A carbon budget for New Zealand houses

Constructing lower-carbon buildings is an important part of reducing greenhouse gas emissions to address climate change. Until recently, there has been little work to calculate the amount of greenhouse gases that a New Zealand house could allowably emit while still moving towards New Zealand's 2050 net-zero carbon goal. The BRANZ carbon budget project calculated this figure for houses being built up to 2050. The project also found that the emissions from typically-sized new-build detached houses today exceeds the carbon budget by several multiples.

In the Climate Change Response (Zero Carbon) Amendment Act 2019, New Zealand has set in law a target to reduce net emissions of greenhouse gases (except methane from plants and animals) to zero by 2050. One of the purposes stated in the Act is to "contribute to the global effort under the [United Nations] Paris Agreement to limit the global average temperature increase to 1.5° Celsius above pre-industrial levels".

Starting in 2021, 5-yearly greenhouse gas emissions budgets will be set for New Zealand. These will become increasingly more restrictive towards 2050 so that eventually our net emissions of all greenhouse gases (except biogenic methane) must be zero.

The building and construction industry will need to play its part. If we start with stand-alone houses, we can calculate a carbon budget to ensure that any emissions are consistent with working towards the 2050 goal. Then we can examine how much greenhouse gases new-build homes emit to see if the houses we are actually building are 'over budget' and, if so, by how much.

Part of the budget calculation is around emissions from the operation of buildings (space and water heating, use of appliances and so on). Part comes from materials-related emissions from the manufacturing of construction materials and the construction, maintenance, replacement and end of life of buildings. This requires analysis of the environmental impact associated with buildings throughout their whole lifetime, using techniques such as life cycle assessment (LCA) or carbon footprinting.

Scientists from BRANZ and Massey University have developed a method for calculating a carbon budget, which has been shared internationally. In summary, the method takes a top-down approach that assigns a share of the global carbon budget for 2018–2050 to a country, then to its construction sector and finally to a building. This results in a carbon budget for new buildings in New Zealand until 2050.

To estimate the climate impact of the New Zealand detached housing sector, researchers used a stock projection developed by BRANZ. This was based on assumptions including socio-economic growth in different regions of New Zealand, floor area of a new-build detached house and demolition rate. The model consisted of two components. One projected the growth in the number and total floor area of detached houses up to 2050, and the other calculated the associated climate impact.

First, the total number and the total floor area of detached houses that existed at the end of 2017 were modelled and then projected up to 2050 based on their ages and using a 90-year service life.

Next, the total number and total floor area of new-build detached houses for 2018-2050 were projected based on long-term building consent trends.

Finally, the environmental impact of New Zealand detached houses for each year 2018-2050 was estimated based on the calculated impact of the pre-existing and new-build detached houses and the projected number of pre-existing and new-build detached houses for each year from 2018 to 2050.

The typical house was taken as 198 m^2 floor area, based on June 2019 Stats NZ data.

The life cycle stages assessed were:

- product - the embodied emissions of the materials
- construction process - the emissions associated with materials transportation and wastage at the construction site
- maintenance - emissions from activities such as repainting
- replacement - emissions from replacing materials
- operational energy use - emissions from heating, cooking, water heating and so on
- operational water use - emissions from pumping/treating water
- end of life - emissions from demolition activities

With energy use, new houses were simulated to maintain a healthy indoors temperature no lower than 18°C or higher than 25°C. Assumptions were made around heating and cooling, water heating, lighting and plug-in appliances. Current materials manufacturing technology was used, but some materials were not included, including electrical and plumbing, and kitchen and bathroom units.

The carbon budget

The carbon budget represents emissions that can occur between now and 2050 that are 'allowable' based on the Intergovernmental Panel on Climate Change estimates. These estimates are the total amount of carbon that humankind is still able to emit in the period 2018-2050 that will not result in exceeding specified temperature rises (usually specified as 1.5 or 2.0°C). The budget is therefore an allowance between now and 2050 - a transition period before we need to be net-zero carbon.

For the more ambitious Paris Agreement target of limiting global temperature rises to 1.5°C above pre-industrial levels, the budget figure for a newly-built detached house is 35 tonnes CO_2 equivalent. This will gradually change over time as the method refines and the input data improves.

The next step was to assess the levels of emissions our new houses are actually responsible for. BRANZ researchers calculated the carbon footprints of 10 real New Zealand houses. A mix of single-storey and double-storey, the houses range from 75-194 m^2 floor area. Some have been designed to comply with New Zealand Building Code clause H1 *Energy efficiency* requirements and some designed to exceed them. The carbon footprints were calculated with the BRANZ tool LCAQuick and consent documentation. Each house was simulated to maintain a comfortable year-round indoor temperature of 18-25°C in Auckland, Wellington and Christchurch. The total carbon footprints obtained were then averaged.

There is a wide gap between the carbon footprint of what we are typically building and the carbon budget (for a typically sized house) of what we need to be building (Figure 1) - we are substantially over budget.

While some of the houses built to exceed the minimum requirements of clause H1 had lower carbon emissions than the houses built just to comply with H1, this was not true in every case. In other words, higher-performance houses are not necessarily low-carbon houses. They may have lower heating energy demand but may have significant energy demand for plug-in appliances and hot water.

Larger houses can have larger carbon footprints, and this is true for high-performance houses as much as houses that merely meet Building Code minimums. Larger houses with few occupants are not desirable from a carbon perspective.

New-build detached houses contribute around one-third of the projected climate impact of the New Zealand detached housing sector over the decades 2018-2050 (existing houses contributing the balance).

The climate impact of the New Zealand new-build detached houses modelled in this study was lower than the climate impact of detached houses in many other countries. Key factors that account for this are materials used (timber is more common in New Zealand while bricks and concrete are more common overseas) and the fact that around 85% of New Zealand's electricity is supplied from lower-carbon energy sources such as hydro and wind.

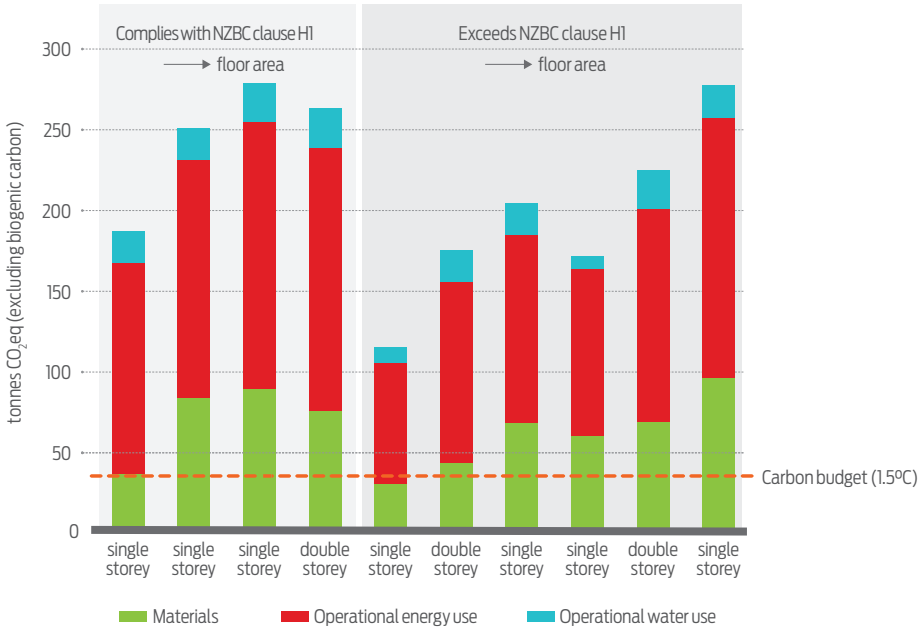

Figure 1. Total global warming potential (tonnes CO_2 equivalent) over 90 years calculated for 10 stand-alone houses.

Notes:

- This excludes consideration of CO_2 adsorbed by sustainable forestry used for manufacture of timber and engineered woods.
- Operation includes space heating/cooling, water heating and plug loads. Many improvements will come from more-efficient appliances, outside the control of building design.
- The carbon budget figure will change over time as methods improve and input data changes.

The contribution of material selection and house design

It has been understood for several years now that energy use in operating our houses accounts for the biggest contribution to greenhouse gas emissions from houses over their 90-year service lives, and this study confirmed that (Figure 2). However, the net-zero carbon commitments in law have introduced an important target date of 2050 for us to work towards. The role of materials increases proportionally by a significant amount when this timeframe is considered, going from just over one-quarter to be closer to one-half.

The embodied carbon involved in house design and material selection therefore needs to be carefully considered. A significant proportion of materials-related greenhouse gases have been emitted well before a house's first occupants step across the threshold.

There is an opportunity to use more bio-based materials such as timber and engineered wood that have captured and stored atmospheric carbon dioxide as the timber was growing. Naturally, the forests producing the timber must be sustainably managed. As a leader in both timber production and the development of engineered wood, New Zealand has advantages here.

When a new-build detached house in the carbon study was credited for the biogenic carbon in its materials, the excess of actual emissions over the carbon budget for materials emissions dropped by about half and in the construction process by a quarter.

Another series of calculations showed that a house using more sustainably sourced bio-based materials may have the potential to be 'net-carbon negative' following construction. Figure 3 illustrates this. House A, which is net-carbon negative following construction, can be operated for over 20 years and is still below the embodied carbon budget of House B following construction.

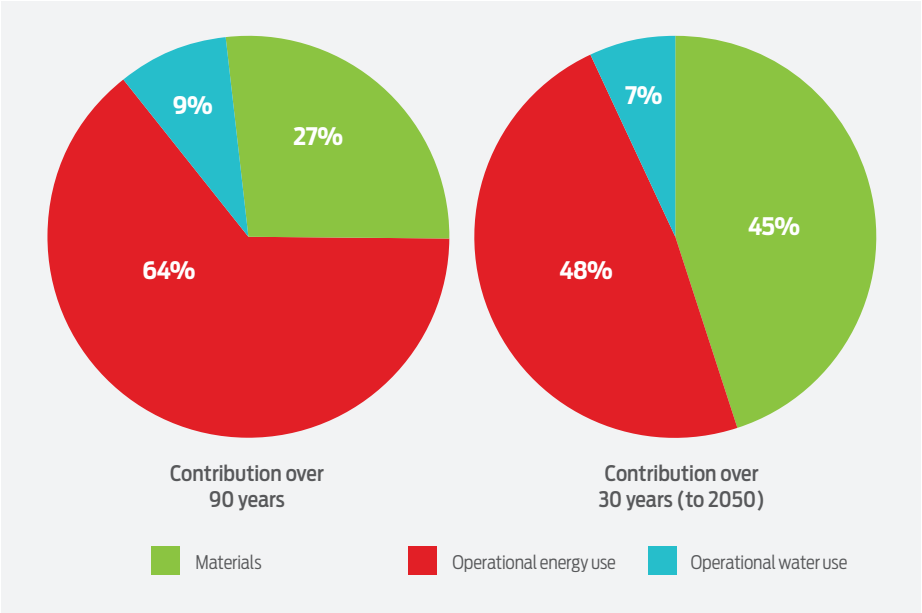

Figure 2. The contribution of materials, energy use and water consumption to a new house's greenhouse gas emissions over different periods of time.

Conclusion

New Zealand has set in law a target to reduce net emissions of greenhouse gases (except methane from plants and animals) to zero by 2050. The building industry must play its part by working towards constructing net-zero carbon buildings. BRANZ and Massey University scientists worked out a carbon budget for new houses being built up until 2050.

BRANZ scientists calculated the emissions that current new-build houses were responsible for, and it exceeded the carbon budget by several multiples. It is imperative to close this gap, applying this knowledge to mainstream construction as soon as possible.

Materials make a more significant contribution to the climate change impact of houses in the shorter timeframe to 2050 compared with a 90-year service life. Consequently, there is an early and important opportunity to reduce our greenhouse gas emissions through considered design and careful materials selection for our new houses.

The figures reported in this Research Now will change as work continues to test assumptions and update input data, such as forecasts of future building activity. Significant updates will be reported on the BRANZ website, in *Build* magazine and elsewhere.

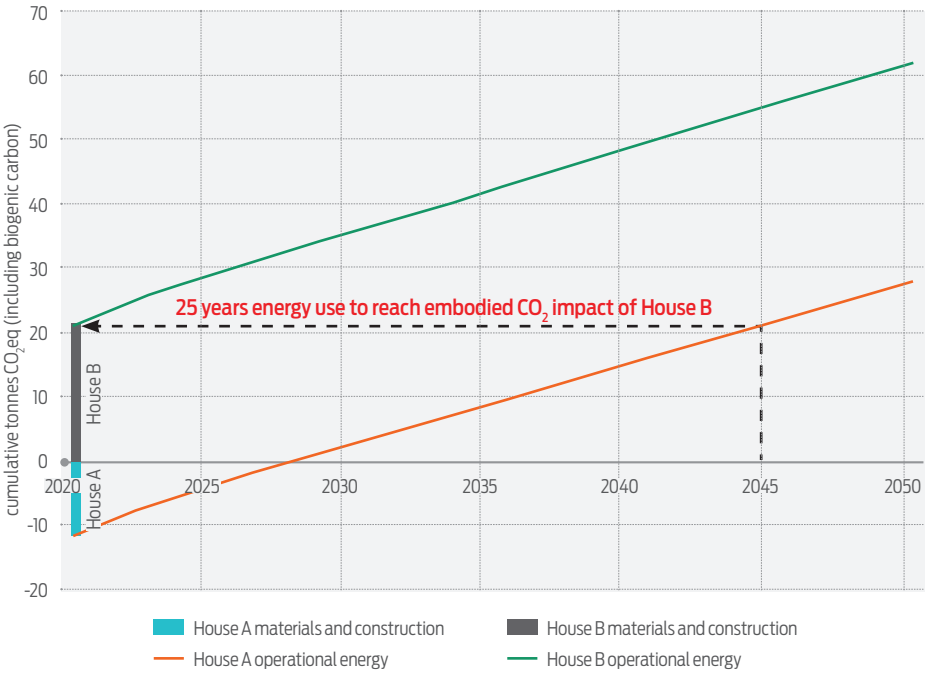

Figure 3. Illustration of the potential opportunity for net-carbon negative houses.

More information

Chandrakumar, C., McLaren, S. J., Dowdell, D. & Jaques, R. (2020). A science-based approach to setting climate targets for buildings: The case of a New Zealand detached house. *Building and Environment*, *169*, 106560.

www.branz.co.nz/environment-zero-carbon-research/

www.level.org.nz

BRANZ Bulletin 651 *Climate change, net-zero carbon and the building industry*

BRANZ Bulletin 608 *Building life cycle assessment*

BRANZ Bulletin 596 *An introduction to life cycle assessment*

The research discussed here is part of the BRANZ programme *Transition to a zero-carbon built environment.*