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Assessing Australia's Residential Building Energy Efficiency Regulations

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ABSTRACT

Australia has had minimum energy efficiency regulations for new residential buildings for over a decade. Assessment is undertaken using thermal modelling software that determines the thermal efficiency of the building envelope and awards a star rating out of ten.

Despite being in place for many years it is only recently that data has been captured and analysed. This has allowed the ability to assess the effectiveness of the regulations and determine strengths and weaknesses in the assessment process.

This paper discusses the initial insights that have been achieved through analysis of the data. Almost 200,000 assessments are in the HStar database, providing insight into how well dwellings are achieving the requirements based on location, dwelling type and dwelling size. Data on construction systems utilised allows analysis of approaches that designers and architects have used to achieve the requirements. This includes building material choices for walls, floors and roofs and insulation levels for each of these elements. Window types, size and orientation are captured and are used to determine how well passive design principles have been employed.

Finally, this paper introduces dashboards that bring together the HStar data and allows access via interactive visualisations. Regulators, assessors, builders, designers and the house buying public will have access and be able to explore and interrogate the data. It is envisaged that these dashboards will lead to greater understanding of how Australia's residential building energy efficiency regulations are working and how the can be improved and strengthened to achieve higher performance dwellings.

Introduction

In Australia, all new residential buildings are subject to the construction regulations contained within the National Construction Code (NCC). The NCC sets minimum requirements for the design, construction and performance of buildings throughout Australia (ABCB 2016). The NCC is primarily focused on health and safety issues, but also contains provisions on the energy efficiency requirements that new constructions must achieve. The residential sector is a major source of greenhouse gas emissions in Australia. 23.6% of emissions from the generation of electricity are attributable to the residential sector, accounting for 44.6 Mt of CO_2-e in 2015 (Department of the Environment and Energy 2017). The stated objective of the energy efficiency requirements is to reduce greenhouse gas emissions and various methods are available to designers to demonstrate compliance with the requirements. The most common method utilised is the modelling of a proposed design in specialised software. Various software tools are available, but all need to be accredited under the Nationwide House Energy Rating Scheme (NatHERS) which is administered by the federal Department of the Environment and Energy (Department of the

Environment and Energy 2018a). Non-residential buildings are also subject to energy efficiency requirements set out in the NCC, but these buildings are assessed using different tools. NatHERS tools cannot be used to assess non-residential buildings.

The NatHERS software tools are primarily thermal modelling tools that evaluate the thermal efficiency of the building envelope at the design stage. All tools use the same thermal modelling engine called Chenath which was developed and is maintained by the Commonwealth Scientific and Industrial Research Organisation, Australia's federal government agency for scientific research (CSIRO 2018). Buildings are given a star rating out of ten based on the modelled estimate of the design's potential heating and cooling energy use. A rating of ten stars essentially means the dwelling will not require any additional heating and cooling energy throughout the year and is effectively a passive designed building. Currently in most jurisdictions in Australia the minimum requirement is a six star rating.

Energy efficiency requirements for residential buildings were first introduced into some jurisdictions in Australia in 2001 and were then adopted into all Australian States and territories in 2003 through inclusion in the Building Code of Australia which then became the NCC. It is estimated that 71% of new residential buildings in Australia use NatHERS accredited software as their means of demonstrating compliance with the NCC (James et al. 2017). Energy efficiency assessments using NatHERS are undertaken by assessors who enter design data into one of the accredited tools. Details on building materials, room dimensions, orientation, building location and climate are all entered in order to perform a thermal modelling simulation. This assessment is done prior to construction starting and should be updated and rerun if design changes occur in order to ensure continuing compliance. However, a recent study has found that usually variations will exist between the as built dwelling and what was modelled at the design stage (Department of State Development 2015). These variations are often minor, such as a different roof colour, but can potentially be a major variation, such as the insulation being different to what was specified or not installed in accordance with the NCC or even not included at all.

Historically, assessments done through the NatHERS tools have been undertaken by assessors on standalone computers with the assessment certificate generated and handed to the relevant authorities. The underlying modelling assumptions, settings and even the modelling results themselves were not captured or stored in any centralised system. Consequently, no record existed of how houses were meeting the requirements and even if they were meeting the requirements. Simple questions such as, how many houses were being built that exceeded the minimum six star requirement, could not be answered due to no data being available. In 2014 one of the NatHERS tools moved their software to an online platform (Sustainability Victoria 2016) and began capturing data, while in May 2016 the remaining NatHERS tools moved to requiring the certificates to be generated through an online portal and likewise started capturing the data (CSIRO 2016). Consequently, from mid 2016 we have been able to assess what type of dwellings are being built, how dwellings are meeting the requirements, how effective the regulations have been and help identify the strengths and weaknesses in the process.

New dwelling profile

As of the end of 2017, almost 200,000 assessments were in the HStar database, as it is known, and from these we can start to build a profile of what new dwelling construction in Australia looks like. Figure 1 shows that around half of all new dwellings are apartments, although this is skewed by an apartment boom in Sydney, Australia's largest city, where almost two thirds of new dwellings are apartments. This shows a significant shift in the type of dwellings being built. Australian Bureau of Statistics data reveals that the profile of the existing dwelling stock is quite different, with 79% being separate houses, 11% flats and apartments and 10% in semi-detached or townhouses (ABS 2012). Outside of NSW, the rest of Australia is dominated by detached dwellings with 91% being of this type. Australian dwellings also appear to be getting slightly smaller, although by international standards they are still very large. When including all interior spaces including garages, new separate houses have an average total area of 209m^2 (181m^2 without the garage), while new apartments have an average area of 78m^2. This is a smaller than the average for the entire stock which is estimated at 214m^2, but still much larger than the average in the UK (76m^2), Germany (109m^2) and even the US (201m^2) (Wilson 2013).

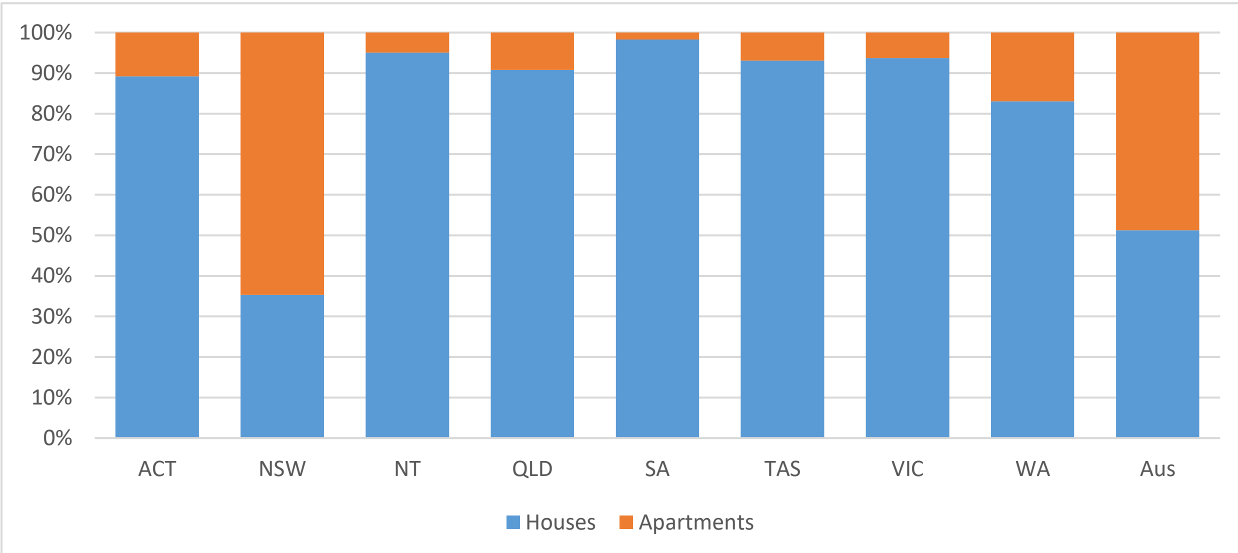

Figure 1. Dwelling construction type by state.

Construction systems utilized by builders for the various elements of a dwelling varies around the country. This is often driven by climate requirements, but local practices and traditions also plays a factor. Table 1 shows the main construction systems employed for the floor, external wall and roof elements. For floors, concrete based systems dominate. 89% of all floor system utilize some form of concrete construction. Tasmania is the only state to show some variation with just under half the floors being suspended timber construction. External walls are typically of brick veneer construction with 63% of walls being constructed this way nationally. Brick veneer is the dominate construction system in all states, except the Northern Territory (NT) and Western Australia (WA). In the NT concrete walls constitute 84% of wall systems, which is mostly due to cyclone building requirements in tropical areas of Australia. In WA, cavity brick makes up 63% of wall systems. This is mainly due to traditional reasons where cavity brick has dominated for decades, although this type of construction does suit the WA climate.

Roof cladding systems are generally either metal decking or concrete tiled. Metal clad roofs are the dominant form, except in Victoria where concrete tiled roofs make up 56% of the total. In tropical areas such as northern Queensland and the Northern Territory, metal clad roofs are virtually mandatory due to cyclone regulations.

Table 1. Construction systems by state and national

		ACT	NSW	NT	QLD	SA	Tas	Vic	WA	Aus
Floors	Concrete Slab	40.7%	34.4%	92.2%	59.9%	91.1%	37.4%	16.3%	88.1%	42.8%
	Suspended Slab	15.1%	10.3%	1.1%	2.1%	0.2%	1.7%	0.2%	4.7%	6.1%
	Suspended Timber Floor	15.8%	13.8%	6.3%	10.2%	6.7%	49.4%	6.0%	6.1%	11.5%
	Waffle Pod	28.4%	41.4%	0.3%	27.9%	1.8%	11.5%	77.6%	0.9%	39.6%
	Other	0.0%	0.1%	0.1%	0.0%	0.3%	0.0%	0.0%	0.2%	0.1%
External Walls	Aerated Concrete	0.6%	8.5%	0.3%	5.0%	14.1%	1.3%	1.6%	0.2%	6.2%
	Brick Veneer	59.3%	62.3%	0.1%	58.3%	73.5%	36.1%	88.1%	5.6%	62.5%
	Cavity Brick	1.2%	6.8%	0.4%	0.1%	0.9%	3.9%	0.2%	63.2%	5.3%
	Concrete	3.5%	2.9%	84.4%	12.2%	0.2%	2.1%	0.4%	0.4%	5.8%
	Extruded Poly Cavity	8.3%	0.7%	0.0%	1.4%	2.0%	0.9%	2.4%	1.4%	1.3%
	Fibre-cement	13.2%	9.0%	2.1%	14.7%	3.0%	30.1%	4.3%	14.3%	10.2%
	Metal Clad	3.0%	1.7%	12.3%	1.6%	1.6%	6.4%	0.9%	9.5%	1.9%
	Timber clad	3.5%	7.4%	0.3%	6.4%	3.3%	16.5%	1.6%	3.6%	6.1%
	Other	7.5%	0.8%	0.1%	0.4%	1.4%	2.8%	0.5%	2.0%	0.8%
Roofs	Concrete	4.5%	5.4%	0.0%	1.2%	0.1%	0.2%	0.1%	1.2%	3.1%
	Metal clad	79.9%	56.5%	99.5%	87.6%	85.3%	93.8%	43.4%	81.1%	66.1%
	Tiles	15.2%	34.8%	0.1%	10.2%	14.5%	4.7%	56.1%	16.8%	28.7%
	Other	0.5%	3.4%	0.4%	1.0%	0.2%	1.3%	0.4%	0.9%	2.1%

Meeting minimum requirements

An important benefit of HStar is it provides the ability to assess the effectiveness of the energy efficiency regulations. As stated earlier, the minimum energy efficiency rating is six stars and on average the star rating for new separate dwellings is exactly 6.0 stars. However, 41% of these dwellings rate below six stars in what would appear to be non-compliance with the regulations. A significant proportion of these lower rating dwellings are located in New South Wales (NSW) where the regulatory requirements do differ from the national requirements. In NSW the average rating is 5.6 stars with the minimum requirement at 5 stars. However, a significant 27% rate below 5 stars, as seen in Figure 2. By contrast, the star rating distribution in Victoria shows an expected distribution with 80% rating at the minimum 6 star requirement and the remainder rating above the minimum. The reason why such a significant proportion of the NSW dwellings are rating below the minimum requirement is not the subject of this paper, but does indicate to the relevant authorities that investigation is needed as to what the cause is. It is interesting to note that in July 2017 the NSW government increased their energy targets by 10% (Department of Planning and Environment 2017) and data since the change indicates that the average star rating has risen from 5.6 stars to 5.9 stars, although 37% still rate below the new minimum target of 5.5 stars.

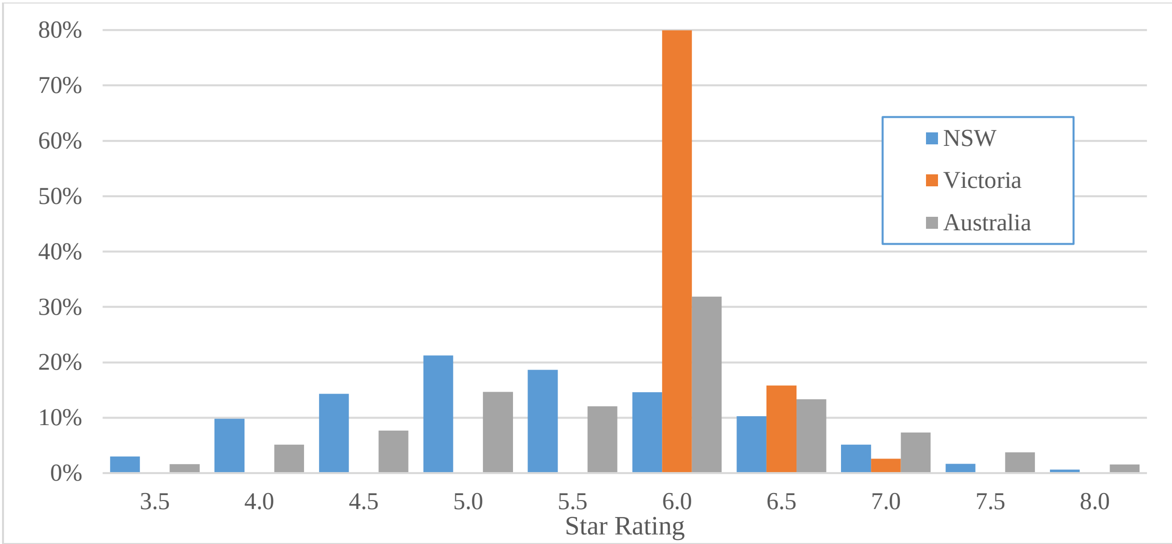

Figure 2. Star rating distribution for detached dwellings in NSW, Victoria and national.

Energy assessor accreditation

A controversial aspect of the energy efficiency regulations is the accreditation of the energy assessors that undertake the thermal modelling. Accredited assessors have undergone training in the use of the software tools and achieved formal qualifications in energy assessment. However, only NSW requires energy assessors to be accredited while in all other states and territories it is not mandatory and many assessments are undertaken by non-accredited assessors. Concerns have been raised by accredited assessors that this risks poor outcomes for consumers and potentially undermines the credibility of all energy assessors (Pitt and Sherry 2014).

Table 2 shows that in NSW virtually all (99.6%) assessments are undertaken by accredited assessors, so the mandatory requirement appears to be working. However, in many other states and territories where accreditation is not required the number of assessments undertaken by accredited assessors is still very high. Victoria (98.1%) and Tasmania and South Australia (96.7%). Only in Queensland and the Australian Capital Territory (ACT) are more assessments done by non-accredited assessors than accredited, 66.6% and 81.6% respectively. It is worth noting that the ACT actually has the highest average star rating of any jurisdiction in Australia at 6.7 stars with an impressive 28% rating at 7 or more stars and none rating below 6 stars. Of course, achieving a high rating does not mean the assessment has been done correctly and perhaps the high number of dwellings that are well exceeding the requirements could be cause for investigation.

Table 2. Energy assessor accreditation by state and territory

Accredited	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
No	81.6%	0.4%	0.0%	66.6%	3.4%	3.3%	1.9%	38.6%
Yes	18.4%	99.6%	100.0%	33.4%	96.7%	96.7%	98.1%	61.4%

Achieving energy efficiency requirements

The data that is collected through the assessment process includes information on the methods that designers and architects have used to achieve the energy efficiency requirements. As the assessment is essentially an evaluation of the thermal performance of the building envelope, most solutions involve the use of thermal mass and insulation, but the use of orientation and glazing can also be observed. Ceiling insulation is the most common with some form of insulation being installed in 89% of all ceilings. Dwellings without ceiling insulation tend to be located in tropical areas were insulation is often not required to meet regulation. In the colder climates (ACT, Victoria and Tasmania) 99% of all ceilings are insulated. Traditionally, insulating external walls was uncommon and amongst the existing housing stock in Australia many dwellings continue to have no wall insulation as retrofitting is expensive (MEFL 2016). Fortunately, with new builds insulating walls is common and 75% of new dwellings have insulated walls. Again, it is homes in tropical areas that tend not to insulate their walls while 99% of homes in colder climates do. Thermal mass is most commonly incorporated through the use of a concrete floor. 88% of all new dwellings utilise some form of concrete floor system.

Windows are essential in dwellings for allowing natural light and natural ventilation to enter the building. However, windows are also a thermal weakness in the building envelope. Up to 40% of a home's heating energy can be lost and up to 87% of its heat gained through windows (Lyons and Hockings 2013). Consequently, reducing glazing area is often used as an effective technique to improve the star rating of the house. Studies have found that new houses have reduced average glazing areas by 24% when compared to older houses (Ambrose et al. 2013). Window performance can be improved through the use of thermally efficient glazing systems, but the use of such systems is still limited in Australia. Figure 3 shows that double glazed windows account for only 15% of all windows in new dwellings, although in the colder jurisdictions of Tasmania and ACT double glazed windows account for 80% and 73% of windows respectively. However, many of these double glazed windows still utilise thermally poor aluminium window frames. Less than 10% of the double glazed windows use timber or uPVC frames, while 81% use aluminium and the majority of these aluminium frames are not thermally broken.

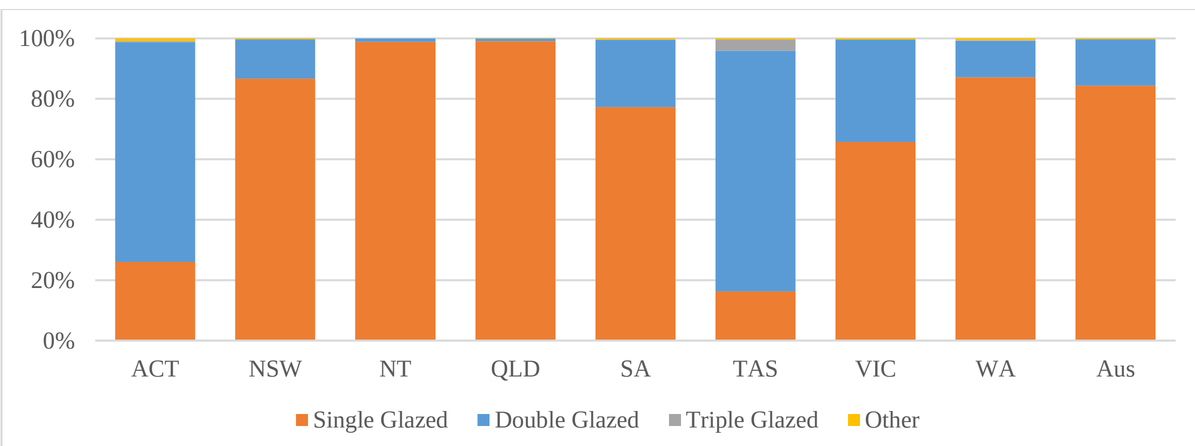

Figure 3. Glazing system by state and territory and national.

Passive design

The orientation of the windows helps to assess how well passive design principles have been utilised. In Australia, orientating living area windows to the north is optimal to capture winter warmth and protect from summer heat. Figure 4 shows that although the north orientation is where most living zone windows are placed, it does not significantly dominate. 21.5% of living zone windows face north, while 17.2% face east, 15.4% face west and 14.7% face south. This indicates that dwelling orientation is not highly considered in the design process. Indeed, major house builders have confirmed that houses are designed to achieve the required star rating on any orientation. This means that standard designs do not need to be redone for each building lot (Sustainability House 2012).

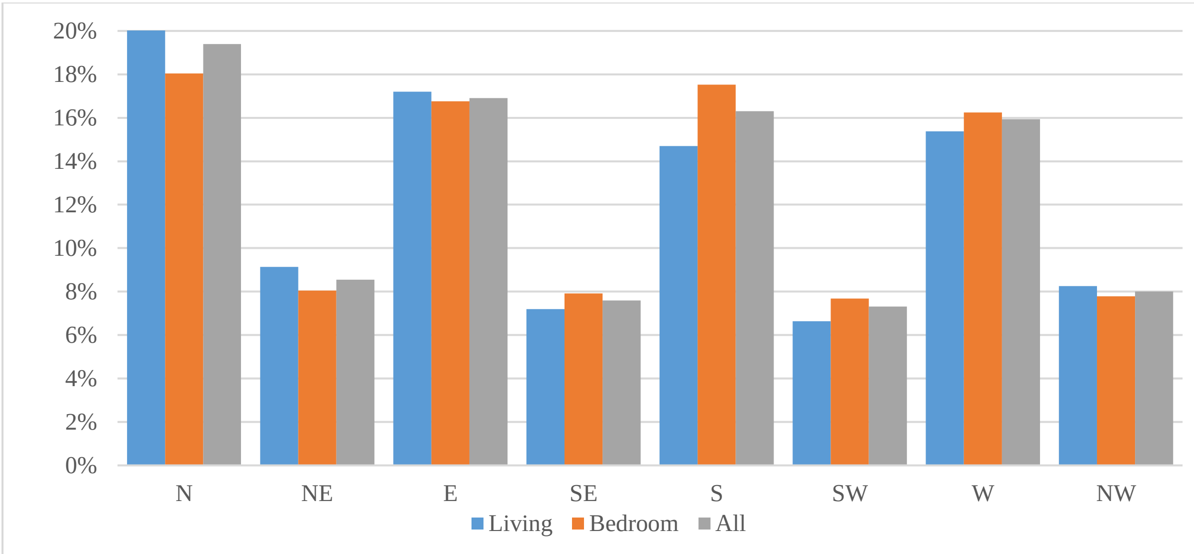

Figure 4. Percentage glazing by orientation for dwelling zones.

Another interesting aspect of the window orientation data is the dominance of the main cardinal points (north, east, south and west). Energy assessors are required to input the actual orientation of the dwelling down to the degree. It would seem unlikely that the majority of building sites in Australia are perfectly aligned along the main cardinals, so this type of distribution is unexpected and may indicate that assessors are simplifying inputs to safe time, but may be compromising the modelling results.

Model energy consumption verses actual

The NatHERS software and the encompassing energy efficiency regulations are designed to rate residential building designs on an equal basis, so consequently a standard set of assumptions are used for all buildings being modelled. This includes assumptions for thermostat settings, ventilation control, building occupancy and air infiltration rates. NatHERS only focusses on heating and cooling energy and is technology neutral, that is, it does not take into account the efficiency of a heating/cooling appliance or even if such an appliance exists in the dwelling. The aim is to assess the building design and how well it is able to maintain internal temperatures within set parameters, rather than the building occupants and the systems that may or may not be installed. This approach has led to criticism over the years that the NatHERS rating and its modelled energy consumption bears little resemblance to the actual energy consumption experienced in the building (Williamson et al 2001, Williamson et al 2007, Hatvani-Kovacs et al 2018, Martek and Hosseini 2018). Most of this criticism is due to the fact that NatHERS does not take into account actual human behavior of the dwelling occupants or the heating/cooling appliances that are installed and therefore as a guide to actual energy performance it is flawed. However, the intent of NatHERS is not as an estimator of actual energy consumption, but as a rater of potential building performance, all other things being equal.

A major study undertaken in 2013 explored whether higher NatHERS rated houses had reduced heating and cooling energy when compared to houses built to lower rating standards (Ambrose et al 2013). This study found that higher rated houses had significantly lower energy use in winter, especially in the colder climate zones in Australia. For example, in Melbourne higher rated houses reduced their winter heating energy by 56% compared to lower rated houses. However, the study also found that in summer, cooling energy increased in the higher rated houses in some climate zones by up to 15%. The report's authors speculated that the increase may be due to the increased insulation levels in the higher rated houses and the lack of natural ventilation that is occurring in these houses due to occupants not opening windows to allow night time purging of trapped heat. NatHERS assumes a certain degree of natural ventilation is occurring through the opening of windows, but if this does not occur then overheating may occur that requires additional cooling energy to compensate.

Some NatHERS tools can be run in "non-rating" mode that allows the NatHERS assumptions to be modified to better simulate actual energy performance. In a study done by Ren et al (2013) the modelling predicted the total annual energy consumption of a house within 6.5% of the actual consumption. In the version of the software tool used, all energy loads could be modelled including heating/cooling appliances, lighting, hot water and plug in loads. The heating/cooling loads were under predicted by 19% because of uncertainties in the occupant's actual thermostat settings and possible opening of windows and doors.

Dashboards

The capturing of Australia's energy efficiency compliance data for new residential buildings has for the first time allowed detailed analysis of dwelling design solutions to be undertaken and track the effectiveness of the regulations. There are many stakeholders involved in the process of delivering energy efficient dwellings that would benefit from access to the HStar data including regulatory authorities both state and national, NatHERS administrators, energy assessors, industry bodies, NatHERS software developers, product manufacturers, builders and building researchers. Consequently, work is underway to develop interactive online dashboards that will provide access to HStar and allow interrogation of the data to answer a myriad of questions.

The HStar data is similar in many respects to the Energy Performance Certificates (EPC) that are required in most European Union countries, although HStar data is currently only collected for new residential buildings as there is no requirement in Australia to assess existing residential buildings. EPC's main objective is to provide owners and occupiers with objective information to assess, compare and improve their properties' energy performance (Arcipowska et al 2014), whereas for HStar the main objective is to provide regulators with insight into the effectiveness of Australia's energy efficiency regulations. Consequently, although data is available for an individual dwelling, HStar data is aggregated to the postcode level to ensure privacy. However, individual dwelling data may be available to building inspectors to allow compliance checking. Similar to approaches that France, Slovakia, Hungary, Ireland and the Netherlands have taken with their EPC web portals, a series of online dashboards have been developed that cover a range of areas including overall NatHERS ratings, building types, construction systems utilised, energy efficiency measures utilised, assessment details and trends. Powerful data visualisation software has been utilised that allows virtual real time access, mapping capabilities and sophisticated filtering of the data. Figure 5 shows an example of what a dashboard may look like for displaying NatHERS information. The left hand side of the dashboard allows filtering of the data by state, class of building (separate house or apartment), type of construction (new build, renovation, addition or existing dwelling) and the time period. Data for this visualization is organized at both a state and postcode level. The map in the centre is divided into postcode areas and displays the average star rating for each postcode using a coloured scale. Hovering over the postcode areas displays additional information for that postcode including a histogram of star rating distribution. This distribution can be compared to the state based star rating distribution histogram which is displayed on the right hand side. Across the bottom are the averages for the selected state for star rating, cooling and heating loads, conditioned area and the total number of dwellings that were included in the calculations.

The dashboards help to visualize data that is complex and detailed in a way that allows for quick and easy analysis. The dashboards have already been able to identify construction trends in specific regions, NatHERS rating hotspots that reveal the impact of high efficiency housing developments, shifts in certificate trends and ratings due to regulatory intervention and problems in how energy assessors are assigning project location information. As the dashboards will be freely accessible, it is hoped that this will empower all stakeholders involved in the delivery of residential buildings to demand better compliance with the current regulatory requirements and push for improvements in those requirements to deliver even higher efficiency buildings in the future. It is planned that the initial dashboards will be available online in mid 2018 with subsequent dashboards added over time.

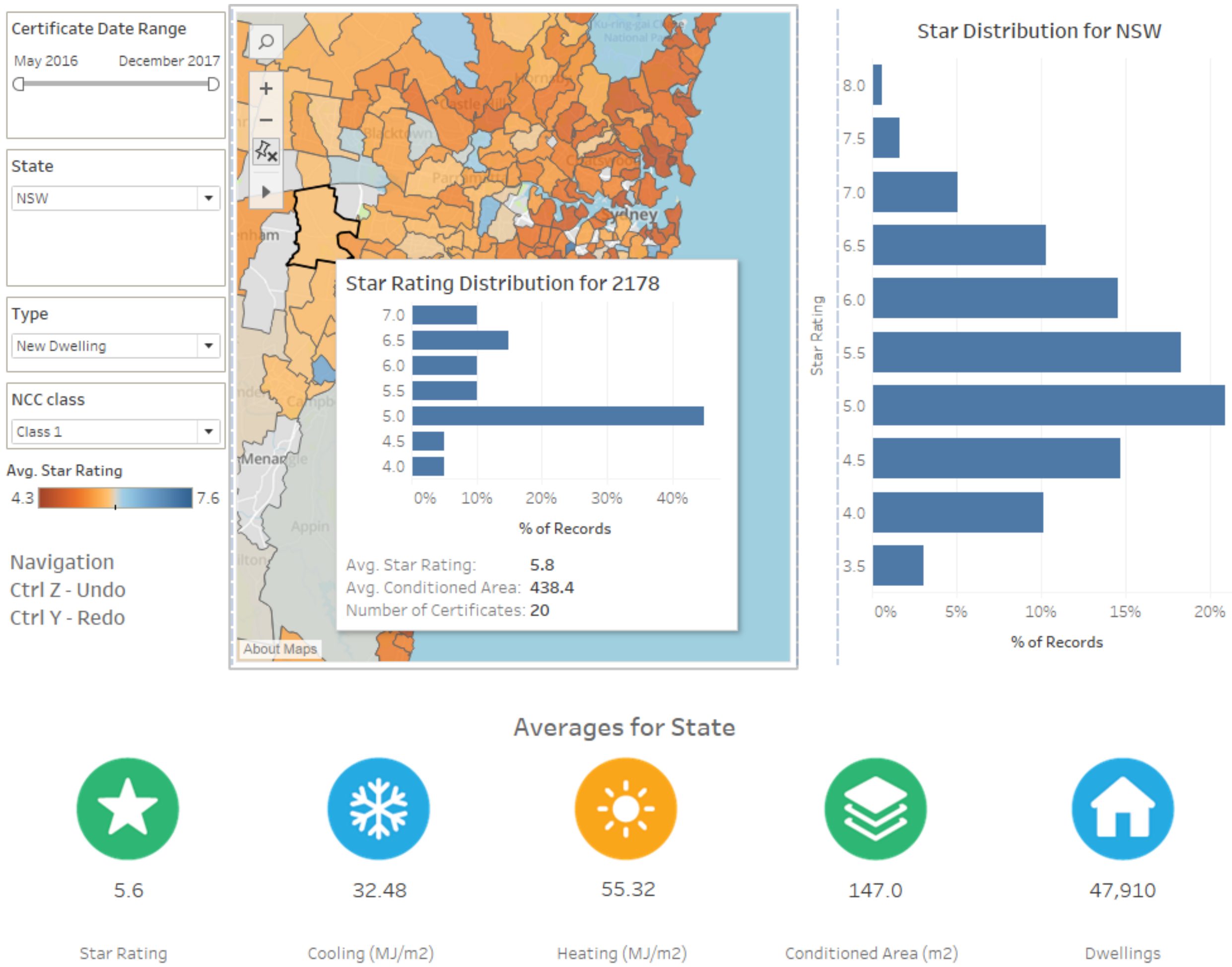

Figure 5. Example dashboard for NatHERS star ratings.

Mandatory energy efficiency disclosure for existing dwellings

As HStar grows it may play an important role in providing energy efficiency disclosure information to purchasers of existing dwellings, just as EPCs are doing in the European Union. Currently in Australia only the ACT requires mandatory disclosure of a dwelling's energy efficiency at time of sale. However, over the years there have been calls for other jurisdictions to introduce a similar scheme, including from industry bodies such as the Housing Industry Association (HIA 2013). It is worth noting that for commercial buildings with a net lettable area of 1000m^2 or more it is a regulatory requirement that the owners obtain a Building Energy Efficiency Certificate (BEEC) when the building is offered for sale or lease. BEECs are valid for 12 months and include the building's National Australian Built Environment Rating System (NABERS) energy for offices star rating and a tenancy lighting assessment of the relevant area of the building (Department of the Environment and Energy 2018b).

A study into the regulatory impact of such a scheme for residential buildings was undertaken in 2011 and found that although there would be additional costs involved, the benefits associated with a mandatory disclosure scheme would outweigh the costs (Allen Consulting Group 2011). The study also found that disclosure of such information may lead to an increase in investment in measures that improve energy efficiency, which would consequently lead to energy bill savings and greenhouse gas savings.

The Victorian government has been considering introducing a scheme that would extend disclosure to lease and rental properties as well as properties being sold (Aliento 2015), but so far no indication has been given about when such a scheme would be introduced.

Any such schemes would benefit from being aligned with the NatHERS scheme that is used to assess new buildings as this would help ensure consistency and avoid confusing the house buyer. Capturing this additional data on existing dwellings would greatly enhance the power of HStar and would allow assessment of energy efficiency improvement incentives and schemes that are on offer from various government authorities, such as the Victorian government's Victorian Energy Upgrades program (Environment, Land, Water and Planning 2018). Currently, the ACT scheme is based on an early version of the NatHERS scheme, but the data is not captured in the current database.

Conclusion

Greenhouse gas emissions from residential buildings are significant. Ensuring new dwellings are constructed to enable energy efficient operation is critical in reducing the impact from this sector. Australia has taken steps in this direction by being one of the early adopters of energy efficiency requirements in the country's building regulations. However, data associated with the assessment of designs was not captured, which made it difficult to assess the effectiveness of the regulations and identify potential problems. This has led to concerns about compliance with the regulations. Since May 2016, data has been captured in the HStar database from thermal modelling undertaken in NatHERS software. This is the main method that designers use to assess compliance with the energy efficiency regulations. HStar data has allowed researchers to examine the types of dwellings that are being designed and the methods that are being employed to achieve the energy efficiency requirements. It has also highlighted potential issues that may need further investigation to determine if the regulations are being appropriately met.

HStar data only covers new residential building designs, but has the prospect of being used to capture data from existing residential buildings should Australian regulators move to mandatory disclosure and rating of existing housing stock. HStar is not designed to capture data from non-residential buildings as this data is already captured through other existing programs.

HStar data has benefits to a wide range of stakeholders in the residential construction industry as well as house buyers themselves. Consequently, work has begun on developing freely accessible dashboards that will provide structured access to HStar and enable users to explore the data and answer a myriad of questions. HStar will also provide regulators with the ability to assess the effectiveness of the energy efficiency regulations, identify issues and help determine possible future regulations and then track their implementation. The objective of Australia's energy efficiency regulations is to lower greenhouse gas emission and with access to this HStar data this objective will be easier to track and achieve.

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