By *Dave Dowdell, Principal Scientist - Sustainability*

Rules of thumb to cut carbon

Recent BRANZ modelling provides a starting point for designing lower-carbon houses by quantifying carbon emissions savings from six design rules of thumb. In part 1 of this 2-part series, we explain the modelling and cover the first two rules of thumb.

WHEN PREPARING the BRANZ Carbon Challenge webinars in March 2022, we developed six rules of thumb to help designers deliver lower-carbon houses. They are intended for those that want to consider lower carbon in design but do not yet have the capability, time and tools to quantify the greenhouse gas emissions of their designs.

Urgent need to change new builds

We know from BRANZ and others' research that there is now a pressing need to reduce greenhouse gas emissions from our building stock. New builds present an opportunity that, if they are designed and built for lower carbon, reduces the scale of low-carbon retrofits needed in the future.

These rules of thumb are intended as a starting point. They are not exhaustive - other strategies can reduce greenhouse gas emissions further. They consider the New Zealand climate zones defined in the 5th edition of Building Code H1/AS1, due to become mandatory in November 2022, but do not consider site-specific issues - for example, ground conditions and shading.

Based on a modelling approach, the outputs need to be considered alongside other design issues, and these are addressed in the practical companion articles by Greg Burn - *Rule of thumb 1: Increase insulation* (page 34) and *Rule of thumb 2: Expose the concrete floor slab* (page 39).

Specific designs in specific locations should, ideally, be modelled in energy simulation software to inform the design process. However, in the absence of this, the rules of thumb provide options that, if implemented appropriately, should help towards achieving a lower-carbon outcome.

Research scope and method

The research focused on estimating the carbon reduction achievable for a reference house with the following characteristics:

- Stand-alone with a gross floor area of 156 m², excluding an attached garage.
- Single storey.
- Four bedrooms, two bathrooms.
- Carpeted concrete floor slab.
- Designed to achieve current H1/AS1 construction R-values, adjusted to include a 34% wall framing ratio, following Building Research Levy-funded research carried out by Beacon Pathway. See *Moving beyond the bridge* in *Build* 182.

Building carbon footprints were calculated assuming a 90-year service life, with the following scope:

- Whole-of-life embodied greenhouse gas emissions from manufacture of materials, transport to the construction site, installation - waste generated and end-of-life routes for materials, maintenance and intermittent replacement of materials over the building service life and building end of life.
- Operational greenhouse gas emissions, arising from simulated heating and cooling, as well as hot water and plug loads. While they were included, no strategies considered reductions in energy for

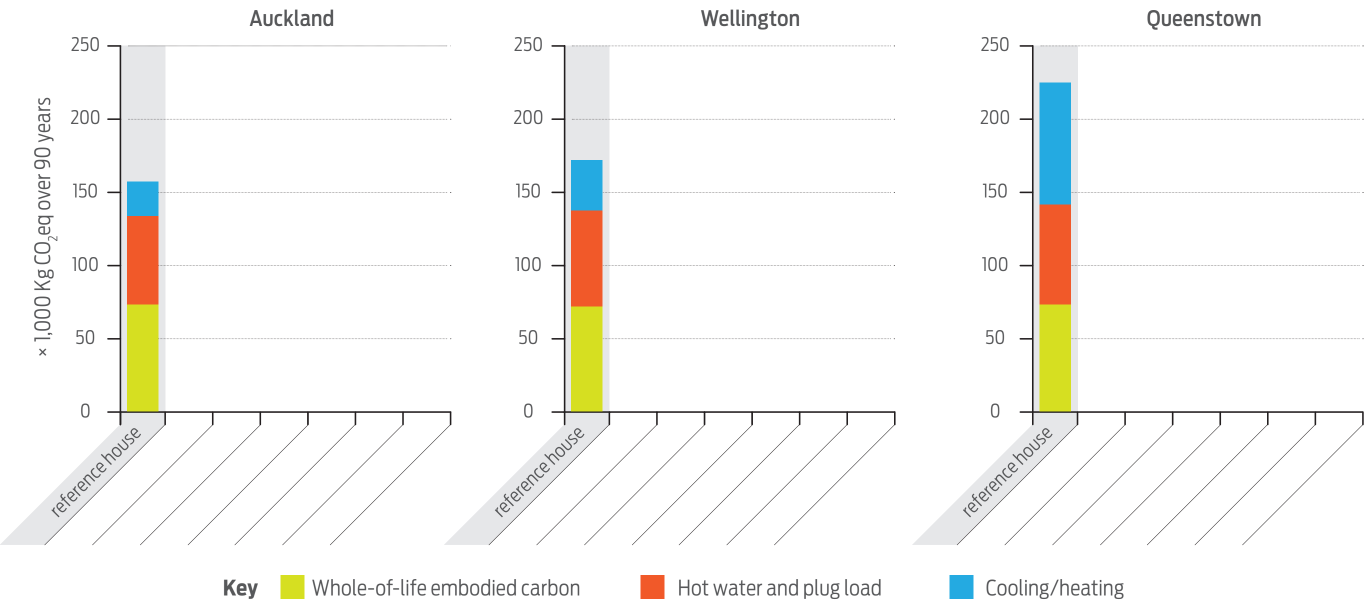

Figure 1: Reference house total carbon footprint over a 90-year service life.

hot water and plug loads, so these did not change.

The carbon footprint of providing potable water to and removal of wastewater from the house was excluded.

Additional carbon benefits - for example, from carbon sequestration - that may be derived by sourcing timbers and engineered woods from sustainable forestry and recycling or reuse of materials was not included.

Reference building emissions

The reference house building carbon footprint is shown in Figure 1 assuming its location in Auckland (zone 1), Wellington (zone 3) and Queenstown (zone 6). It ranges from over 150 tonnes CO_2eq in Auckland to 225 tonnes CO_2eq in Queenstown - the difference primarily due to increased requirements for temperature control.

While a significant proportion of the embodied emissions occur during construction, emissions from energy use are incremental, occurring year on year as the occupants live in the house.

Methodology

The process for carrying out the research follows - further details can be found in the methodology report:

- Using the EnergyPlus 9.4 energy simulation software, a simple box model house was developed.
- Different variables such as window-to-wall ratio and window distribution (and settings for these) were tested through the box model house to estimate energy use. Our base assumption is that the occupants keep their house within a year-round temperature range of 18-25°C to ensure that our rules of thumb do not compromise achieving warmer, drier and healthier homes.

Table 1

Modelled construction R-values

BUILDING ELEMENT	CLIMATE ZONE		
	1	3	6
Roof	R5.0	R6.0	R7.4
Walls	R2.4	R2.8	R3.8
Floor (slab on ground)	R1.9	R2.5	R3.6
Windows	R0.39	R0.45	R0.62

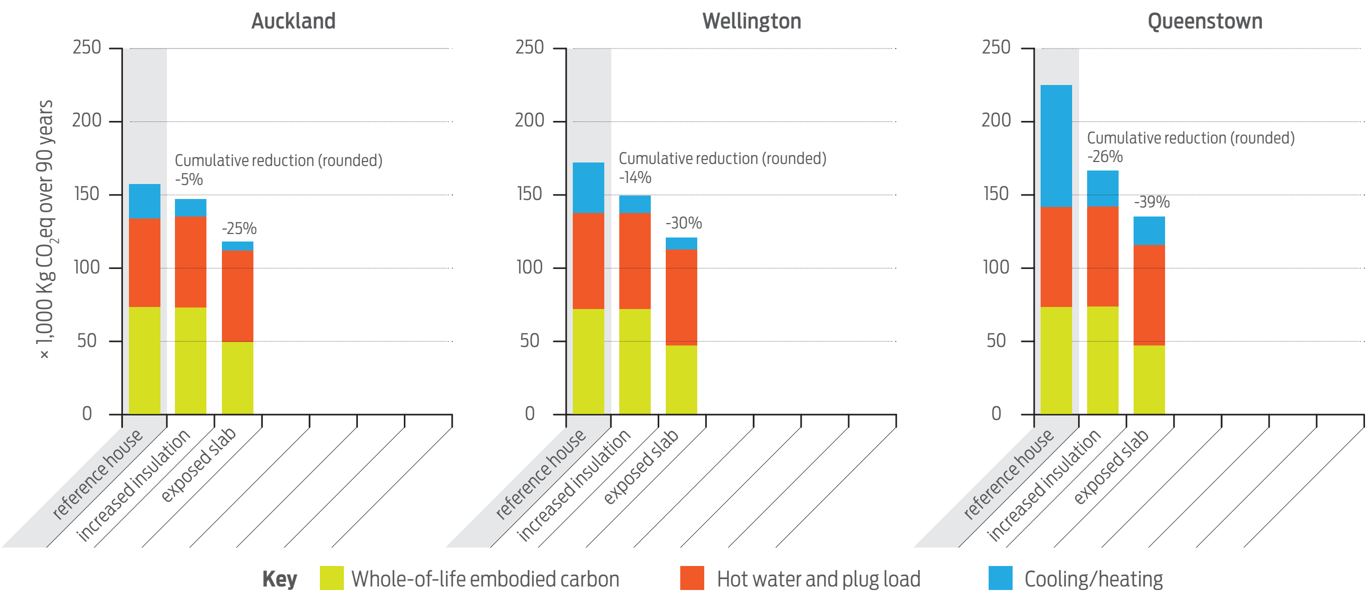

Figure 2: Rules of thumb 1 and 2 – cumulative modelled carbon reduction achieved.

- Building carbon footprints were then calculated.
- Preferred settings for each of the tested variables were identified to determine rule-of-thumb optimums.
- Each of these optimums were then cumulatively applied to a simplified version of the reference house.
- Potential carbon reductions when each rule of thumb was applied were calculated and total cumulative carbon reductions obtained.

Rule of thumb 1: Increase construction R-values

Adding more insulation to a house adds embodied carbon. However, it provides a more comfortable, drier and healthier environment for the occupants and can reduce energy use.

As this research pre-dated MBIE's release of the H1/AS1 5th edition, this assessment used the construction R-values in Table 1 - these are comparable to international standards and were Option 2 in MBIE's *Consultation document Building Code update 2021*.

The result of reaching the construction R-values in Table 1 compared to current H1/AS1 settings (adjusted for framing ratio) is illustrated in Figure 2. Despite a modest increase in embodied carbon of 1-2.5 tonnes CO_2eq to achieve the higher construction R-values, overall carbon savings range from 5% in Auckland to 26% in Queenstown.

Increasing construction R-values beyond those in Table 1 may yield further carbon benefits, but this was not specifically tested.

When seeking to increase construction R-values, consider the embodied carbon of the elements making up the thermal envelope. The BRANZ CO_2RE tool can help with selection of wall, floor and roof elements, and the NZGBC Homestar Embodied Carbon Calculator tool can help with calculating building carbon footprints. Both are free, intuitive and available for download.

Rule of thumb 2: Expose the concrete floor

Exposing the concrete floor slab provides two potential greenhouse gas benefits:

- It avoids the embodied carbon of floor coverings, which have shorter service lives than the house itself and may need multiple replacements. This benefits the embodied carbon.
- It exposes the thermal mass of the concrete, which helps to moderate temperatures experienced in the house. This benefits the operational carbon.

For this assessment, we assumed carpet was used throughout the house and was replaced every 12 years. The replacement of floor coverings may occur because of change of house ownership and not solely because they are worn out. Figure 2 illustrates the cumulative greenhouse gas benefit of implementing rules of thumb 1 and 2.

There are two limitations with the modelling:

- The operational carbon reduction due to exposure of the concrete thermal mass benefits from our base assumption that the occupants seek to keep the indoor temperature at 18–25°C year round. The operational carbon benefit relative to the reference house is reduced in situations where this is not the case.
- Manufacturing emissions for materials that need to be replaced in the future are based on current manufacturing emissions due to the availability of data. However, we expect manufacturing emissions to decrease in the future in line with the goal to move towards a net-zero carbon economy. Therefore, the embodied carbon benefit is likely to be overstated.

Suspended timber floor

We also considered the same house but with the concrete floor slab replaced by a suspended timber floor. We found a greater embodied carbon saving due to the lower carbon footprint of manufacturing timber compared to concrete but a lower operational carbon saving due to the loss of thermal mass in the suspended timber floor option. Overall, carbon savings relative to the reference house were similar.

The embodied carbon of the suspended timber floor option can be reduced further by using timber and engineered woods sourced from sustainable forestry. One way is to procure product certified by a responsible forest management scheme such as the Forest Stewardship Council (FSC) or Programme for the Endorsement of Forest Certification (PEFC). Carbon footprint data on the manufacturing emissions of different materials is provided in CO_2NSTRUCT, which is freely available on the BRANZ website.

To reduce greenhouse gas emissions, it is also worth considering:

- whether a material is needed at all
- whether reused materials can be used or materials with a high recycled content
- whether it is possible to avoid waste during construction, and if waste is generated, whether it can be reused or recycled
- durability – whether the material can last significantly longer than alternatives
- ease of maintenance and how the design facilitates maintenance.

More information

- Watch the BRANZ Carbon Challenge webinars, see www.branz.co.nz/pubs/previous-webinars.
- BRANZ Carbon Challenge Seminar parametric energy simulation: methodology, background and assumptions – www.branz.co.nz.
- BRANZ tools (CO_2RE, CO_2NSTRUCT), see www.branz.co.nz/calculators-tools/
- NZGBC Homestar Embodied Carbon Calculator tool, see www.nzgbc.org.nz (select Green Homes/Technical Resources).

For more The second article in this series in *Build* 191 will set out rules of thumb 3 to 6.