Indoor temperatures and the predicted impact of climate change

A random selection of stand-alone houses consented in 2016 were assessed for their thermal performance - how well they were able to maintain comfortable indoor temperatures naturally, without using any appliances. The findings were compared to those for a sample of houses consented in 2012 and also to the performance 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. Calculations also show the potential impacts of climate change on indoor temperatures.

A random selection of 210 house building consents was made from Auckland, Hamilton City and Christchurch City Councils, and the houses were thermally modelled in detail. The thermal performance of the houses was 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: energy use and CO_2 emissions, indoor environment, water, functional resilience, affordability, consumer demand, industry capacity and policy and regulation. This Research Now covers indoor environment and resilience to climate change.

Comfortable indoor temperatures in a key occupancy zone

The 70 randomly selected consented houses from Christchurch were initially computer simulated to better understand the level of occupant comfort achieved just through passive solar means, such as north-facing building orientation and window design that optimises indoor temperatures. The idea was to determine whether there were any changes between 2012 and 2016 in the performance of the homes when no space heating appliances were used.

The proxy for whole-house thermal comfort used was the number of daytime hours that the main living room temperature achieves thermal comfort without added heating or cooling. The comfortable temperature band was 18-25°C for the hours 7am-11pm year round. Figure 1 shows the amount of time the living room temperatures were comfortable from 7am-11pm for the randomly selected 2016 new-builds. In these snake diagrams, the daytime comfort hours for each house are shown as a circle, with the circles for each house shown in ascending order. The median

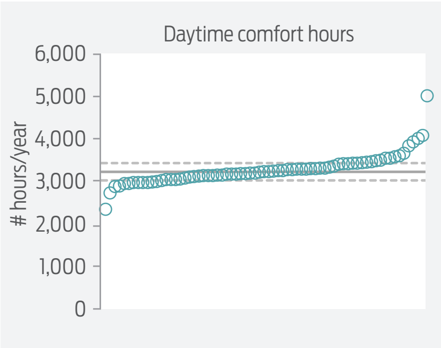

Figure 1. Comfortable living area daytime temperatures for Christchurch houses in 2016.

is a continuous grey line, and the 20th and 80th quintiles are dotted grey lines.

Table 1 extracts some key statistics, including calculations for the NOW Home in a Christchurch environment, and shows that 2016 results are almost unchanged from the 2012 results.

There is a vast difference between the thermal competence of the randomly selected stand-alone houses and the NOW Home. This is true even through the NOW Home was designed for Auckland's considerably more temperate climate, for which the New Zealand Building Code requires lower thermal envelope insulation values.

Table 1. Daytime living area comfortable temperatures via passive solar means.

LOCATION	NOW HOME®		MEDIAN	
	HRS/YR	% OF DAYTIME	HRS/YR	% OF DAYTIME
Christchurch (2012)	4,419	76%	3,296	56%
Christchurch (2016)			3,229	55%

Table 2. Key overheating statistics in the 2016 Christchurch houses.

OVERHEATING (DEGREE-HOURS/YR)	NOW HOME®	MEDIAN
Christchurch (2012)	151	**417**
Christchurch (2016)		412

Indoor temperature extremes

These measurements focus on temperature extremes achieved with no added heating or cooling. They provide a good performance indicator of a dwelling's passive solar capability, where indoor thermal comfort is dictated by its construction, internal zoning and orientation. In effect, it is a good indicator of a dwelling's overall thermal design competence.

Both 2012 and 2016 houses were simulated using a dynamic simulation program and hourly climate files, with the living room used as a proxy for the thermal performance of the whole house.

Figure 2 shows the amount of time the main living room temperatures are uncomfortably hot (temperatures greater than 25°C) for the 2016 houses. It shows the extreme performance difference between houses that have been well designed and those that have not, with a factor 9 difference in the discomfort metric used.

Table 2 compares the performance of the NOW Home and the Christchurch homes. It shows that the median figure for overheating (temperatures greater than 25°C) is almost unchanged between 2012 and 2016 in the Christchurch homes. Compared to the NOW Home, these homes have considerably more overheating in the lounge. This suggests that the designs didn't consider shading in a meaningful way.

Figure 3 shows the amount of times (number of days per year) the main living room temperatures are critically cold (the human body is put under considerable physiological stress) when not using artificial heating/cooling in the houses. Only one house bests the NOW Home in providing fewer critically cold living room temperatures, with zero days per year against the NOW Home's 17.

In Table 3, the NOW Home displays its considerable thermal advantage, demonstrating how a well-designed home performs in terms of keeping its occupants thermally protected against unhealthily low temperatures.

Once again, there is a large difference between the thermal competence of the randomly selected houses and the NOW Home. The thermal performance of the NOW Home is considerably better in terms of limiting both uncomfortably hot and unhealthily low temperatures when using the main living space as a proxy for the whole house.

Resilience – climate change implications on indoor thermal comfort

The initial assessment of the 2012 houses examined the predicted climate change implications on indoor thermal comfort for a subgroup of the sample of detached houses in Auckland, Hamilton and Christchurch. Thermal modelling and simulations were undertaken for the NIWA-predicted climates of 2030 and 2080.

The NIWA climate change models that applied in 2012 remained relevant when the 2016 houses were being assessed. As the thermal aspects of the house designs have not changed noticeably in the 4-year period, the thermal simulations were not repeated. The 2012 report's findings remain valid and therefore unchanged for the 2016 report (see More information).

The climate change elements scientists have the most confidence in are temperature, sea level, drought, fire risk and UV radiation. A New Zealand summary of these elements is shown in Table 4.

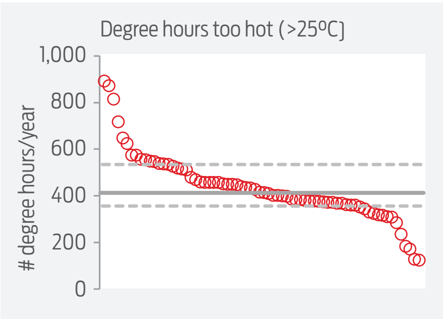

Figure 2. Overheating severity in the main living room for the Christchurch houses.

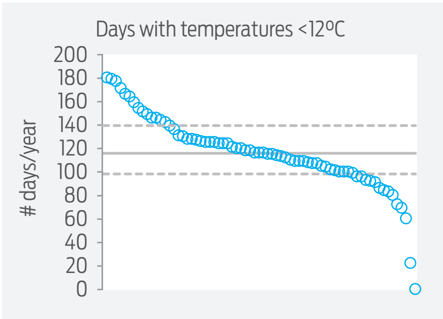

Figure 3. Critically cold living room daytime temperatures for Christchurch houses.

Table 3. Daytime length living rooms are critically cold in Christchurch houses.

LOCATION	# DAYS OUTSIDE TEMPERATURE FALLS BELOW 12°C (DAYS/YEAR)	NOW HOME® # DAYS MEAN INDOOR TEMPERATURE <12°C (DAYS/YEAR)	MEDIAN # DAYS INDOOR TEMPERATURE <12°C (DAYS/YEAR)
Christchurch (2012)	258	17	126
Christchurch (2016)			116

Table 4. Future implications of climate change.

CLIMATE CHANGE ELEMENT	2030	2080
Annual mean temperature rise	0.4–0.8ºC	1.0–2.4ºC
Mean sea level rise	0.07–0.16 m	0.23–0.52 m
Frequency of days above 25ºC	Increase	Doubling or more
Drought (1 in 20-year events)	More frequent (excluding Hokitika)	Up to 5–10 years (excluding Hokitika)
UV radiation (cf. 1980)	2% higher	0% (i.e. recovered)

Of all the climate change-related impacts, those concerning temperature change are the least complicated to computer model and quantify. These are therefore the predicted trends on dwelling comfort that were explored.

Scenarios were chosen and compared to present-day climate data (defined as the 1971-2000 period). The impact on the number of days the maximum outside daily temperature exceeds 25°C can be seen in Table 5.

The predicted climate change impact on indoor discomfort for a representative sample of stand-alone houses was thermally modelled using hourly climate files. Summer overheating and winter underheating in the main living areas was examined, based on the average of the scenarios for 2030 and 2080. Due to the large amount of computation required, only five typical houses from each of the three locations were used.

Tables 6 and 7 show the severity of the average overheating (greater than 25°C) and underheating (less than 18°C) of the houses. Computer thermal simulations assume no additional heating or cooling.

The overheating increases are considerable for all three centres in 2030 and massive in 2080 for Auckland and Hamilton especially when compared to the current situation.

Indoor overheating can be greatly reduced with carefully considered window design combined with the use of well-placed external window shading features, specific to orientation. This is by far the best mitigation strategy.

Table 5. Number of days/year where the outside maximum daily temperature exceeds 25ºC.

MAX. TEMP > 25ºC	PRESENT DAYS	ADDITIONAL DAYS IN 2030	ADDITIONAL DAYS IN 2080
Auckland	21.3	6.9 –14.6	25.9 –52.6
Hamilton	25.6	4.8 –14.9	21.3 –49.2
Christchurch	31.2	2.7 –10.2	12.7 –30.2

Table 6. Average estimated overheating period per day in main living area due to climate change for three locations.

LOCATION	CURRENT	2030	2080
Auckland	1 hour 22 minutes	2 hours 12 minutes	4 hours 50 minutes
Hamilton	1 hour 59 minutes	2 hours 37 minutes	5 hours 9 minutes
Christchurch	2 hours 4 minutes	2 hours 23 minutes	3 hours 20 minutes

Table 7. Average estimated underheating period per day in main living area due to climate change for three locations.

LOCATION	CURRENT	2030	2080
Auckland (over 4 months)	7 hours 12 minutes	5 hours 20 minutes	4 hours 10 minutes
Hamilton (over 7 months)	7 hours 18 minutes	6 hours 4 minutes	5 hours 43 minutes
Christchurch (over 9 months)	8 hours 30 minutes	7 hours 21 minutes	4 hours 1 minute

On the flipside, there will be progressively less underheating in the homes of each of the three centres as predicted climate changes take place.

Conclusion

There has been no improvement in the passively obtained comfortable daytime temperatures in the main living areas of the Christchurch houses between 2012 and 2016. There is a vast difference between the thermal competence of the randomly selected stand-alone houses and the carefully considered NOW Home design.

Considering living room temperature extremes, there are enormous differences between the houses that are well designed and those that are not.

Calculations were made on the likely effect of climate change on the indoor temperatures of a sample of houses. In all three centres (and especially Auckland and Hamilton), overheating would increase - and increase massively by 2080 - while the hours of underheating would reduce.

More information

BRANZ Research Now: Measuring our sustainability progress #1 *Energy use and CO_2 emissions*

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.