NEW ZEALAND'S BUILDING PERFORMANCE PATHWAYS

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ABSTRACT
An unprecedented opportunity to rebuild a more sustainable city in New Zealand arose due to the Canterbury Earthquakes of 2010 and 2011, when the central city was decimated by a series of earthquakes, which included an aftershock that produced one of the highest peak ground accelerations on record. New Zealand's Building Codes for thermal performance and natural ventilation lag behind those of the rest of the western world. This paper carries out a comparative analysis of international best practice, guidance, codes and legislation surrounding sustainability and building performance. The paper challenges the minimum standards of the New Zealand Building Code (NZBC) and analyses energy rating tools proposed for domestic construction. A case study building, the 'WHARE' is used and dynamically thermally modelled to illustrate how the chosen pathways will affect a typical building. Comparisons of Irish, Australian and NZBCs, utilisation of Passive House thermal performance, and comparative analysis of LEED, DEAP and Homestar rating systems are carried out. The Living Building Challenge (LBC) rating tool is discussed in the context of '*Tangata Whenua'*, the indigenous people of the land. The findings provide information on the implications of the compliance frameworks and on the current performance standards. The paper also examines site context considerations embedded within the various rating frameworks and how they compare with the LBC.
Keywords: building code, DEAP, energy rating, Homestar, LBC, LEED, passive, sustainability.

1 INTRODUCTION

The New Zealand Building Code (NZBC) has its origins in the early 1800s when European settlers arrived in New Zealand. At this time, construction was predominantly from timber. Regulation was based more or less on established building methods imported from the United Kingdom and there was no strict enforcement. The Napier earthquake of 1931 resulted in extensive damage and loss of life from damage sustained by masonry buildings. As a result, the Buildings Regulation Committee and Standards New Zealand were established in 1932, largely through the efforts of the New Zealand Institution of Engineers, with the first Model Building Bylaw (a building code adapted to suit New Zealand) published in 1935 [1]. This became the forerunner to the development of further Bylaws, Regulations and various Acts, set up for governing the way New Zealanders built houses. In 1991, in a radical departure from the concept of 'prescriptive codes' the government introduced the carefully developed concept of generic 'performance requirements'. Thus, the 'Building Code' came into effect – a set of minimum performance requirements that all new building work had to meet [2].

Following the Canterbury Earthquakes in 2010 and 2011, a strong desire emerged from local citizens, politicians and architects to rebuild a more resilient city, better adapted to its context, through a refined definition of place accounting for geological, geographical,

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environmental and cultural considerations. Key resilience challenges the city faces include: earthquake, economic shifts, flooding (coastal and rainfall), hurricanes, typhoons, cyclones, rising sea levels and coastal erosion [3].

In 2012, an international, award-winning, public consultation process was undertaken by the Christchurch City Council (CCC) called *Share an Idea* [4], seeking public opinion on the rebuild, with *Green City* emerging as the most important of six key themes identified [5]. In response to this, the CCC developed the Christchurch City Council's Proposed Christchurch Replacement District Plan and the BASE (Building a Sustainable Environment) rating tool, developed in consultation with the NZGBC. Within the plan, new rules stipulated that all new residential dwellings in Christchurch should be built to a minimum 6 Homestar rating. This was initially opposed by professional institutions associated with the industry on the grounds that it would add unnecessary costs to the building process [6]. However, despite these objections being withdrawn, the opportunity to implement higher sustainability requirements for the Christchurch rebuild was missed. In 2013, Auckland City Council released the Draft Unitary Plan, making 6 Homestar rating mandatory for five or more homes in one development and within designated Special Housing Areas (SHAs) and to take effect immediately [7]. Research conducted in 2013 by Jasmax (architects) assisted by Rawlinsons (quantity surveyors) has put additional capital costs for 6 Homestar at less than 2.2% of standard construction costs, with lower running costs [8].

Currently, the New Zealand government chooses not to regulate for sustainability. New Zealand has low residential, sustainability policy targets and there is no planned future pathway for uplift. Although sustainability is considered within the framework of the Building Act, criteria are either lacking or weak in the NZBC performance [9].

In around 1250 to 1300 CE, Polynesians settled in the islands that were to become New Zealand, and developed a distinctive Māori culture. *Tangata Whenua* is a Māori term and literally means 'people of the land', from *tangata*, 'people' and *whenua* 'land'. This differs from the European concept where people own land, while in the Māori culture the land is regarded as a mother to the people [10]. This is of particular relevance in New Zealand, where the voice of *Tangata Whenua* is required under the Treaty of Waitangi [11], generally considered the founding document of New Zealand as a nation, to be considered in law making, particularly with regard to customs and cultural preferences [12].

The Building Code is predominantly driven by British culture and not from the Maori viewpoint. An example of a building rating system that reflects this viewpoint is the Living Building Challenge (LBC). This paper examines the criteria used in a variety of rating systems and highlights the absence of the Maori viewpoint.

2 OVERVIEW OF GREEN BUILDING RATING TOOLS

Many countries have developed sustainable building standards with the intention of mitigating the impact of buildings on the environment. The certification systems vary in their overall intention, approach and field of application [13].

This paper discusses aspects of five assessment tools that have been designed for rating residential construction: Leadership in Energy and Environmental Design (LEED), Dwelling Energy Assessment Procedure (DEAP), Homestar, Passive House and the LBC. The tools have been devised to allow for comparisons between rating systems developed for temperate climates in New Zealand, the United Kingdom, Ireland, North America and Australia, and the tools are used in these countries on buildings with similar heating and cooling profiles as in the case study used in this paper, as well as to focus on countries that share cultural and political connections. Comparative analysis is carried out using LEED, DEAP and Homestar (see Fig. 1 for an overview). Passive House thermal performance U-Values are used and LBC criteria are referenced as part of the analysis.

LEED originated in North America and was administered by the US Green Building Council (USGBC). In 1998, the USGBC launched the first pilot, LEED version 1, a single standard for new construction. The latest update, version 4, released in 2013 comprises a series of interrelated standards, comprehensively covering a range of phases in the life of buildings: from design and construction to operation and maintenance. It is the most widely recognised and widely used certification programme internationally [14]. LEED is not a static system, and criteria have evolved and become more stringent with each update [15]. LEED for Homes v. 4 relies on REM (Residential Energy Modelling) to generate a HERS (Home Energy Rating System) input, to gain credits in the Energy + Atmosphere (EA) section of the tool.

DEAP, used in Ireland, is administered by the Sustainable Energy Authority of Ireland (SEAI) and is based on SAP, the methodology used by the UK Government to assess and compare the energy and environmental performance of dwellings and is compliant with the EU Energy Performance of Buildings Directive (EPBD) 2010. DEAP is the rating tool used for 'single family houses of different types' and was first introduced in Ireland in 2006. It has been regularly updated and refined. DEAP has two main purposes: firstly, DEAP models expected energy consumption and associated CO_2 emissions for the dwelling under standardised operating conditions and secondly, it enables publication of a BER (Building Energy Rating). A BER is required under the EPBD when a building is constructed, sold or rented. DEAP is published by the SEAI.

Homestar, established in New Zealand in 2010, builds on international home rating tools, especially the US's (voluntary) LEED for Homes tool and the UK's mandatory Code for Sustainable Homes [16]. These tools have been extensively modified to suit New Zealand's culture, climate and building requirements. It is the most commonly used framework for measuring residential sustainability in New Zealand. A certified rating is approved by the NZGBC (a member organisation of the WGBC) and is a built rating, checked by an accredited professional. The tool is regularly updated, with the latest version 3, launched in November 2015. Homestar can be used in conjunction with inputs from ALF [17] (Annual Loss Factor), a free online aid to the thermal design of houses. Presented in a step-by-step

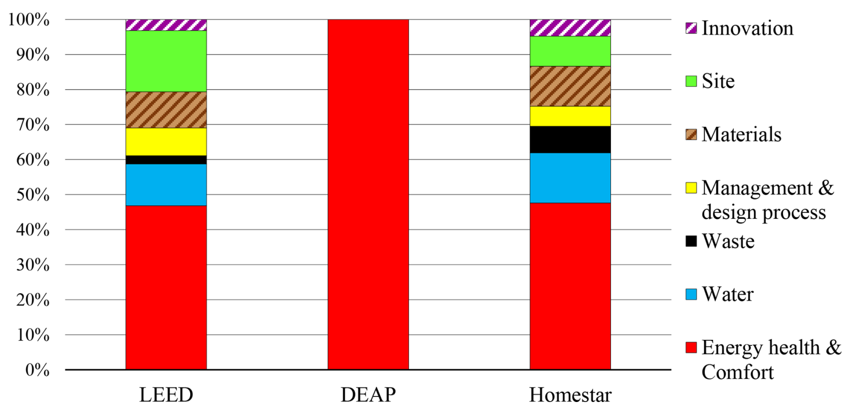

Figure 1: Comparison of LEED DEAP & Homestar – weightings.

format, it provides a simple method of calculating the energy performance of conventional New Zealand houses. ALF 3.2 is a verification method for determining the Building Performance Index (BPI), which can be used to show compliance with the Energy Efficiency Clause H1 of the NZBC. Homestar can also be used in conjunction with IES dynamic thermal modelling energy load inputs [18].

The **Passive House** Standard is a performance standard that originated in Germany, which can be applied to any building type, not only to residential as the English translation suggests. As of August 2010, there were approximately 25,000 such certified structures of all types in Europe. The Passive House Institute was founded in 1996 to regulate and promote the standard. A calculation tool benchmarked against the performance of actual buildings verifies the performance of the design. Three key standards must be met: energy demand, peak heating load and airtightness [19].

The LBC was launched in 2006 by the Cascadia Green Building Council (CGBC). In 2011, the International Living Future Institute took over the management of both the CGBC and the LBC. The LBC is an outcomes-based rating tool, with estimated or performance-modelled criteria audited a minimum of 12 months after project completion to ensure that design criteria have been met. LBC Standard 3.0 was released in April 2014 with a total of 192 certified projects across North America, Europe Asia and Australasia [20]. The LBC makes stringent demands such as 100% net zero energy, 100% net zero water, on-site renewable energy and water and 100% recycling or diversion of construction waste. It can be applied to all building typologies, infrastructure, landscapes and neighbourhoods. Three certification types are available: Living Certification, Petal Certification and Net Zero Energy. The Standard describes the Challenge as *'a philosophy, certification and advocacy tool for projects to move beyond merely being less bad and to become truly regenerative.'* [21]

3 OVERVIEW OF BUILDING CODES

New Zealand's Building Codes are lagging behind the rest of the world as seen in Tables 1 and 2. Comparatively, NZBC [22] is pre 1995 England [23] and pre 1997 Ireland code [24] for minimum thermal performance of building envelope. The building codes selected for comparative analysis within the selected green building rating tools are from countries with temperate climates, with similar heating and cooling profiles and which share construction methodologies and materials. For U-Value diversity, different performance ranges are used for simulation; i.e. New Zealand, Ireland, Australia and Passive House.

At the core of the performance-based NZBC is the intention that innovation and improved performance are encouraged; however, the default position is that acceptable solutions

Table 1: Current U-Values – Australia, NZ, UK, Ireland & Passive House (W/m^{2}K).

	NZ Zone 3	Australia 2016	Ireland 2011	England 2013	Passive House
Roof	0.3	0.2	0.16	0.13	0.1
Walls	0.5	0.35	0.21	0.18	0.15
Floor	0.77	0.36	0.21	0.13	0.15
Windows	3.85	2.2	1.6	1.4	1.5
Roof W	3.23	2.2	1.6	1.4	1.5

(Prescriptive) that achieve code minimums are adhered to. A Study Report by BRANZ in 2011 concluded that: 'The typical sustainability of the New Zealand housing stock is compliant with the requirements of the NZBC applicable at the time of construction.' [25]

Prescriptive codes contain a menu of options describing maximum and minimum values for various construction elements or systems. Code compliance is enforced by officials responsible for verifying the items listed. Advantages and disadvantages of prescriptive codes are listed in Table 3.

Performance-based codes that specifically relate to energy use contain energy-efficiency goals that are generally verified based on computer modelling. Performance-based codes are sometimes called 'Modelled Performance' codes [26]. This nomenclature emphasises that energy use is not guaranteed, rather it is predicted based on simulation. Refer to Table 4.

The structure of outcome-based codes considers the whole building's energy use over a specified time period post-occupancy. This is a relatively new methodology and one of the main problems with its implementation is the need for codes to evolve to extend the compliance procedure beyond the time an occupancy certificate is issued. Building energy disclosure ordinances, already gaining traction in several cities in the US, will likely become an essential tool in the adoption of outcomes-based codes [27]. Refer Table 5 below.

Table 2: Superseded U-Values of UK & Ireland (W/m^{2}K).

	Current	Superseded			
	NZ Zone 3	Ireland 2005	England 2002	Ireland 1997	England 1995
Roof	0.3	0.16	0.2	0.25	0.25
Walls	0.5	0.27	0.35	0.45	0.45
Floor	0.77	0.25	0.25	0.45	0.35
Windows	3.85	2.2	2.2	3.3	3
Roof W	3.23	2.2	2.2	3.3	3

Table 3: Advantages and disadvantages of prescriptive codes.

Prescriptive codes	
Advantages	Disadvantages
• Simple to use for both designers and verifiers • Building owners and designers know what to expect • Embody past experience • Provide a consensus view • Require minimal CPD (cost)	• Often not flexible, imposing solutions rather than objectives • Do not necessarily provide optimum solutions • Do not utilise a whole building approach • Only include items that are easily verified • Can lag behind design practice and technological advances

Table 4: Advantages and disadvantages of performance-based codes.

Performance-based codes	
Advantages	Disadvantages
• Flexibility allows design team to design for project-specific opportunities and risks • Innovation can be brought to design solutions • Costs can be reduced through alternative design solutions • Allow design solutions to be compared on a capital cost and operational costs basis • Require design team, owner and occupier to consider energy use explicitly • Take a whole building approach	• Unregulated energy loads are not considered • Require significant expertise on both the design and compliance checking teams, often require specialty software and a trained energy modeller, which add cost • There is no enforcement to ensure that the building operates at the energy use level modelled by the software • Assume that equipment is correctly installed and commissioned • Modelled results are only as good as the data entered

Table 5: Advantages and disadvantages of outcomes-based codes.

Outcomes-based Codes	
Advantages	Disadvantages
• Guarantee energy savings • Metering and sub-metering links occupant behaviour to energy use • Encourage design innovation • Allow for the use of new technologies • Take a whole building approach • Inherently consider all passive design strategies • Offer feedback that can inform building energy improvements and future code revisions	• Building owners, designers and contractors may be unsure of the extent of energy efficiency savings for which they will be held accountable • Maintenance, commissioning and systems calibration need to be accounted for in the budget • Require a fundamental shift in the way energy codes function • Owners, occupiers, developers and regulators will have to upskill to adjust

4 METHODOLOGY

Four approaches are used to determine the effect the minimum codes have on thermal performance, examining specifically the heating and cooling loads and resultant ratings of the case study building. A comparative analysis of the thermal performance as well as the natural ventilation minimum prescriptive requirements of each code is dynamically thermally modelled using the Integrated Environmental Solutions Virtual Environment (IES) software, which provides the results for the base case building and Variants 1 to 4 listed in Table 6. The results obtained from the rating tools are compared using the base case and variants as a framework: NZ Homestar, Irish DEAP (BER) and North America's LEED.

The '*Red Zone'* in Christchurch, previously a residential area, is an area where all buildings have been marked for demolition due to the instability of the ground for safe habitation and use (see Fig. 2 and link for the Red Zone map http://maps.cera.govt.nz/html5/?viewer=public). '*WHARE'* is the Māori word for house. **The Red Zone WHARE** is a building that has been removed from the Red Zone and gifted to CPIT by Southern Response Earthquake Services Ltd., along with the support of a number of sponsors in the construction industry. It is currently being monitored for live testing for retrofit solutions. The WHARE is a three-bedroom house with an open plan kitchen, dining and living room. The fabric U-Values are listed in Table 1 and will be used in the comparative analysis, the only exception being that the windows used for the New Zealand and Australian scenarios are 2.2 W/m^{2}K, which is superior to the respective minimum codes. Christchurch's Dry Bulb air temperatures are experienced at an average ranging from 2ºC to 21ºC. During winter the average minimum temperature remains above freezing point.

The climate data by temperature alone indicates a mild, temperate climate that requires heating during the winter season and some during the spring and autumn period. To compare climate zones for the rating tools used, a degree day table has been created, see Table 7. It should be noted that DEAP is based in Ireland and it is a steady-state analysis tool, LEEDs HERS rating is calculated using REM and Seattle was selected as the location as it is in a temperate, marine climate.

The building is a single-storey dwelling, with timber frame construction and lightweight thermal mass. It has a timber floor over a 450 mm floor void. The floor area is 82 m^2 and the volume is 196.8 m^3 when measured using internal dimensions to external walls. The site is located in Christchurch CBD, on the corner of Barbados Street and Ferry Road. The simulations

Table 6: Base Case and Variant codes used.

	Base Case NZ Zone 3	Variant 1 NZ with vents	Variant 2 Australian Zone 7	Variant 3 Irish	Variant 4 Passive House
Infiltration	0.3 ach	0.3 ach	0.3 ach	0.2 ach	0.03 ach
Abbreviation	NZ Z3	NZ Vent	OZ Z7	Irish	Passive

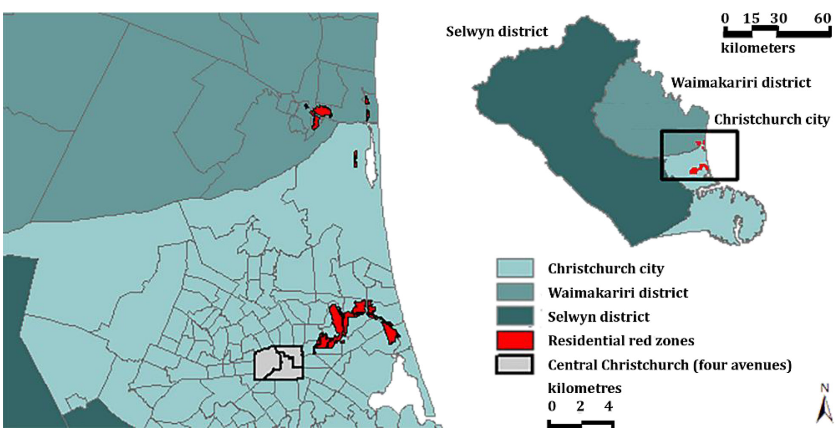

Figure 2: Statistics of New Zealand residential red zones Christchurch map.

Table 7: Degree days heating and cooling.

	HDD	CDD	Total
Christchurch	1763	303	2066
Dublin	2193	94	2287
Seattle	1641	520	2161

Table 8: Occupancy of the house.

Children		Adult 1		Adult 2	
20:00-07:30	Bedroom 2+3	23:00-07:00	Bedroom 1	23:00-07:00	Bedroom 1
07:30-08:30	Living area	07:30-08:30	Living area	07:30-23:00	Living area
08:30-16:00	Not in house	08:30-17:00	Not in house		
16:00-20:00	Living area	17:00-23:00	Living area		

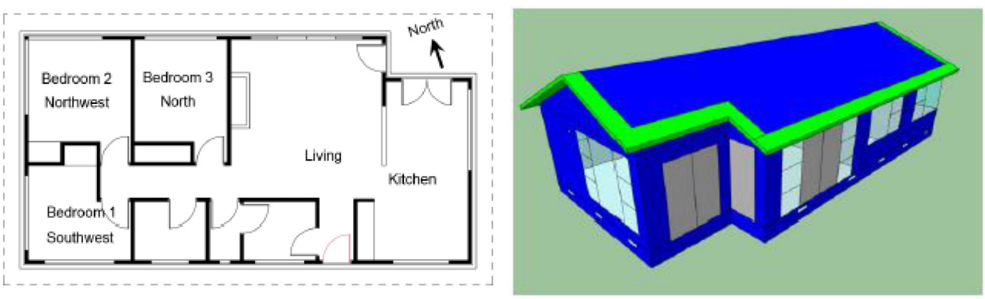

Figure 3: The Red Zone WHARE plan and IES digital model.

are run assuming a household of 4: 2 adults and 2 children. Figure 3 shows the floor plan of the dwelling. Table 8 shows the times the building is occupied, and which rooms are in use.

IES Virtual Environment (IES) 2014 software (ApacheSim) was used to dynamically thermally model the base case building and the variants. The simulations were linked to network flow models (Macroflow) and solar shading analysis (SunCast).

The model was built using Model-IT representing the building, accounting for volumes and boundary conditions with all fenestration and vents in place. Window profiles were set to account for opening and leakage by way of infiltration. Heat pump loads were examined to analyse efficiency improvements with a heating set point of 20°C and cooling set point of 23°C.

Homestar was used to determine the Star rating by inputting data from the BRANZ ALF tool for heat loads and the results were then compared with results from IES inputs. Finally, a comparative, tabulated review of the methodologies embedded in the tools used for modelling was compared with LBC and Passive House frameworks was applied. Particular focus was the *Tangata Whenua* definition of place, which includes criteria relating to cultural uniqueness.

5 RESULTS

The results from IES and ALF as illustrated in Fig. 4 show a significant deviation in the heating load estimates. This is also found when comparing IES and REM results and less so with DEAP. Note that IES and ALF are both located in Christchurch.

The poorer the thermal performance, the greater the resultant deviation appears; IES being dynamically thermally modelled would imply it is more accurate. The Homestar tool gives the same result for cooling loads for all variants. DEAP does not calculate cooling. IES and REM show some variation. The results in Table 9 illustrate that the NZBC base case variant

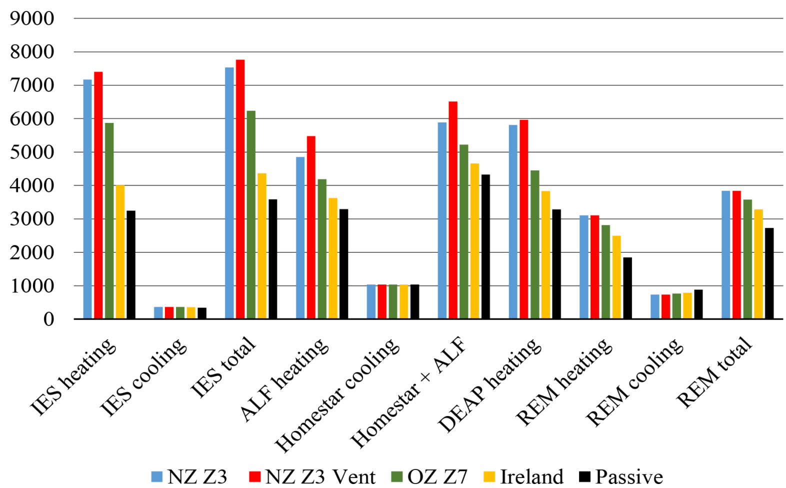

Figure 4: Heating and cooling loads IES, ALF homestar, DEAP, and REM.

Table 9: Ratings and kWh/m^2.

Tool	Rating				
	NZ Z3	NZ Vent	OZ Z7	Irish	Passive
ALF Home*	6 Star	6 Star	7 Star	7 Star	7 Star
IES Home*	3 Star	3 Star	6 Star	7 Star	7 Star
IES BER	B1	B1	B1	A3	A2
DEAP BER	B1	B1	A3	A3	A2
HERs Rating	109	109	106	104	94
	kWh/m^2				
ALF Home*	71.8	79.5	63.7	56.8	52.7
IES	91.9	94.7	76.1	53.3	43.7
DEAP	70.8	72.7	54.3	46.7	40.0
REM for HERs	46.9	46.9	43.6	40.1	33.3

could achieve a 6 Star or 3 Star depending on which approach is taken to determine a Homestar rating, and that a 3 Star rating could be achieved if IES isused.

Minimum thresholds exist with the Homestar rating structure at 3, 6 and 7 stars. When ALF is used, a result of 10+ energy points is generated, whereas when IES is used the energy points generated fall below the threshold resulting in 9.8 energy points, causing the Star rating to fall by 3 stars. This result implies that decision making on the project could be greatly impacted by the approach to energy modelling to achieve the required rating .

Again, when utilising DEAP to produce a BER there is a significant difference in the energy use generated by using DEAP compared with IES. The most significant rating change is viewed when the Australian code is compared: DEAP gives an A3 rating and IES gives a B1 rating. BER ratings are across bands determined by kWh/m^2. Refer Table 9 and Fig. 5.

From the analysis carried out utilising the rating tools (LEED, DEAP and Homestar) a review of the tools used and of Passive House and LBC are tabulated in Table 10 to track

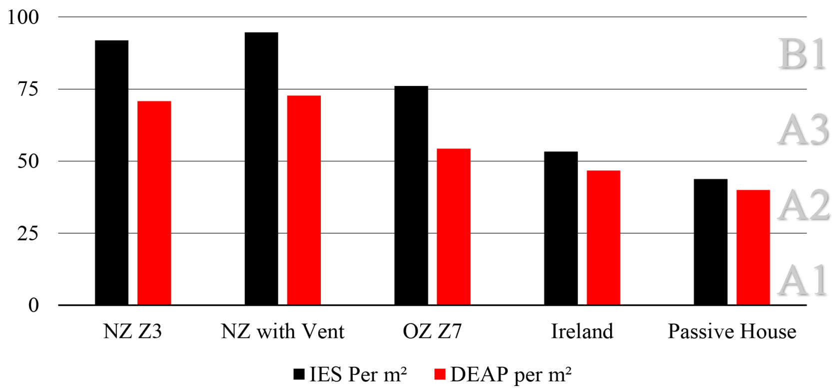

Figure 5: BER (kWh/m^2).

Table 10: Comparison of rating tools.

	Energy use	Airtightness	Integrative process	Location + transport	Sustainable sites	Water efficiency	Energy + atmosphere	Materials + resources	Indoor environment	Innovation + design	Limits to growth	Urban agriculture	Limits to growth	NET ZERO WATER	NET ZERO ENERGY	Civilised environment	Health and happieness	Biophilic environment	Red list chemicals	Carbon footprint	Living economy	Net positive watse	Responsible industry	EQUITY	Beauty + spirit	Inspiration + education
LEED	fully	partly	fully	fully	fully	fully	fully	fully	fully	fully	partly	partly	partly			partly	partly					partly				partly
DEAP	fully	partly																								
Homestar	fully	partly		fully	fully	fully	fully	fully	fully	fully	partly	partly	partly			partly	partly					partly				
Passive House	fully	fully																								
LBC	fully	partly	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully	fully

fully considered requirement | partly considered criteria | not considered different criteria considered in each methodology. It can be seen from the criteria *'Beauty + spirit'* that the LBC is the only tool in the comparison that deals with the *Tangata Whenua* concept, where we are part of the ecosystem and not owners. This demonstrates that the evolution of green building rating tools has begun to include the philosophies of indigenous people. This is particularly pertinent in New Zealand in relation to the Treaty of Waitangi and has implications in the development and application of the NZBC.

6 CONCLUSIONS

Depending on the thermal analysis tools used with the NZBC, a massive impact on Homestar rating with poor thermal performance is possible – the rating is only as good as the data inputted; for example, IES input yielded a 3 star rating versus ALF that yielded a 6 star rating. Homestar takes account of significant differences in thermal performance, which in effect will encourage better envelope design, whereas LEED takes less account proportionally of thermal envelope performance, with more of an emphasis on active technological solutions. It was found that in order to achieve a Homestar rating higher than 7 stars, utilisation of active energy efficiency technologies was required.

LEED, DEAP and Homestar can yield ratings that can influence and confuse the decision making processes during the design, construction and occupancy phases. As architectural professionals and educators, this leads us to believe that curriculum and CPD evolution is required to develop best practices and comprehension of the architecture, engineering and construction industry with respect to the holistic design of buildings and environments.

From the literature review and the modelled results it is clear that the minimum NZBC for thermal performance is in need of major adjustment when compared to EU and Passive House standards. To achieve this, the New Zealand government needs to embrace legislating for sustainability and a major first step is bringing minimum thermal performance codes in line with international best practices. It is extremely difficult to compare rating tools in any meaningful way.

From a *Tangata Whenua* context, place, culture and spirit are absent from most rating standards and further research is required to evaluate how LBC will evolve the direction of existing approaches and green rating tools. This research will provide information on health, community, reducing energy reliance and being responsive to local context. The findings may influence the building performance pathways chosen by policy makers in response to the increasing need to address global climate change and resilience.

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