Energy use and CO_2 emissions

A random selection of stand-alone houses consented in 2016 were assessed for their energy use and CO_2 emissions. The findings were compared to those for a sample of houses consented in 2012 and also to the energy performance and CO_2 emissions of a very well-designed house. The results show no significant improvement in 4 years and a huge gap between good design and what is actually being built.

A random selection of 210 house building consents was made from Auckland, Hamilton City and Christchurch City Councils, and the houses were modelled in detail. To provide a fair comparison between houses, all user behaviour was standardised. Energy performance and CO_2 emissions were compared with a well-designed home, Beacon Pathway's Waitakere NOW Home, built in 2005. For the Hamilton and Christchurch comparisons, the performance of the NOW Home design was calculated for the local environment. The NOW Home was designed and built to budgets and constraints typical of ordinary New Zealand housing - it was not a high-cost eco-home aimed at the top of the market. It shows what is practically achievable in New Zealand.

Eight areas were studied overall: energy use and CO_2 emissions, water, indoor environment, functional resilience, affordability, consumer demand, industry capacity and policy and regulation. This Research Now covers the first area studied - energy use (specifically space heating and water heating) and CO_2 emissions. Although the sampled population is too small to be statistically significant, it provides useful indicative figures.

Initial assessment

The 70 Christchurch houses were first assessed for space heating to maintain comfort (Table 1).

As there was no significant difference in thermal performance between 2012 and 2016 for the coldest climate, it was considered very likely that the 2016 metrics for Auckland and Hamilton would also reflect the 2012 situation for space conditioning. Based on this assumption, only the Christchurch results were modelled for the space conditioning indicators.

Active space conditioning

As with the 2012 houses, three metrics were used to examine the 2016 space heating energy use:

- Space heating energy required per unit of floor area (kWh/m²).
- Space heating energy required per household (kWh/household).
- Space heating and cooling energy required per occupant (kWh/person).

Table 1. Christchurch space heating energy intensity – 2012 and 2016 houses, kWh/m².

LOCATION	SAMPLE SIZE		MEAN SPACE HEATING ENERGY AND 95% CONFIDENCE INTERVAL	
	2012	2016	2012	2016
Christchurch	68	70	76.7±2.2	73.7±3.6

Detailed thermal simulations were carried out on the Christchurch houses (Figure 1 and Table 2). Data from the NOW Home was used as a comparison. In these snake diagrams, the metrics for each house are shown as a circle, with all the circles shown in ascending/descending order. The median is a continuous grey line, and the 20th and 80th quintiles are dotted grey lines.

While there is a clear difference between the worst-performing and best-performing houses, there is a particularly large gap between the median Christchurch house and the NOW Home. This holds true for whichever energy use metric (by area, by household or by occupant) is chosen. This is surprising when the Christchurch homes are designed to cope in the harsher South Island winters - for example, with better insulation.

CO_2 emissions for water and space heating

Space heating and water heating account for the two largest uses of energy in houses and may

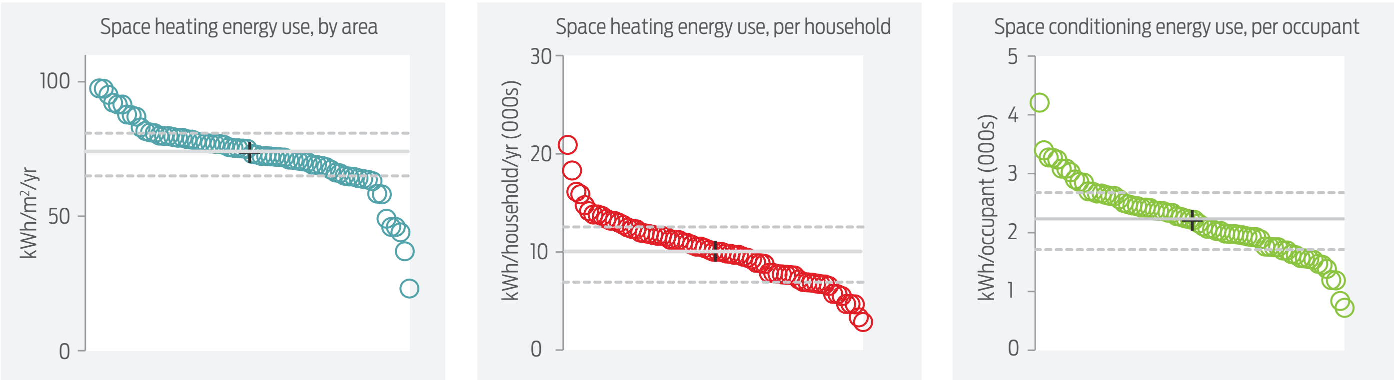

Figure 1. Space heating/cooling energy use by area, household and occupant, in descending order. (2016)

therefore account for the largest emissions of carbon dioxide. In the 2012 study, the assessment of appliance emissions was limited to just water heating. For the 2016 study, emissions likely from space heating were also assessed to give a more complete picture of the likely emissions profile of a typical new house. The new emissions metric is kg CO_2/yr/household, and the calculations were made for both the 2012 and 2016 houses to allow comparison to be made. For this part of the study, calculations were made for all the houses in Auckland, Hamilton and Christchurch.

There is a huge gulf between a carbon-efficient water heating system in the NOW Home and what is typically being installed (Table 3). The emissions in Auckland and Hamilton are over three times greater than what is readily achievable - for Christchurch, almost three times. The larger CO_2 emission footprints for Christchurch in 2016 compared to 2012 are likely due to a shift to instantaneous gas for water heating.

The calculations of space heating-related CO_2 emissions for Auckland and Hamilton were made for the 2012 houses and for Christchurch were made for both the 2012 and the 2016 houses (Table 4). Once again, there is an extraordinary difference between what is achievable in the NOW Home and what is being built. (While there seems to be a decline in the amount of yearly CO_2 per household for the Christchurch houses, this is not statistically significant.)

Potential of site for harnessing solar energy

The potential of each site for harnessing of energy and likely shading influences was studied, with the shading aspects examined more thoroughly in 2016.

NIWA's online SolarView tool quantifies the solar energy collection potential (in kWh/yr) of a given address, accounting for topographic influences. In both 2012 and 2016, the solar potential of all the sites in the three cities was close to 100% of what was available - shading from surrounding geographic features was close to nil.

The potential influence of more local shading due to nearby buildings, based on what is allowable when adhering to local recession plane rules, was explored as a mini study. District plan recession plane regulations were examined. A 2016 house was selected that had passive thermal performance characteristics close to the mean. It was assumed that developers on the neighbouring site would design to the recession plane to maximise site coverage, so shading on the chosen property would also be maximised. The living room's thermal comfort performance was simulated. Table 5 shows the potential impact of shading from a local recession plane on living room thermal comfort from 7am-11pm.

Each of the three cities' district plans has a big impact on daytime winter comfort when adjacent homes are designed to the maximum

Table 2. Key space heating statistics for the Christchurch homes.

	NOW HOME®	MEDIAN	
Christchurch		2012	2016
Space heating energy use			
By area (kWh/m²)	36	76	74
By household (kWh/household)	4,354	9,571	10,042
Space conditioning energy use			
By occupant (kWh/person)	1,146	2,040	2,220
By area (kWh/m²)		77	76

Table 3. Household water heating-related CO_2 emissions (kg CO_2/person/yr).

	NOW HOME®	MEDIAN	
Location		2012	2016
Auckland	73	264	258
Hamilton	86	296	289
Christchurch	101	240	228

Table 4. Household space heating-related CO_2 emissions (kg CO_2/household/yr).

	NOW HOME®	MEDIAN	
Location		2012	2016
Auckland	75	463	Not calc
Hamilton	151	645	Not calc
Christchurch	345	1,128	1,020

recession planes in the northern aspect. Building to the limit gives an average 72% more discomfort, assuming an 18°C comfort threshold.

The vast difference between the regions needs to be explored further with councils and the Ministry for the Environment's current national planning standards initiative, which seeks to rationalise the differences of approaches by councils.

Whole-house resource efficiency rating

The whole-house resource efficiency indicator is the ratio of the conditioned area of the house to the number of bedrooms. The lower the number, the more spatially efficient the house is likely to be. The NOW Home addresses the issue by designing out hallways and having compact bedroom spaces. Its ratio - 29 - is a good result. The figures for Auckland, Hamilton and Christchurch appear in Table 6. There is very little movement in the numbers between years for all three locations, but the scores for Hamilton indicate very good spatial efficiency.

Embodied carbon for house-lot of core building materials

Studies have shown that material-related CO_2 can make up a substantial portion of a house's total lifetime carbon emissions. This 'carbon spike' at construction can dominate life cycle emissions in the timeframe relevant to national climate mitigation/net-zero carbon goals. It has been argued that greater weighting should be attached to material-related emissions over future emissions savings in economic analyses and policy making.

Table 7 provides an estimate of the climate change impact (based on CO_2 equivalent) from materials in new-build stand-alone construction in New Zealand in 2016. These figures are an underestimate because they do not include material wastage on site, transport to site and linings, insulation, floors, paint, services and fixtures and fittings (labelled 'other' in Table 7).

It is likely that this indicator will broaden in future work to include more building components, reflecting the growing information available. It is also likely that this metric will become increasingly important as New Zealand tries to meet its carbon obligations, mainly to achieve net-zero carbon by 2050.

Conclusion

For both 2012 and 2016, there was a big difference between the active space heating requirements of the worst-performing and best-performing houses. The highest space heating use required per household was nearly three times the figure in the NOW Home.

There is also a huge gulf between the carbon-efficient water heating system and space heating system in the NOW Home and the CO_2 emissions from what is typically being installed.

The government's Committee on Climate Change stated in 2019: "Where properly planned and used, our homes can be low-carbon, more comfortable to live in, better for our health, and more affordable to run." Based on the findings in this project for the 210 houses consented in 2016, detached New Zealand homes are far from well planned. For the health and comfort of New Zealanders, this situation needs to be remedied urgently. There must also be big changes if New Zealand is to meet its net-zero carbon 2050 goals.

More information

BRANZ Research Now: Measuring our sustainability progress #2 *Indoor temperatures and the predicted impact of climate change*

BRANZ Research Now: Measuring our sustainability progress #3 *Demand, supply and affordability of key sustainability features in housing*

The research outlined here is part of an ongoing BRANZ research programme - see:

Jaques, R. (2019). *Measuring our sustainability progress: New Zealand's new detached residential housing stock (first update)*. BRANZ Study Report SR426. Judgeford, New Zealand: BRANZ Ltd.

Jaques, R. (2015). *Measuring our sustainability progress: Benchmarking New Zealand's new detached residential housing stock*. BRANZ Study Report SR342. Judgeford, New Zealand: BRANZ Ltd.

Table 5. Annual daytime discomfort in a typical lounge during heating season resulting from adjacent site (degree-hours).

LOCATION	NO BUILDINGS AND NO SHADING	BUILT TO LOCAL RECESSION PLANE RULES	RESULTING INCREASE IN DAYTIME DISCOMFORT
Auckland	1,226	2,795	128%
Hamilton	3,340	5,289	58%
Christchurch	10,794	14,190	31%
Unweighted mean of three regions			**72%**

Table 6. Key statistics for whole-house resource efficiency in Auckland, Hamilton and Christchurch (conditioned area in m²/number of bedrooms).

LOCATION	NOW HOME®		MEDIAN	
	2012	2016	2012	2016
Auckland			31	30
Hamilton	29		30	30
Christchurch			32	33

Table 7. Estimated elemental embodied carbon in new detached houses in 2016.

ELEMENT TYPE	EMBODIED CARBON (TONNES CO2 EQ.)
Total for framing	-173,791
Total for foundations	180,422
Total for roofing (excluding other)	72,850
Total for wall claddings (excluding other)	33,070
Grand total all houses	**112,551**
Embodied carbon per house	**5.28**