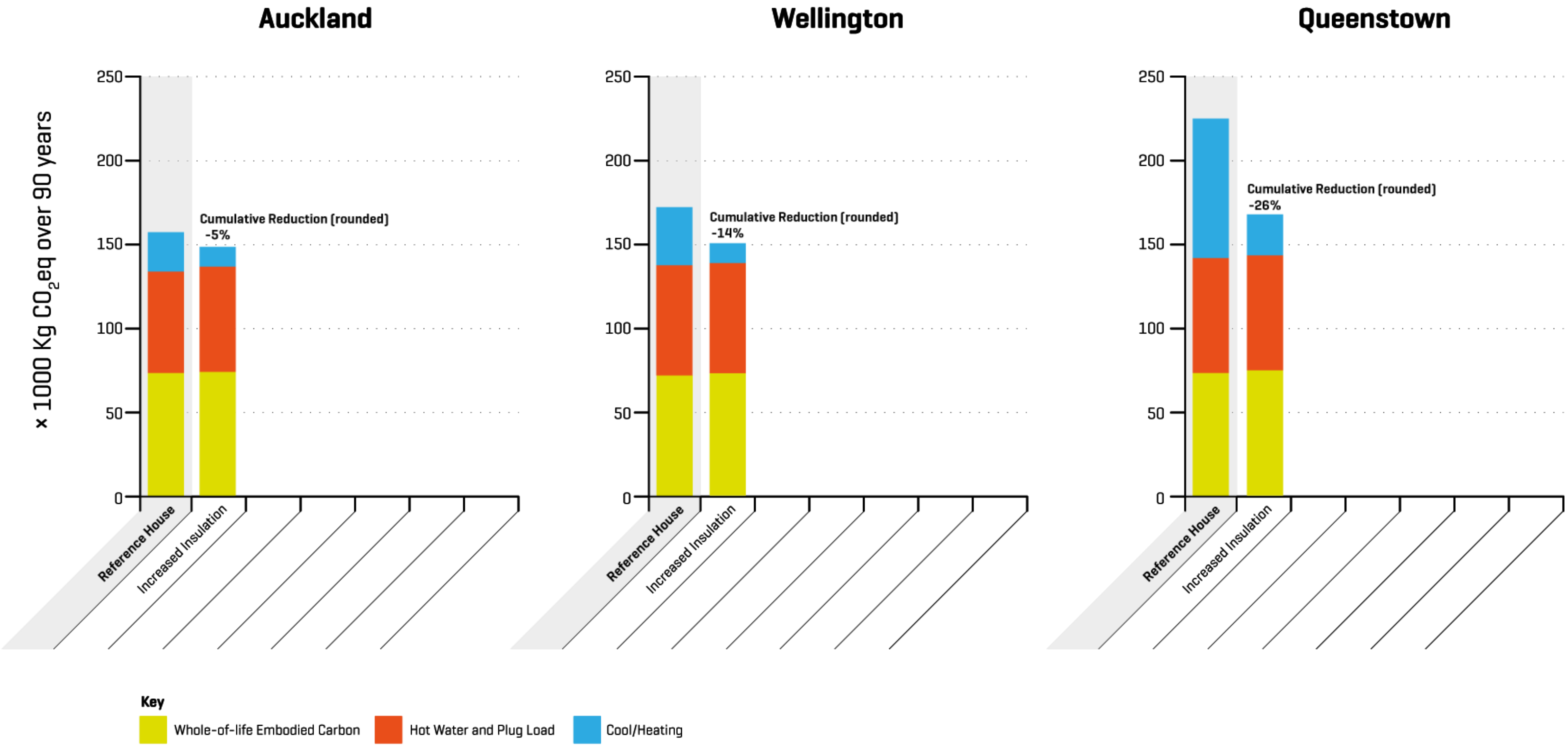
Optimisation strategy 1: Increase construction R-values



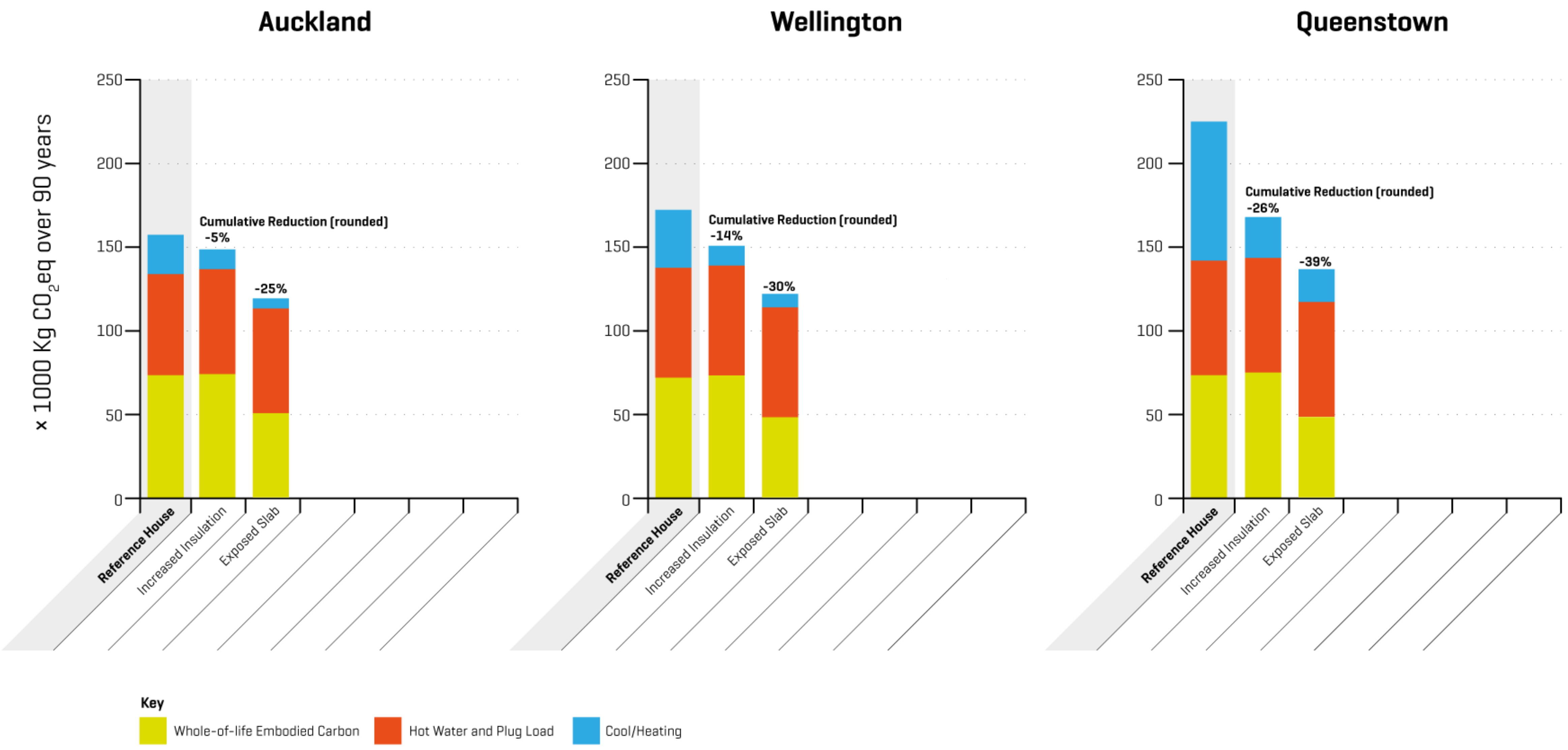
Optimisation strategy 2: Exposed floor

Expose the concrete slab floor

Magnitude of carbon reduction depends on:
- Type of floor covering (we have assumed carpet throughout)
- Carbon footprint of floor covering (varies considerably)
- Frequency of carpet replacement (we have assumed every 12 years)

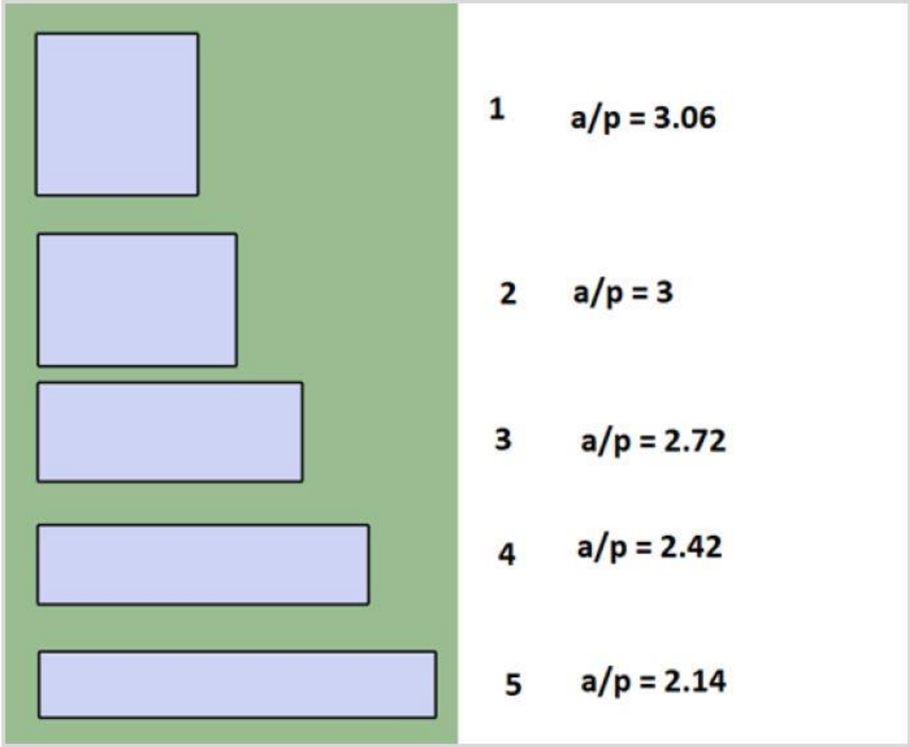
Broader issues relating to materials selection:
- Is a product or material really necessary?
- Does installation create much waste?
- How durable/resilient is it?
- How easy is it to maintain?
- Can it be reused from somewhere else?
- Can it be made with more recycled content?
- How easy is it to reuse/recycle at its end of life?

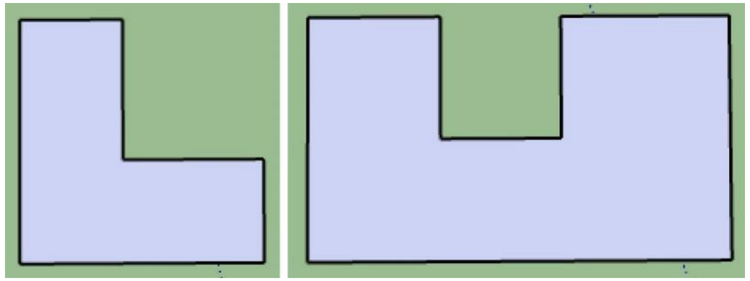
Optimisation strategy 2: Exposed floor



Optimisation strategy 3: More compact plan form

Higher area/perimeter ratio = more compact form





L shape a/p ~ 2.5
U shape a/p ~ 2.3

More complex house shapes mean:

- Less compact = greater external envelope area = greater heat loss and more material use
- Need for more corner junctions = thermal bridging
- Potential for alcoves where windows may be shaded by other parts of a house (not assessed here)

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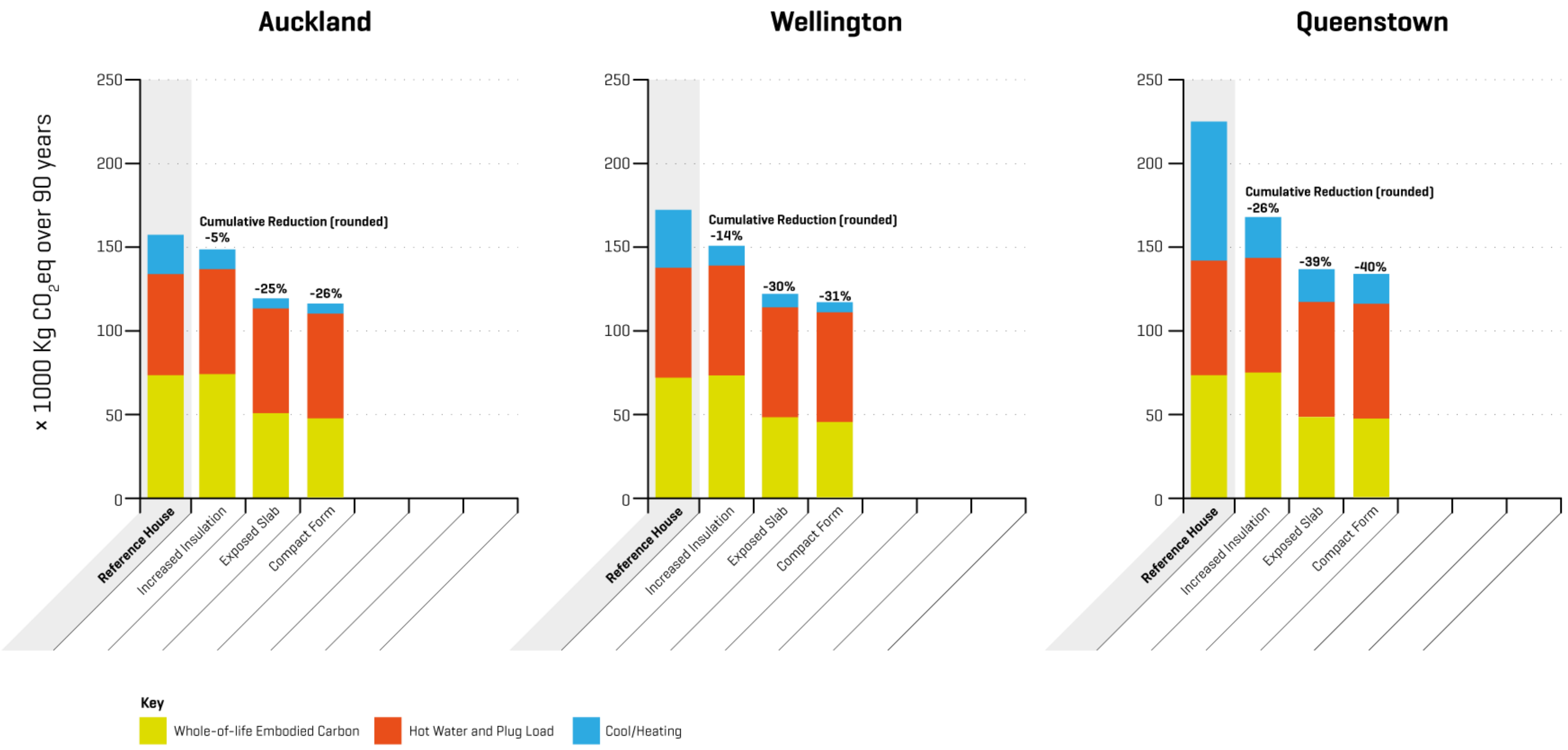
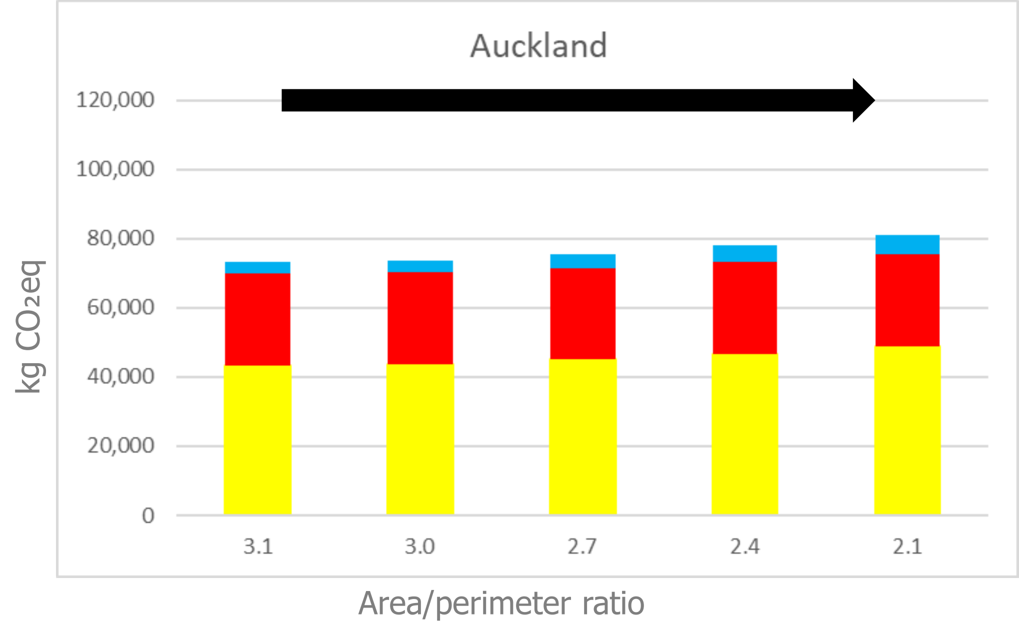
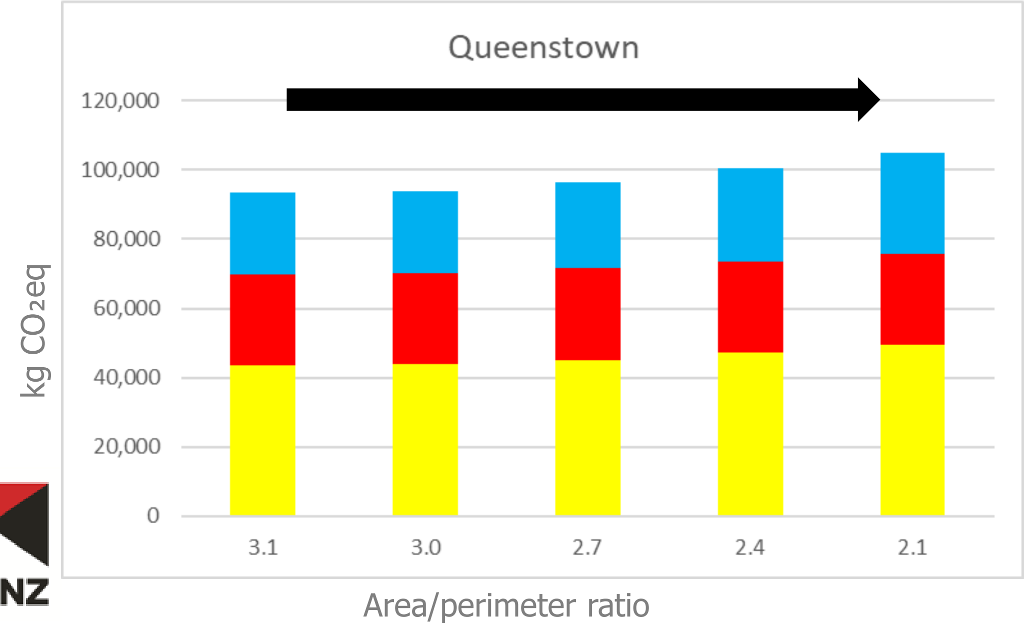
Optimisation strategy 3: More compact plan form



Optimisation strategy 3: More compact plan form





Shifting from a more compact square form (A/P = 3.1) to an elongated form (A/P = 2.1) results in:

- 11–12% increase in climate change impact
- Increases in embodied and operational carbon

Cooling/heating

Hot water and plug load

Whole-of-life embodied carbon

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Optimisation strategy 4: Window to wall ratio (WWR)

Complex – different factors having confounding affects including:

- Trade-offs between heating and cooling

Depends on:

- Location
- Occupants’ perception of internal comfort

Aiming for a WWR of 15–25% appears reasonable

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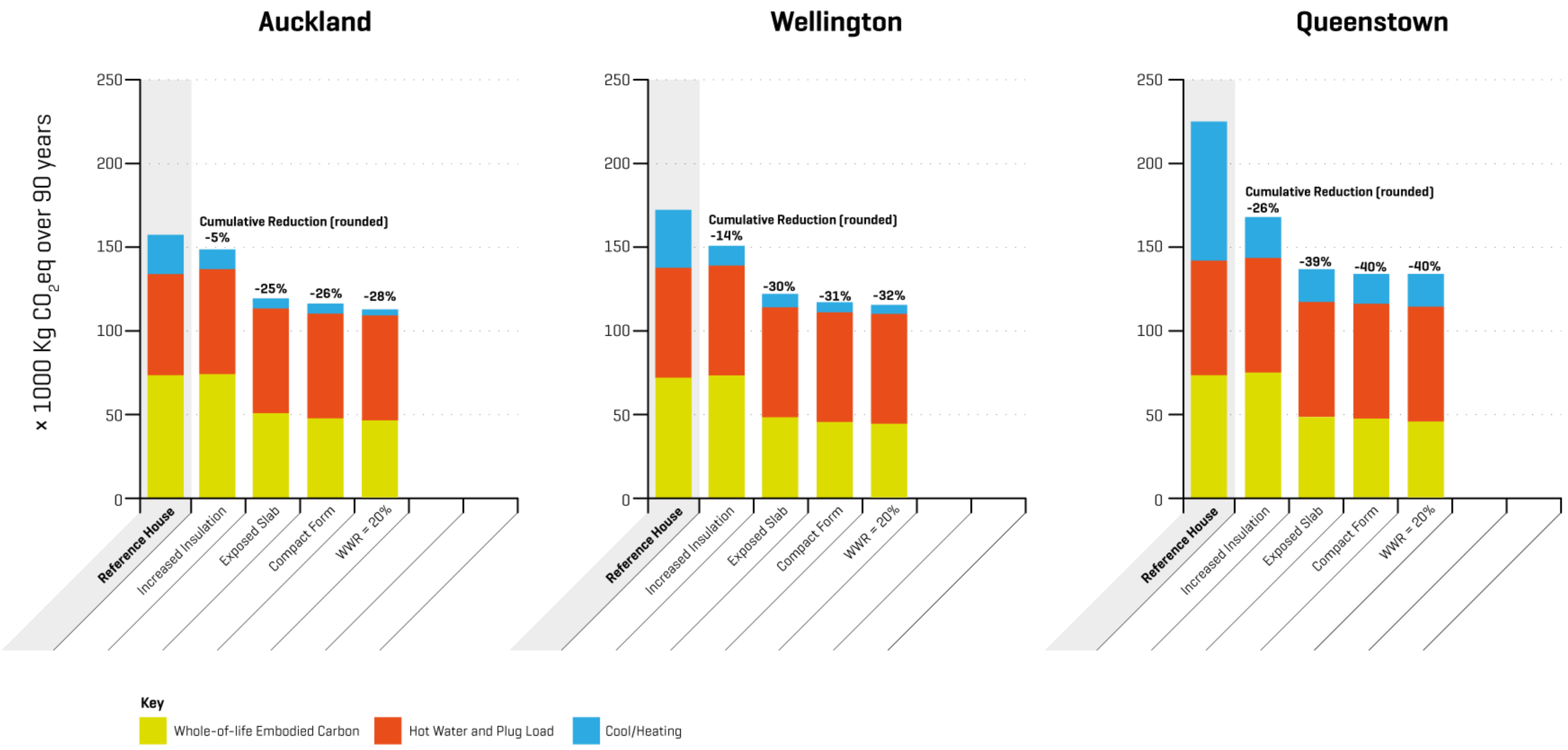
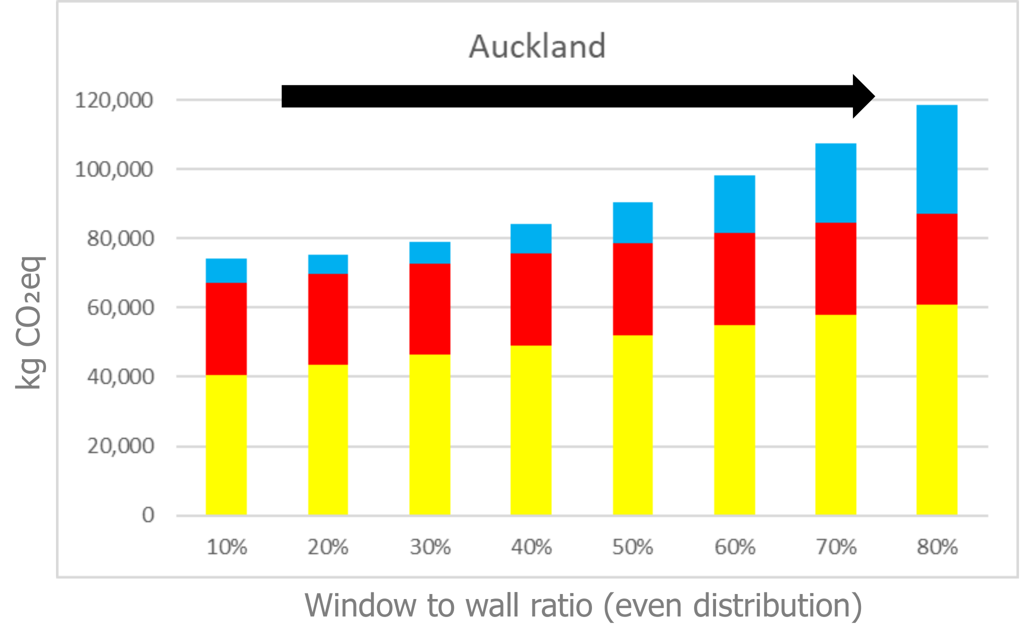
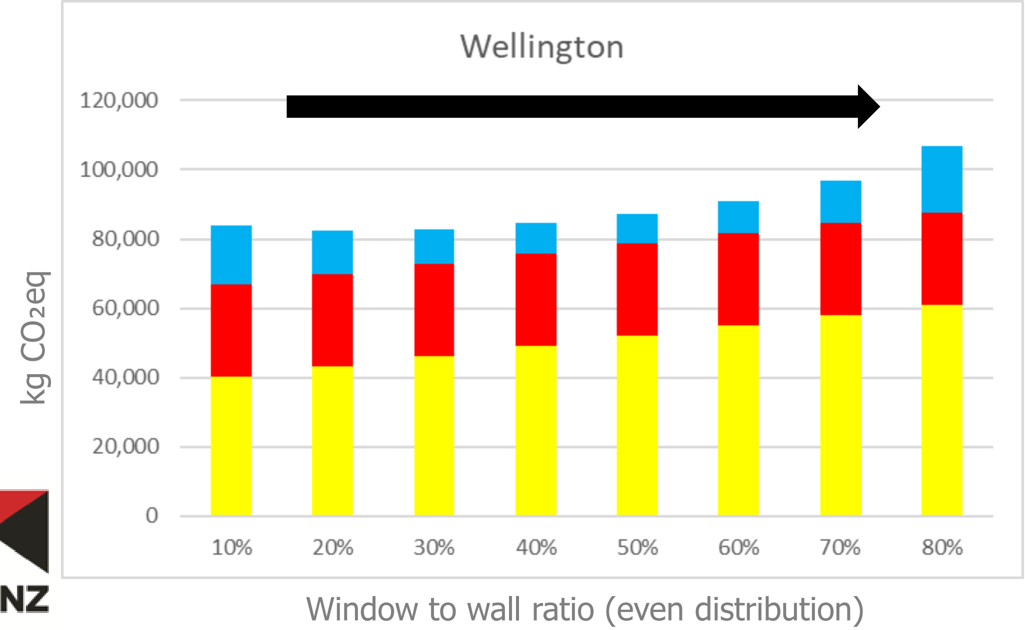
Optimisation strategy 4: Window to wall ratio (WWR)



Optimisation strategy 4: Window to wall ratio (WWR)





Increasing the WWR from 20% to 80% (even distribution of windows) results in:

- **Auckland**: 57% increase in climate change impact
- **Wellington**: 30% increase in climate change impact
- Increase in embodied carbon
- Operational carbon varies with location

Cooling/heating

Hot water and plug load

Whole-of-life embodied carbon

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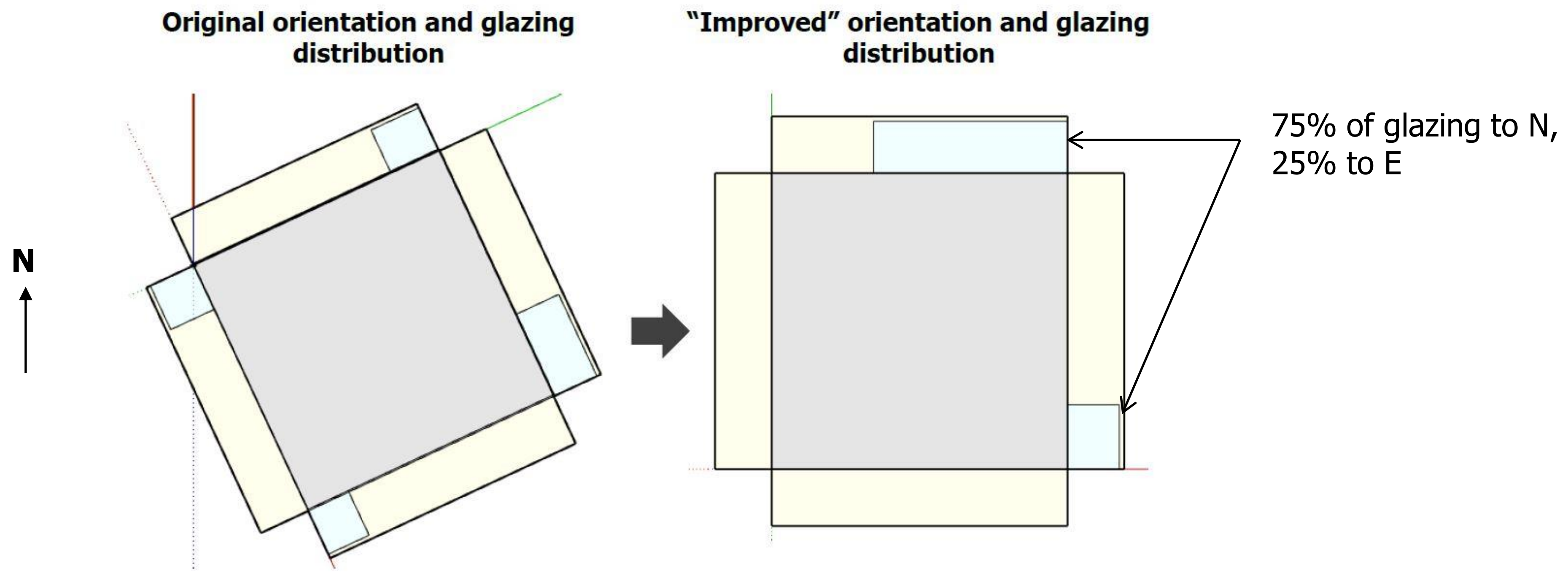
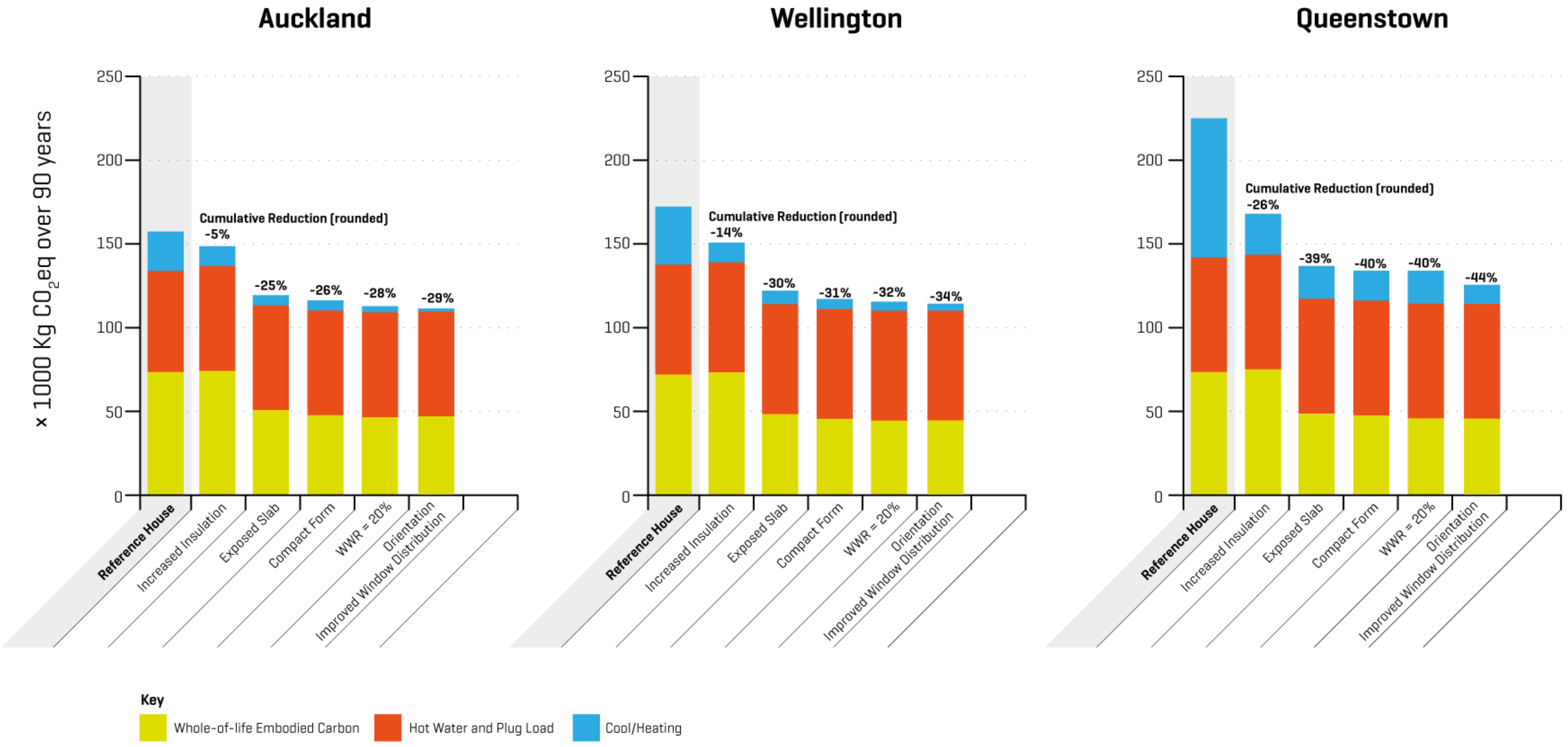
Optimisation strategy 5: Improved orientation and window distribution

Also complex – different factors have confounding affects
WWR set at 20%
Higher WWR = greater potential effects if not optimised
Floor type – exposed concrete floor slab
Active heating vs active cooling

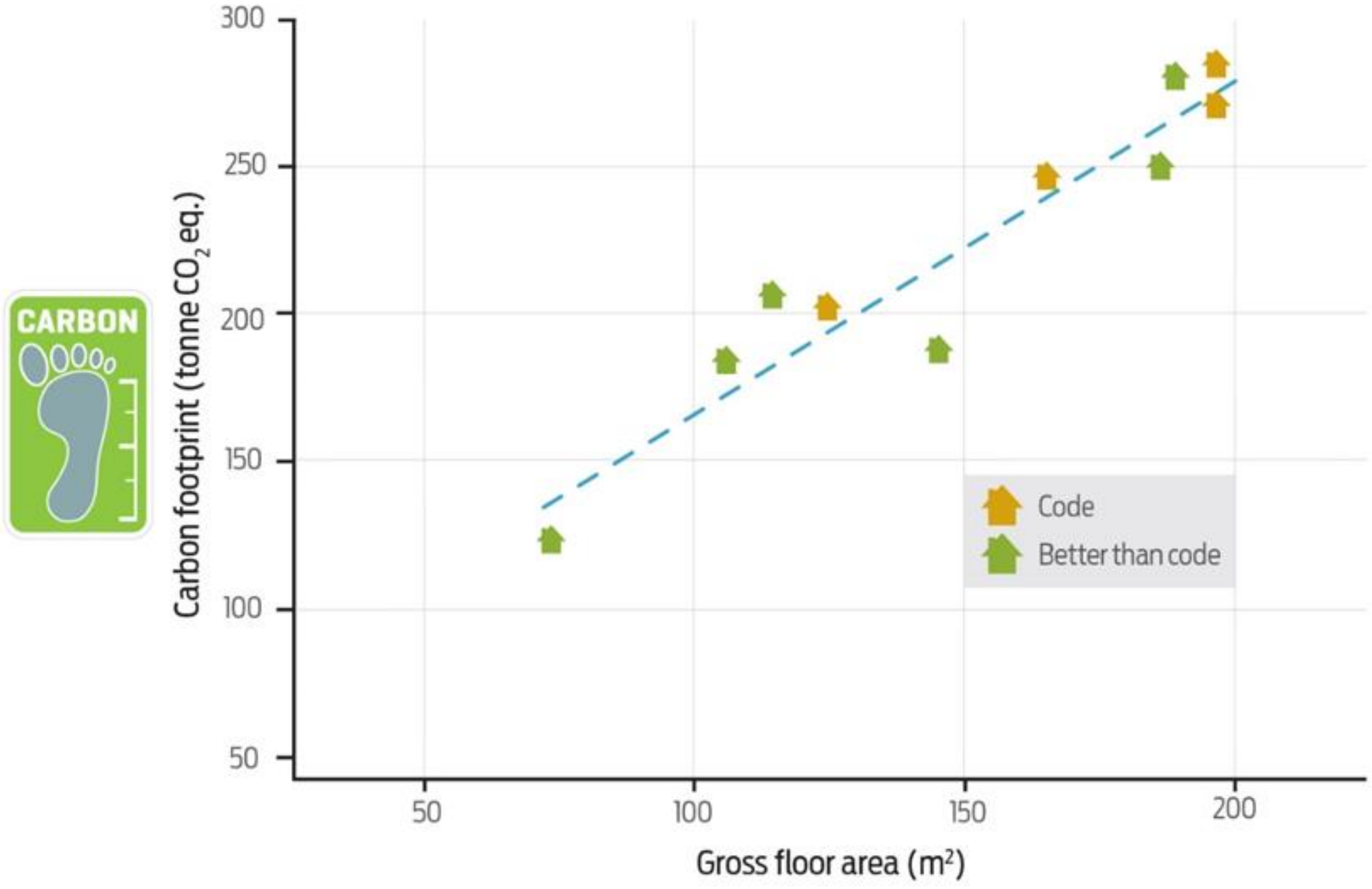


Optimisation strategy 5: Improved orientation and window distribution



Optimisation strategy 6: Reduce house size

Bigger house = greater area to heat/cool and more materials



- Average house in 1960s was 128 m², in 2010 it was 205 m² (Source: QV)
- Larger houses have larger carbon footprints (also true of high-performance houses)
- Occupancy also important

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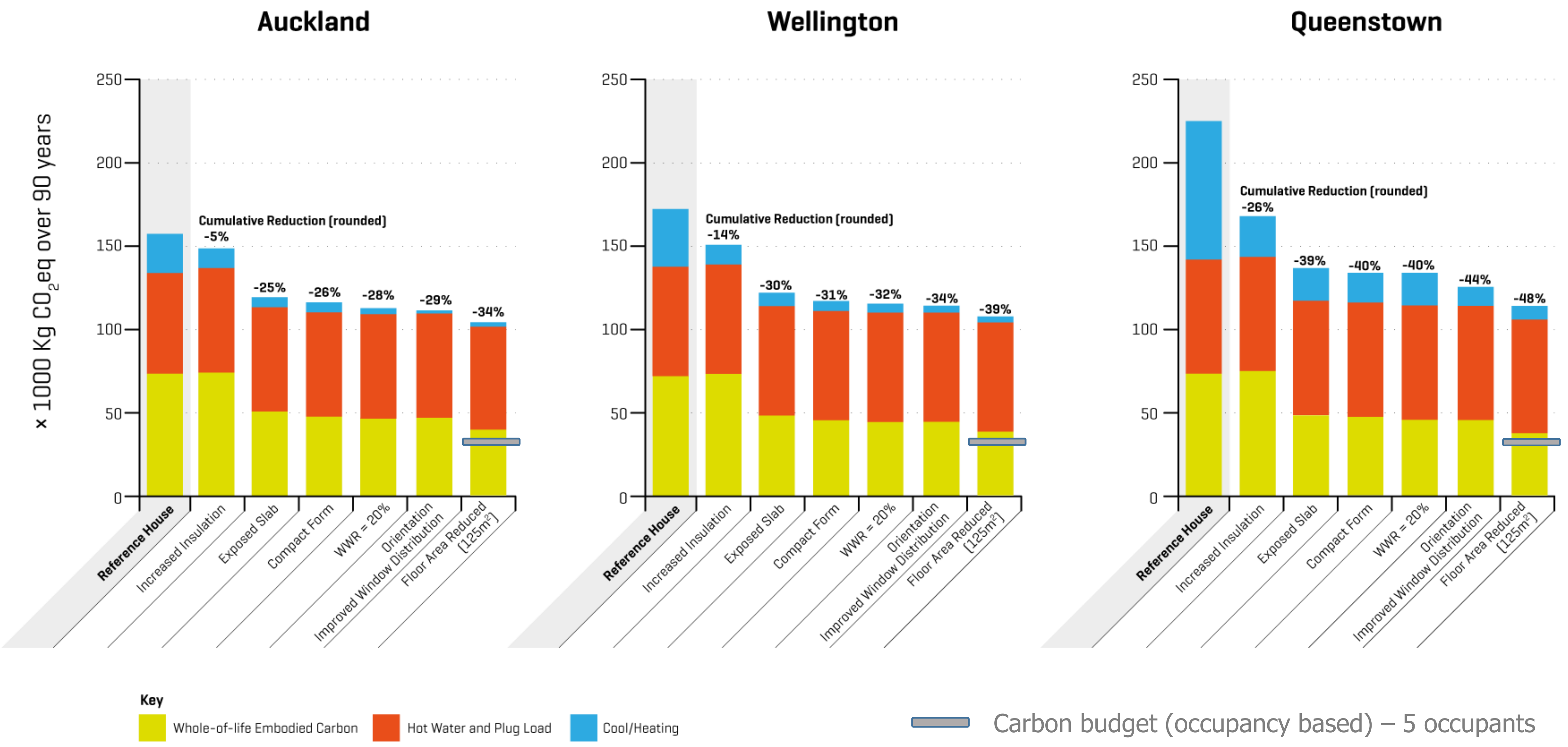
Optimisation strategy 6: Reduce house size (125 m²)



Optimisation strategies – summary

From this analysis, employing 6 'rule of thumb' strategies has the potential to reduce carbon (relative to BAU) by:

- 34% (Auckland) (32 tonnes CO_2eq embodied, 20 tonnes CO_2eq operational = **52 tonnes CO_2eq saving**)
- 39% (Wellington) (33 tonnes CO_2eq embodied, 34 tonnes CO_2eq operational = **67 tonnes CO_2eq saving**)
- 48% (Queenstown) (33 tonnes CO_2eq embodied, 74 tonnes CO_2eq operational = **107 tonnes CO_2eq saving**)

Strategies are:

- Increase construction R-values
- Expose the concrete floor slab
- Compact form
- WWR ~15–25%
- Ideally, orient north and consider glazing distribution – we used 75% N, 25% E
- Reduce house size – we used 125 m² for 5 occupants

No substitute for assessing a specific design in a specific place through the design (and build) process

Same house with a suspended timber floor

Same 6 'rule of thumb' strategies have the potential to reduce carbon (relative to BAU) by:

- Auckland: 38 tonnes CO_2eq embodied, 9 tonnes CO_2eq operational = **47 tonnes CO_2eq saving**
- Wellington: 38 tonnes CO_2eq embodied, 26 tonnes CO_2eq operational = **64 tonnes CO_2eq saving**
- Queenstown: 39 tonnes CO_2eq embodied, 61 tonnes CO_2eq operational = **100 tonnes CO_2eq saving**

- More sensitive to WWR and orientation/window distribution – lower WWR and less glazing to N and W in warmer climate zones better to reduce overheating risk
- Overall, similar magnitude of carbon savings (greater earlier savings, smaller ongoing savings)
- Sourcing timber/engineered woods from sustainable forestry – reduces overall calculated carbon footprint (due to incorporation of biogenic carbon sequestration

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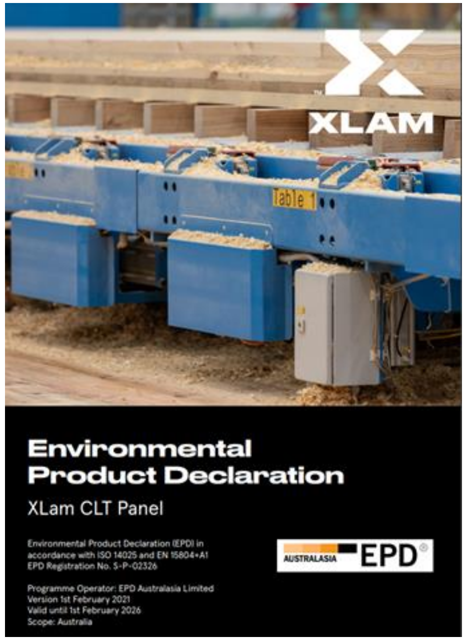
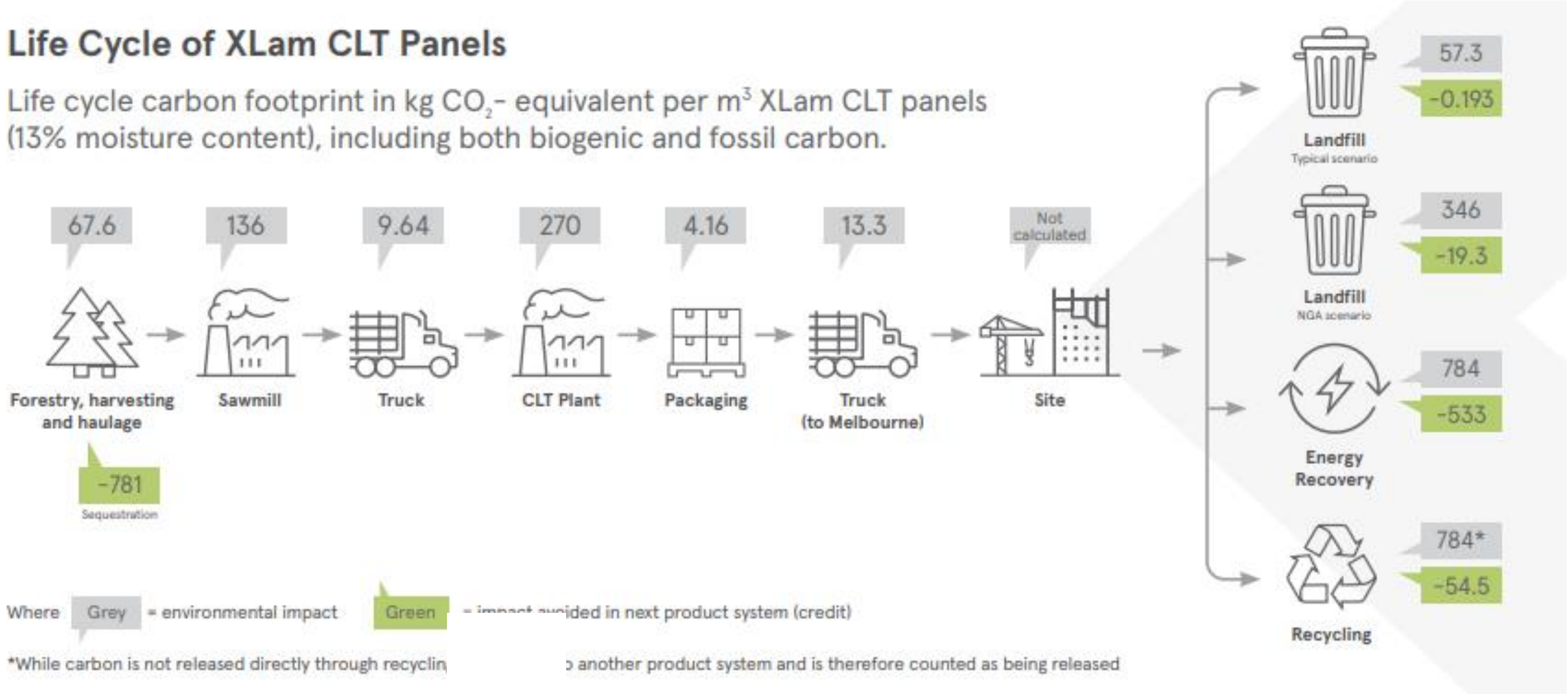
A mention about biogenic carbon





Carbon neutrality can be assumed for:

- Products certified under an established certification scheme for sustainable forest management (FSC or PEFC)

FSC PEFC

Source: EN 16485: 2014; Round and sawn timber – Environmental Product Declarations – Product category rules for wood and wood-based products for use in construction

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Test – alternative scenarios

Warmed climate (2050) – we found:

- Heating down, cooling up (as expected)
- May want to consider WWR at the lower end of 15–25% suggested range (particularly for warmer climate zones)
- Overall, suggested strategies remained valid

Relaxed heating/cooling schedules – we found:

- Significant reduction in heating and cooling energy (as expected)
- Moderating benefit of thermal mass of exposed concrete floor slab reduced
- Lower requirement for cooling means WWR may trend towards upper end of 15–25% without too much penalty – less cooling needed due to tolerance for higher indoor temperature (27°C vs 25°C)
- Otherwise, suggested strategies remained valid

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Option 1: CO_2NSTRUCT

- Can use to compare climate change impacts from manufacture of alternative materials.
- Be aware that alternatives may require different quantities to fulfil the same function in a building

Carpeting

Go to summary of material classes	Material	Qty	Embodied carbon (kg CO_2eq/qty)	Embodied energy (total) (MJ (NCV)/qty)	Embodied energy (non-renewable) (MJ (NCV)/qty)	Embodied energy (renewable) (MJ (NCV)/qty)	Notes (see below table)	Data quality
Product code								
PR_35_57_11_62_1	Carpet - tile, tufted (pile material 1000 - 1100 g/m² recycled polyamide 6, heavy bitumen base with fibre glass reinforcement) (total recycled content = 23.4%)	m²	10.00	213.10	198.00	15.10	ca1	C
PR_35_57_11_62_2	Carpet - tile, needled (pile material 700 - 800 g/m² polypropylene, heavy bitumen base with fibre glass reinforcement)	m²	4.31	151.49	145.57	5.92	ca2	C
PR_35_57_11_62_3	Carpet - tile, needled (pile material 1350 - 1450 g/m² polypropylene, heavy bitumen base with fibre glass reinforcement)	m²	6.18	214.86	206.53	8.33	ca3	C
PR_35_57_11_62_4	Carpet - tile, needled (pile material 1750 - 1850 g/m² polypropylene, heavy bitumen base with fibre glass reinforcement)	m²	7.59	259.43	249.47	9.96	ca4	C
PR_35_57_11_62_5	Carpet - tile, flat woven (pile material (maximum) 700 g/m² polyethyleneterephthalate (PET), ethylene vinyl acetate (EVA) and felt heavy base) (total recycled content = 12%)	m²	12.30	296.70	258.00	38.70	ca5	C

Materials/construction

Should also consider service life of materials – default materials service life data available at www.branz.co.nz/buildinglca (and select "Data") – see *Building materials replacement (module B4) v2 – final.xlsx*

Option 2: CO_2RE/HECC

- CO_2RE: Compare whole-of-life embodied carbon for residential wall, floor, roof constructions – taken largely from the BRANZ *House insulation guide* (5th edition) – results presented per m²
- HECC: Calculate a dwelling carbon footprint, using areas of constructions

NZGBC HECC Tool

Option 3: LCAQuick (or other building LCA tool)

- Can develop your own construction build-ups
- Results presented as whole-of-life embodied carbon (using embedded BRANZ service life defaults)

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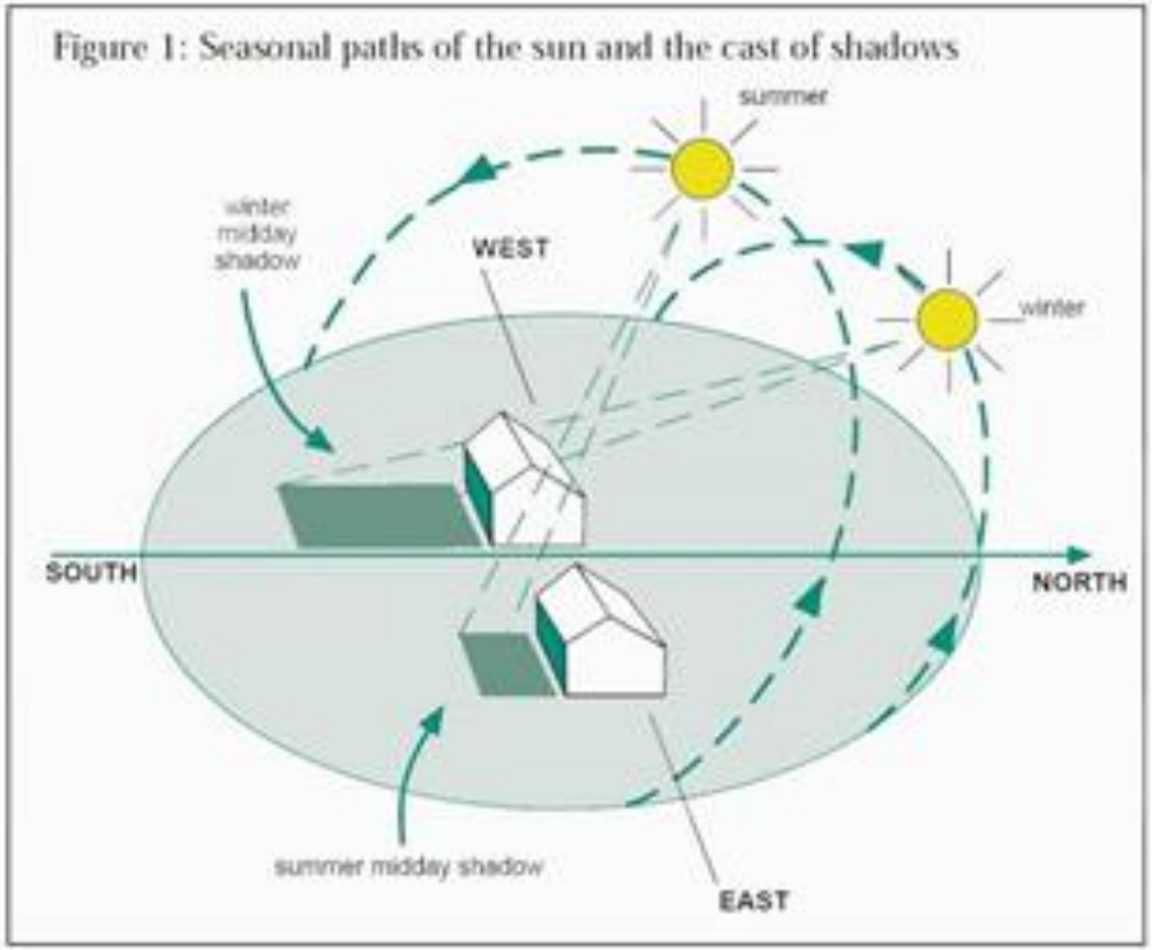
www.branz.co.nz/calculators-tools/
www.nzgbc.org.nz (select Green Homes/Technical Resources)

Other considerations: Basic passive design principles

Consider the simple stuff:

- Liveability
- Room orientation
- Seasonal sun paths
- Solar access/shading
- Prevailing warm/cold winds
- Supplementary natural ventilation
- Adjacent trees/structures



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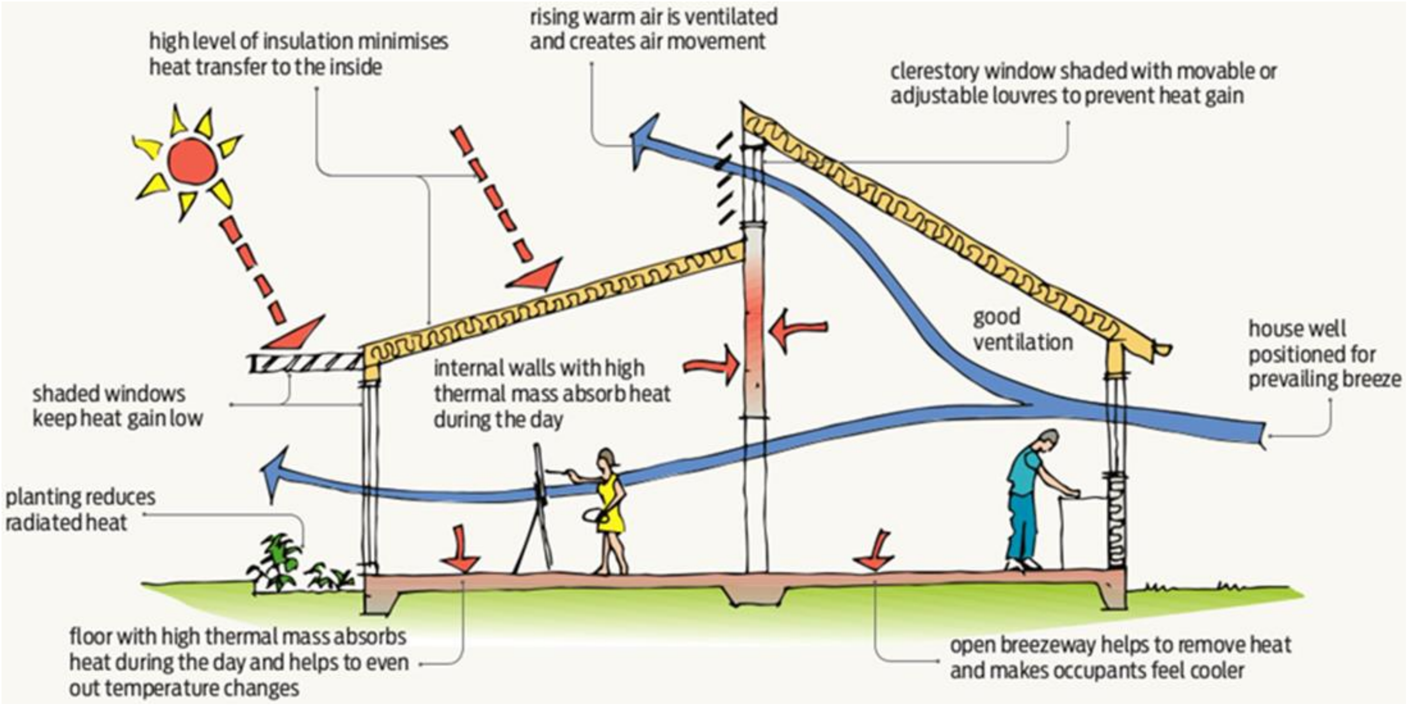
Other considerations: Using the breeze

Narrow plan across prevailing breeze facilitates internal cross-flow

Enhance with stack effect ventilation

Cooling will become more important (IEQ)



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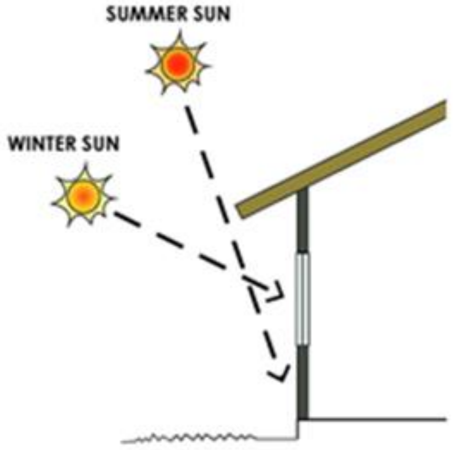
Other considerations: Glazing

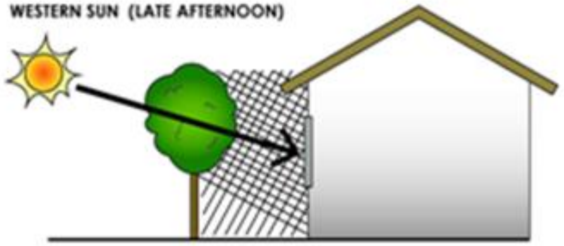
Exterior glazing is critical for overheating/cooling:

- Manage north and west facing glazing
- Consider the solar heat gain coefficient (SHGC) of the glass
- Opening percentages/location (ventilation)

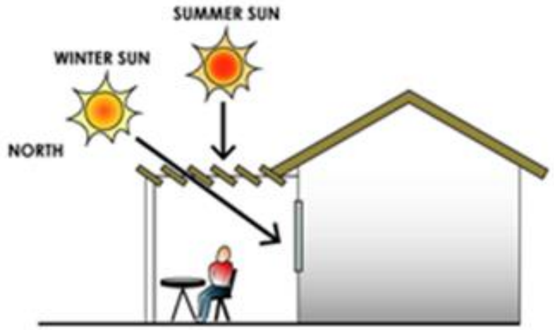
Even high-performance windows/doors are significantly less thermally efficient than the wall they are installed in



Eaves & shading devices can protect windows from direct sunlight in summer and allow winter sun to penetrate internal living areas



Strategic tree planting around your home can help protect windows from late afternoon western summer sun.



Shading devices fitted to external verandahs & pergolas can allow winter sun to penetrate internal living areas while blocking the harsh summer sun

Other considerations: MDH passive principles

Orientation
Glazing
Shade

Fewer dwellings per ‘block’
Articulation

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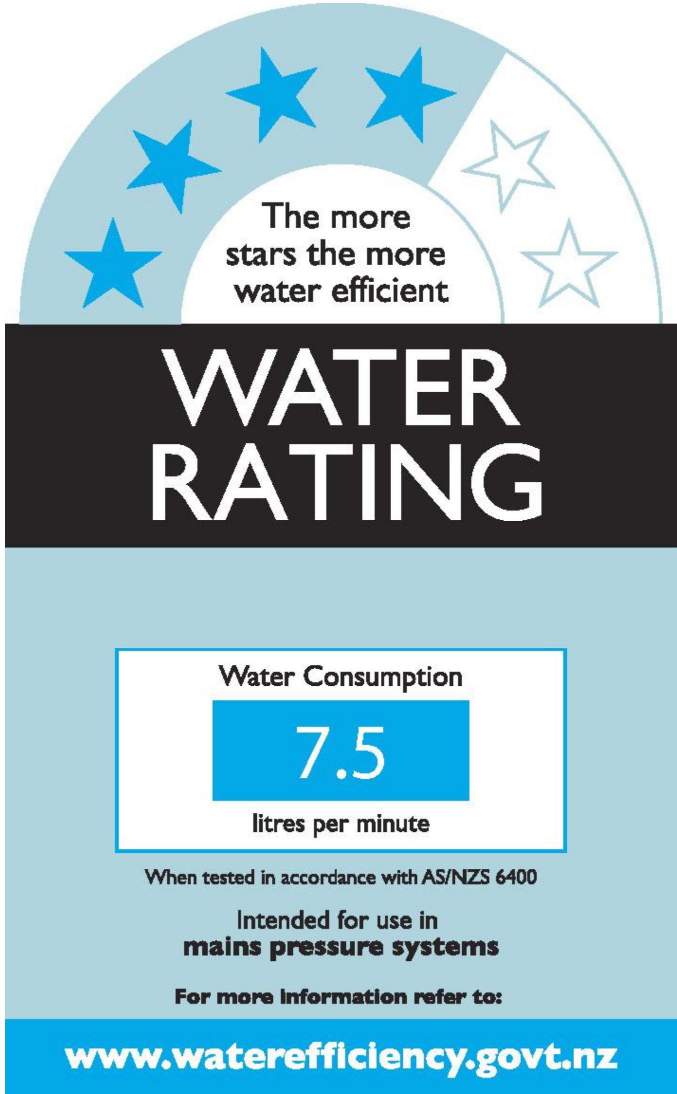
Other considerations: Reduce reticulated water use

Designs that reduce water use result in:

- Minimal impact on lifestyle
- Lower energy use
- Improved sustainability as water shortages become more common



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Other considerations: Water efficiency

Only requires:

- Water-efficient fittings
- Rainwater harvesting
- Changes to occupant behaviour

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Other considerations: Energy-efficient water heating

Most energy efficient:

- Heat pumps (with CO_2 refrigerant)
- Wetbacks on compliant wood and pellet burners (when used regularly)
- Solar

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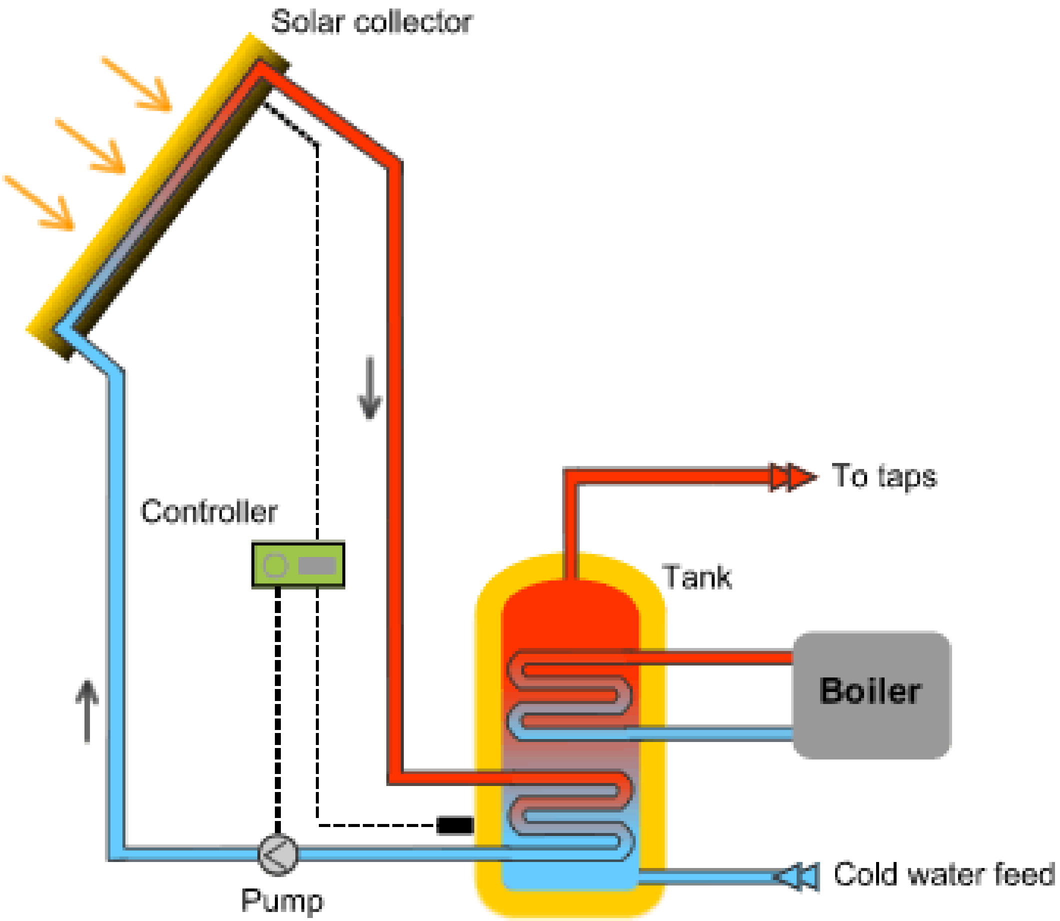
Other considerations: Energy-efficient water heating

BRANZ research under way:

- Three photovoltaic direct systems and one heat pump system (being compared to standard electric HWC)



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Other considerations: Photovoltaic (PV) power systems

Improved quality/durability

Shorter payback period

Potential 40–70% reduction in energy use

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Key messages

Key messages

- Best approach is to analyse specific designs in specific locations – upskill on available tools
- Some starter "rules of thumb" to think about:
  - Increase construction R values
  - Expose the floors as much as possible
  - Compact form
  - WWR 15 – 25%
  - Orientate north, with most windows facing north and some facing east.
  - Reduce house size

Key messages

Key messages

- Assess carbon intensity of materials and constructions using free BRANZ tools, and NZGBC HECC tool
- Ensure timber / engineered woods from sustainable forestry e.g. FSC or PEFC
- Other opportunities, for example:
  - Good passive solar design
  - Ventilation
  - Managing water demand
  - Water heating
  - Potential for PV

Key organisations

A number of organisations are focused on improving building performance:

- NZGBC
- Passive House Institute New Zealand
- Eco Design Advisors
- SUPERHOME movement
- Lifemark
- Beacon Pathway
- BRANZ

Useful links

BRANZ zero-carbon built environment research programme
www.branz.co.nz/environment-zero-carbon-research/transition/

Building LCA
www.branz.co.nz/buildinglca

CO_2NSTRUCT
www.branz.co.nz/co2nstruct

LCAQuick:
www.branz.co.nz/lcaquick

Building LCA case studies
www.branz.co.nz/pubs/case-studies/lcaquick/

Datasheets
www.branz.co.nz/buildinglca (and select 'Data')

Contact: david.dowdell@branz.co.nz

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