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Australia's Experience of Combining Building Energy Standards and Disclosure Regulation

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Multiple market failures have historically delivered housing that is environmentally and economically sub-optimal. Minimum energy standards are a popular policy tool for lowering energy use and anthropogenic carbon emissions in the built environment, but evidence shows they fail to drive performance beyond that minimum. Mandating the disclosure of energy performance on sale or lease of property has been introduced in some jurisdictions to transform the building stock and encourage energy and carbon saving improvements. These policy instruments address different market failures and have the potential to act as complementary regulation, but to date there has been little evidence that the combination may deliver greater benefits than each individual policy measure. The analysis of 342,674 housing energy assessments in Australia from May 2016–June 2021 highlights the impact of complementary vs. single policy instruments. We find that the building regulatory process alone delivers certainty regarding minimum performance, but when matched with disclosure regulation, the market is pulled slightly toward higher performance outcomes than for where building regulations alone are used. While only a small improvement in performance, the data supports the power of complementary regulation for long-life housing assets, similar to the benefits found for shorter-life assets such as household appliances; in essence creating both a carrot and a stick for consumers and the wider market. The data from Australia presented in this paper suggests that the use of complementary regulation may deliver improved environmental and economic outcomes and could help jurisdictions governing a transition to more sustainable housing as part of the wider transition to sustainable cities.

Keywords: house energy rating, energy efficiency, thermal performance, mandatory disclosure, building energy standards, energy policy, complementary regulations

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INTRODUCTION

The need to reduce energy consumption and the carbon emission impact of housing is pressing (Intergovernmental Panel on Climate Change, 2014, 2018). Intergovernmental Panel on Climate Change (2018 p. 17) notes that "… limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings) …". Improving the minimum level of building energy efficiency has been demonstrated to be a cost effective tool for policy makers seeking to reduce

anthropogenic greenhouse gas emissions and the impact of climate change, yet net energy use in housing, other buildings and our cities more broadly continues to climb globally (International Energy Agency, 2018).

Typically, policy mechanisms have been the driver of improving many jurisdictions such as the United Kingdom, European Union, North America and Australia (International Energy Agency, 2013; Berry and Marker, 2015; Evans et al., 2017; Horne, 2018; Doyon and Moore, 2020). The policy spectrum to improve the energy efficiency of housing has been broad, and they have been found to have multiple benefits (International Energy Agency, 2014; Enker and Morrison, 2020). These policy mechanisms have ranged from wider market based responses such as carbon pricing to accelerating product uptake through financial incentives to information provision to regulatory approaches such as building and product codes and standards (Berry and Marker, 2015; Evans et al., 2017; Moore, 2018). There are many policy options or combinations of policy options from which to choose. Similarly, the benefits of energy efficiency are numerous with human health, poverty alleviation, energy security and equity, and environmental improvements amongst the multiple reasons for policy implementation (International Energy Agency, 2014; Moore et al., 2017; Bouzarovski, 2018; Willand and Horne, 2018; Daniel et al., 2019; Willand et al., 2019; Kearns, 2020; Gower, 2021).

Numerous studies have demonstrated that for many markets the energy performance of housing is sub-optimal when considered from an environmental and economic perspective (Moore, 2014; Berry and Davidson, 2015; Berry and Marker, 2015; Shim et al., 2018; O'Neill and Gibbs, 2020). The intangibility and invisibility of energy (Aune, 2012), or the relative importance of other factors such as location, convenience and cost (Edwards and Pocock, 2011) often result in house energy performance being a lower order consideration for real-estate transactions. Market failures including split incentives, information asymmetry, public goods and externalities result in the market delivery of housing with both lower private and public benefits than expected (Gerarden et al., 2017; Horne, 2018; Hurlimann et al., 2018; Martek et al., 2019a; Moore et al., 2019).

There is substantial evidence to show that minimum energy standards have been an effective policy mechanism to improve building energy efficiency and reduce related anthropogenic carbon emissions (International Energy Agency, 2013; Intergovernmental Panel on Climate Change, 2014). Most developed nations and many developing nations choose to improve minimum energy efficiency requirements for new housing using planning or building regulatory instruments (Janda, 2009; Evans et al., 2017). The Australian experience of utilizing regulation to improve building energy efficiency is similar to many other nations (Berry and Marker, 2015; Moore and Holdsworth, 2019). A national approach to building energy regulation was formalized in the National Construction Code at the beginning of the 21st Century, although regional standards had been introduced by a few jurisdictions a decade earlier. At various points in time the Australian housing energy regulations have been increased in standard and broadened in scope, although are still falling behind both World's best practice as a minimum performance target, and well-short of what is needed to transition to a more energy efficient and environmentally sustainable built environment (Horne et al., 2005; Moore et al., 2014; Berry and Marker, 2015; Martek et al., 2019a; Doyon and Moore, 2020).

Similarly, mandatory disclosure of house energy rating or environmental performance has been introduced throughout the European Union and a limited number of other jurisdictions to address information asymmetry issues and allow the market to more easily value higher energy performance to varyingly levels of effectiveness (as discussed in Section Literature Review below) (Brounen and Kok, 2011; Fuerst et al., 2013; Hårsman et al., 2016; Fuerst and Warren-Myers, 2018). The Australian experience of energy or environmental performance disclosure has been contained to various short-term voluntary regional trials, and one long-term 20 year mandated scheme in the Australian Capital Territory (ACT) which has required the disclosure of a home's thermal efficiency rating at point of sale or lease (Berry et al., 2008; Department of the Environment Water Heritage the Arts, 2008; Fuerst and Warren-Myers, 2018). It is this 20-year scheme from which we will draw the evidence to explore the value of mandating the public disclosure of building energy efficiency on sale of housing.

These policy instruments (i.e., minimum performance requirements and mandatory disclosure) are designed to address different market failures and therefore have the potential to act as complementary regulation. However, to date there has been little evidence that the combination of the two may deliver greater benefits than each individual policy measure (Wiese et al., 2018; Doyon and Moore, 2020). Wiese et al. (2018) [p. 2152] note within the European context that "… the magnitude and importance of interaction effects is yet unclear". This paper addresses this knowledge gap by exploring the value of complementary regulations to eliminate or reduce the influence of market failures, and encourage improved house energy performance, by testing the research question: does the combination of minimum building energy standards *and* mandatory disclosure of energy efficiency increase the average energy rating of new homes when compared to just setting minimum building energy standards? The hypothesis being that the two synergistic policies together will produce better outcomes than one alone as they address different drivers within the market. In doing so, the evidence in this paper will guide future house energy policy development for the energy end-user not only in Australia but other jurisdictions who have minimum energy efficiency and performance requirements and may be considering introducing other policy mechanisms such as mandatory disclosure as part of an approach to delivering sustainable cities.

To explore the research question, Section Literature Review examines the concept of using single and multiple regulatory instruments to improve market efficiency. Section Materials and Methods describes the methods with Section Results detailing the results of the analysis. Section Discussion discusses the key findings drawing on comparisons with previous studies. Section Conclusion and Policy Implications provides a summary of the major findings

and highlights the key policy implications, both in Australia and internationally.

LITERATURE REVIEW

Various policy issues from time-to-time have necessitated action to address building energy efficiency and energy end-use. Environmental sustainability including global climate change, energy security issues such as the oil crises of the 1970s/80s, economic efficiency and human health have been important factors encouraging governments to address the energy efficiency of residential and non-residential buildings (International Energy Agency, 2013, 2014). Most recently, global climate change has been the principal policy driver facilitating an aggressive revision of building energy standards in many jurisdictions, and the introduction of mandatory building energy performance disclosure regulation, amongst a broad suit of policy options (Horne, 2018; Harrington and Hoy, 2019; Newton et al., 2019; Enker and Morrison, 2020; O'Neill and Gibbs, 2020).

Building energy codes and standards that establish minimum performance requirements have been used since the 1960s to deliver significant energy savings from residential and commercial buildings (Halverson et al., 2002), and have been mandated in many countries and regions (Janda, 2009; Evans et al., 2017; International Energy Agency, 2020). With a relatively long history as a policy instrument, building energy codes are a cost effective mechanism to reduce energy end-use and improve sustainability in the built environment and across our cities (International Energy Agency, 2013; Sustainability House, 2013; Intergovernmental Panel on Climate Change, 2014; Aydin and Brounen, 2019; Newton et al., 2019; Thonipara et al., 2019).

Similarly, minimum energy performance standards have been used effectively in many nations to increase the efficiency of shorter-life products such as household appliances and equipment, with the effect of reducing net household energy use against business-as-usual projections (Meyers et al., 2003; Energy Efficient Strategies, 2006, 2014; Yu et al., 2015; Martínez-Montejo and Sheinbaum-Pardo, 2016). Energy Efficient Strategies (2014) found that by 2013 appliance and equipment minimum energy performance standards had been adopted by more than 70 nations. Minimum energy performance standards have been effective in changing the market for a range of household appliances providing vastly different energy services including refrigerators, clothes washers and dryers, air-conditioners, light bulbs, televisions, dishwashers, and water heaters (Energy Efficient Strategies, 2016; Nadel, 2019).

The purpose of energy codes and standards is to raise the minimum performance to a socially acceptable level, essentially lifting the bottom of the market (Warren-Myers et al., 2020). The Australian experience for housing is similar, albeit later, when compared to many developed nations. Nation-wide housing energy standards were introduced in 2003, many decades after similar minimum housing energy performance standards were introduced in the UK, USA and various European nations (Berry and Marker, 2015). The available evidence for housing in Australia shows that whilst minimum building energy standards have been effective at lifting energy performance to that target for the vast majority of homes, few are built beyond that performance standard (Moore et al., 2019). This has also been found in other jurisdictions highlighting the challenge faced around the world to improve the energy and environmental performance of housing (International Energy Agency, 2020). Unless these minimum building energy standards increase significantly in many jurisdictions, other policy instruments are likely needed to drive the market beyond the minimum requirement if we are to rapidly transition to a low carbon built environment future (Newton et al., 2019).

Mandatory disclosure of energy ratings or expected performance has also been used as a policy instrument to improve the energy efficiency of household appliances, household equipment, and in some cases vehicles. Popularly known as energy labeling, this policy instrument has been effective in encouraging the purchase of higher efficiency appliances and reducing related household energy use in Australia, North America, Asia and Europe (Energy Efficient Strategies, 2006; Wiel et al., 2006; Mills and Schleich, 2010; Fuerst and Warren-Myers, 2018). By making energy performance visible to consumers, future energy savings from higher performance appliances can be incorporated into purchase decision making.

More recently the concept of energy labeling has been applied to housing in some jurisdictions (Geller et al., 2006; Kok and Kahn, 2012; Fuerst and Warren-Myers, 2018). For example, in California voluntary labeling through programs such as Energy Star, LEED for Homes and GreenPoint have realized increased value of about 9% against comparable homes (Kok and Kahn, 2012). In Europe, the Energy Performance in Buildings Directive (Directive 2002/91) extended the energy labeling concept to buildings, and later (Directive 2010/31) established mandatory building energy performance disclosure as an important climate change policy instrument (European Commission, 2010).

In Australia, the regional government of the ACT mandated in 1999 that the energy efficiency rating of houses be calculated and communicated as a part of all house sales and leases (where a rating already exists), and disclosed in all advertising materials (Berry et al., 2008; Fuerst and Warren-Myers, 2018). This 20-year policy history provides a relatively strong dataset to understand the effectiveness of having a more informed housing market. Most importantly for this study, the policy of mandatory energy performance disclosure for residential buildings has been enacted in parallel to mandatory minimum house energy performance requirements for new buildings and major renovations, acting as concurrent policy instruments for over 20 years (Moore and Holdsworth, 2019).

For the other regions in Australia there has been more than a decade of formal discussions about a nationally consistent policy instrument to disclosure of energy efficiency of residential buildings, but little action except for a few short-term, voluntary trials in Queensland and Victoria. In 2003, the National Framework for Energy Efficiency's Building Implementation Committee on behalf of the Council of Australian Governments (COAG) Ministerial Council on Energy, explored the introduction of voluntary energy performance disclosure

for residential buildings (Council of Australian Governments Energy Efficiency Greenhouse Working Group, 2003). In 2009, the COAG Ministerial Council on Energy introduced the National Strategy on Energy Efficiency which proposed mandatory disclosure of building energy, greenhouse and water performance at the point of sale or lease for residential properties (Council of Australian Governments, 2009; Department of Climate Change Energy Efficiency., 2012). To date these efforts have not been able to achieve an Australian-wide consistent approach to residential energy performance disclosure, although a voluntary National Scorecard was launched in 2021 which may fill this gap in due course.

Whilst the evidence of impact from energy performance disclosure for short-life assets such as appliances is strong, the literature finds the value of mandatory disclosure for more complex, high cost, long-life assets such as housing is mixed. Much of the literature has demonstrated a significant positive relationship between market value and energy performance disclosure for housing (Department of the Environment Water Heritage the Arts, 2008; Fuerst et al., 2013, 2016; de Ayala et al., 2016; Cajias et al., 2019; Franke and Nadler, 2019), whilst other researchers have found little or no relationship (Murphy, 2014; Hårsman et al., 2016).

Researchers have suggested the amount and/or type of information disclosed may be important in achieving the intended outcome (Aune, 2012; Martek et al., 2019b), although the information disclosed through regulation may not be the sole energy or environmental sustainability influencer of market value (Fuerst and Warren-Myers, 2018). In Australia, mandatory disclosure legislation in the ACT has been effective in establishing a strongly significant correlation between the house energy rating and price the market is willing to pay, with a premium of around 3% paid for each additional star improvement in the rating (on a 10 star scale), after all other factors such as age, location, and size have been eliminated (Berry et al., 2008; Department of the Environment Water Heritage the Arts, 2008; Fuerst and Warren-Myers, 2018). This legislation in the ACT has been in place across a similar period as the requirement for minimum standards for new housing.

Energy efficiency regulation such as minimum performance requirements and mandatory labeling exist to address various market failures including informational barriers, the presence of negative externalities or public goods (International Energy Agency, 2013; European Commission, 2015). In many cases without energy efficiency regulation the market would not deliver economically efficient outcomes for private consumers, nor provide socially optimal outcomes.

The combination of minimum energy performance regulations and mandatory energy performance disclosure requirements has successfully "pushed and pulled" the market for household appliances and equipment to higher energy efficiency levels (Wiel et al., 2006; Harrington and Brown, 2007; Energy Efficient Strategies, 2016; Yilmaz et al., 2019), with minimum standards pushing up product performance to meet community standards, and labeling pulling the market above those minimum standards. Harrington and Brown (2007, p. 5) note "The impact of MEPS [in addition to labeling] was substantially larger than labeling alone." Combined, these complementary regulations have delivered significant energy efficiency improvements for white goods, and other household appliances and equipment, in many nations and regions (International Energy Agency, 2018).

As separate policy instruments, although the results may vary across different jurisdictions, both building energy standards and labeling have been shown to be effective tools in addressing the energy and environmental impact of housing (Berry and Marker, 2015; Aydin and Brounen, 2019; International Energy Agency, 2020). As complementary policy instruments, although minimum performance targets and labeling have been used as parallel policy instruments for household appliances, less is known about the effectiveness of combining policies for more complex, longer-life assets such as housing (Wiese et al., 2018). This paper begins to address this knowledge gap and in doing so aims to provide evidence to guide policy development for those jurisdictions who do not yet have some form of complementary regulations to help address wider sustainable housing market failures.

MATERIALS AND METHODS

In Australia, although energy assessments are typically undertaken during the planning and building approval stage for the development of new housing and major retrofits, only the region of the ACT mandates the disclosure of that energy performance information during the real estate sales process. This means there is a unique opportunity to compare the market demand for housing during the same sales period with and without the mandatory disclosure instrument.

The most typically used method of verifying compliance to the National Construction Code's minimum energy efficiency provisions is through the use of the Nationwide House Energy Rating Scheme (NatHERS) framework (NatHERS, 2017). The NatHERS Scheme provides a systematic framework in which to rate a dwelling for energy efficiency, particularly thermal efficiency, using accredited third-party software. The framework is designed to allow competition and promote innovation in the marketplace for energy assessment software, whilst maintaining the validity and credibility of assessment results. Currently around 70% of all new housing is assessed for thermal efficiency requirements of the National Construction Code via a NatHERS star rating (James et al., 2017), although the popularity of that compliance route varies between State jurisdictions.

The ACT uses a similar process to assess the energy efficiency rating of existing and new homes. This rating must be disclosed in all real estate advertising material, and a purpose designed rating certificate must be provided as part of the purchase agreement. Under NatHERS, a house is rated on a scale of 1 (worst) to 10 (best) star, where 10 stars theoretically requires no mechanical heating and cooling input to maintain thermally comfortable conditions. The thermal assessment in MJ/m^2 is unique to the climate zone within which the building is to be located, drawing on a set of behavioral assumptions of building users. Each Star level represents a progressively lower expected energy use to

TABLE 1 | Class 1 dwelling NatHERS certificates by jurisdiction and software tool.

States	Software	2016*	2017	2018	2019	2020	2021*	Total
ACT	AccuRate	40	86	55	13	19	6	219
	BERS Pro	404	583	884	974	1,118	782	4,745
	FirstRate5	181	397	428	547	439	372	2,364
SA	AccuRate	103	153	124	73	54	23	530
	BERS Pro	561	1,207	919	757	882	622	4,948
	FirstRate5	2,052	2,885	2,563	2,561	3,651	2,081	15,793
TAS	AccuRate	12	20	37	34	51	42	196
	BERS Pro	142	291	275	342	481	239	1,770
	FirstRate5	1,281	2,442	2,695	2,585	3,321	2,099	14,423
VIC	AccuRate	635	1,003	1,188	1,040	897	544	5,306
	BERS Pro	3,869	6,832	7,342	6,797	7,470	5,186	37,497
	FirstRate5	29,828	44,123	40,547	39,430	44,689	37,096	235,713
WA	AccuRate	84	125	73	50	89	65	486
	BERS Pro	1,049	1,476	2,218	1,330	1,601	2,870	10,544
	FirstRate5	874	1,357	1,036	1,230	1,921	1,722	8,141
Total		41,115	62,980	60,384	57,763	66,683	53,749	342,674

**2016 data from May 2016 onwards and 2021 data up to end of June 2021.*

maintain human thermal comfort within pre-set parameters. The current minimum standard for new homes in Australia is 6 Stars. At the time of writing, there is a policy proposal to increase this minimum from 6 to 7 Stars in the National Construction Code 2022 revisions (ACIL Allen, 2021).

Since 2014, construction information and rating certificates generated through some NatHERS accredited software (i.e., AccuRate and BERS Pro) has been collated by the Commonwealth Scientific and Industrial Research Organization (CSIRO). Information generated by FirstRate5, another NatHERS accredited software package, has been managed by Sustainability Victoria (James et al., 2017). More recently, a data sharing agreement has facilitated a more complete set of all rating certificates, and information from this repository has become available for analytical purposes (CSIRO, 2021).

The analysis presented in this article draws upon specific data from all NatHERS certificates for new dwellings registered since May 2016 (the commencement of certificate data integration) until the end of June 2021. The analysis is limited to the jurisdictions (called States and Territories) which administer the 6 Star NatHERS building code requirement with a consistent approach, including South Australia (SA), Victoria (Vic), Tasmania (Tas), the ACT and Western Australia (WA). The results for the ACT are provided separately to allow comparison between jurisdictions with and without mandatory energy performance disclosure requirements. The regional jurisdiction of New South Wales, the largest State by population in Australia, employs a planning instrument called BASIX to deliver minimum community energy and environmental standards for housing, and therefore is not included in this study. Comparisons between the effectiveness of BASIX and the National Construction Code to achieve thermal comfort are published separately (Berry et al., 2019). While each NatHERS certificate presents the assessment outcomes to a granularity of 0.1 Star (e.g., 6.3 Stars), for simplicity the analysis below has clustered outcomes at the 0.5 Star interval (e.g., 6.0–6.4 Stars). The analysis focuses on new Class 1 dwellings which in Australia refers to a single dwelling being a detached house, or one or more attached dwellings, each being a building, separated by a fire-resisting wall, including a row house, terrace house, town house or villa unit. It excludes apartments. In Australia almost 68% of all new dwellings between May 2016–June 2021 which have been certified via the NatHERS approach are Class 1 dwellings (CSIRO, 2021). The data set used in this study is available via the following link: https://ahd.csiro.au/.

Certificate Numbers

The number of Class 1 dwelling certificates for each jurisdiction for the period of analysis, disaggregated by the brand of the NatHERS accredited software tool, is shown in **Table 1**. In total there are 41,115 certificates for 2016, 62,980 for 2017, 60,384 for 2018, 57,763 for 2019, 66,683 for 2020 and 53,749 for 2021 (up to end of June 2021) for a total across the time period of analysis of 342,674.

The total number of certificates registered in each State (see **Table 1**) reflects both the difference in population size and growth [e.g., the ACT has a population of ∼430,000 and a 2011–2020 growth rate of 1.4% compared to Victoria which has a population of 6.6 million and a 2011–2020 growth rate of 1.8% (Population Australia, 2021)] and therefore housing construction needs in each location, and the local industry's use of NatHERS as a compliance tool. For example, although the housing construction industry is larger in Western Australia when compared to Tasmania or South Australia, NatHERS is the preferred compliance route in the latter two but is less popular in the former. The National Construction Code allows other compliance routes to assess a house design for thermal comfort.

The popularity of the competing software tools is regionally specific, even though all tools contain the identical energy use

TABLE 2 | Class 1 dwelling NatHERS certificates by jurisdiction and star rating.

	Star rating				
States	**6***	**6.5**	**7**	**7.5**	**8+**
SA	75.5%	14.3%	4.8%	1.1%	0.4%
VIC	84.5%	11.0%	3.0%	0.5%	0.2%
TAS	55.7%	27.5%	13.5%	0.4%	0.5%
WA	66.6%	11.2%	7.2%	3.1%	2.2%
ACT	42.2%	21.7%	17.4%	9.7%	6.8%

**2016 data from May 2016 onwards and 2021 data up to end of June 2021. Note a small percentage of dwellings in the data set did not achieve the minimum 6 star standard and have been excluded from this table so percentages may be less than 100%.*

calculation engine and are required to produce the same energy use result for the same house within the scheme's published tolerances. For example, FirstRate5 is a factor of 6 times more popular in Victoria than BERS Pro, yet the latter is more frequently used in the ACT and Western Australia.

RESULTS

The data analysis shows that across all regions the minimum designed energy efficiency requirement of 6.0 NatHERS Stars is being met for the vast majority of Class 1 houses from the Australian building industry. In fact, **Figure 1** demonstrates an overwhelming bias centered on the 6 Star regulatory minimum, with very few homes achieving a higher or lower energy performance standard. The exact percentage breakdown for each star rating is presented in **Table 2**.

The distribution of Star ratings (see **Figure 1**; **Table 2**) for the sample of 336,640 house energy ratings from South Australia, Victoria, Tasmania and Western Australia for the analysis period shows the relative dominance of the minimum standard. The distribution curve pivots around the 6.0–6.4 Star level, representing the industry's focus on meeting the 6.0 Star regulatory minimum. No State registered <55% of certificates just meeting the minimum standard (for this analysis deemed to be 6.0–6.4 Stars), with Victoria registering over 85% at the minimum level. The tail of the distribution falls away rapidly with no State having >15% of homes designed at 7.0 Stars or above and by the 8.0 Star level they represent <1% of all house designs. Across the time period of analysis South Australia, Victoria and Western Australia averaged 6.2 Stars and Tasmania 6.5 Stars for new Class 1 dwellings.

The distribution of design ratings for the ACT is very different. **Figure 1** shows that although the building energy code sets the minimum benchmark at 6.0 Stars in a similar way to the other States, a relatively substantial share of ACT new homes are energy rated to achieve 7.0 Stars and above (33%), with a long distribution tail reaching out toward 9.0 Stars. Across the time period of analysis the ACT averaged 6.8 Stars for new Class 1 dwellings. This represents a material difference when compared to those jurisdictions (**Figure 1**) that do not have a mandatory disclosure requirement.

The only major house energy policy difference between the ACT (**Figure 1**) and the other States (**Figure 1**) related to the distribution of design ratings for new Class 1 homes is the addition of a complementary mandatory disclosure instrument. The measurable difference between the distributions is potentially the result of complementary regulation.

DISCUSSION

For the research period ∼81% of new Class 1 dwelling designs were energy rated at the minimum standard (6.0–6.4 Stars) in those Australian jurisdictions which require the NatHERS 6.0 Star requirement. Beyond the 6.5 Stars point, the number of new Class 1 dwellings rated at a higher than minimum level rapidly declines, and beyond 7.0 Stars there are very few dwelling certificates. When the results are compared against the economically optimal level for private benefits, which in Australia has been shown to be above 7 Stars (Moore, 2014; Berry and Davidson, 2015), it is clear that minimum energy performance standards do not address all market barriers.

The influence of the regulatory minimum performance standard is even stronger when we consider the designed performance level at whole star intervals. In South Australia over 89% of new homes were designed in the 6.0–6.9 Star range, for Victoria it was over 95%, and for Tasmania and Western Australia 83 and 86%, respectively, failed to reach the 7.0 Star level. It is clear that for these States the building industry is focussed on meeting the minimum 6 Star energy standard only, and few consumers are demanding materially higher performance, even though the "rational consumer" would expect to receive substantial economic benefits at or above the 7.0 Star performance level. Leading European and North American jurisdictions with comparable climate zones typically are at least 40% more stringent than for minimum new housing energy standards in Australia, even when adjusting for the last significant changes to the standards in 2010 (Horne and Hayles, 2008).

The distribution of ratings for the ACT is fundamentally different both in relation to the slightly higher average Star rating and the profile across the Stars when compared to all other jurisdictions considered in this study, particularly at or above 7.0 and 8.0 Stars. The combination of mandatory disclosure and minimum standards may be addressing market failures such as information asymmetry, and empowering consumers to demand slightly improved energy performance. That the majority of consumers are not acting rationally by demanding economically optimal performance may reflect problems of energy literacy, whereby the relationship between the NatHERS rating and economic outcome (future energy bills) may not be sufficiently transparent.

Whilst the ACT data suggests that the two policies are acting in a complementary manner to encourage slightly higher energy efficiency outcomes, it should be noted that the authors were unable to control for other important market influencing factors such as income or educational attainment which are relatively high in the ACT. However, given that Tasmania, which has the lowest per capita income and educational attainment of

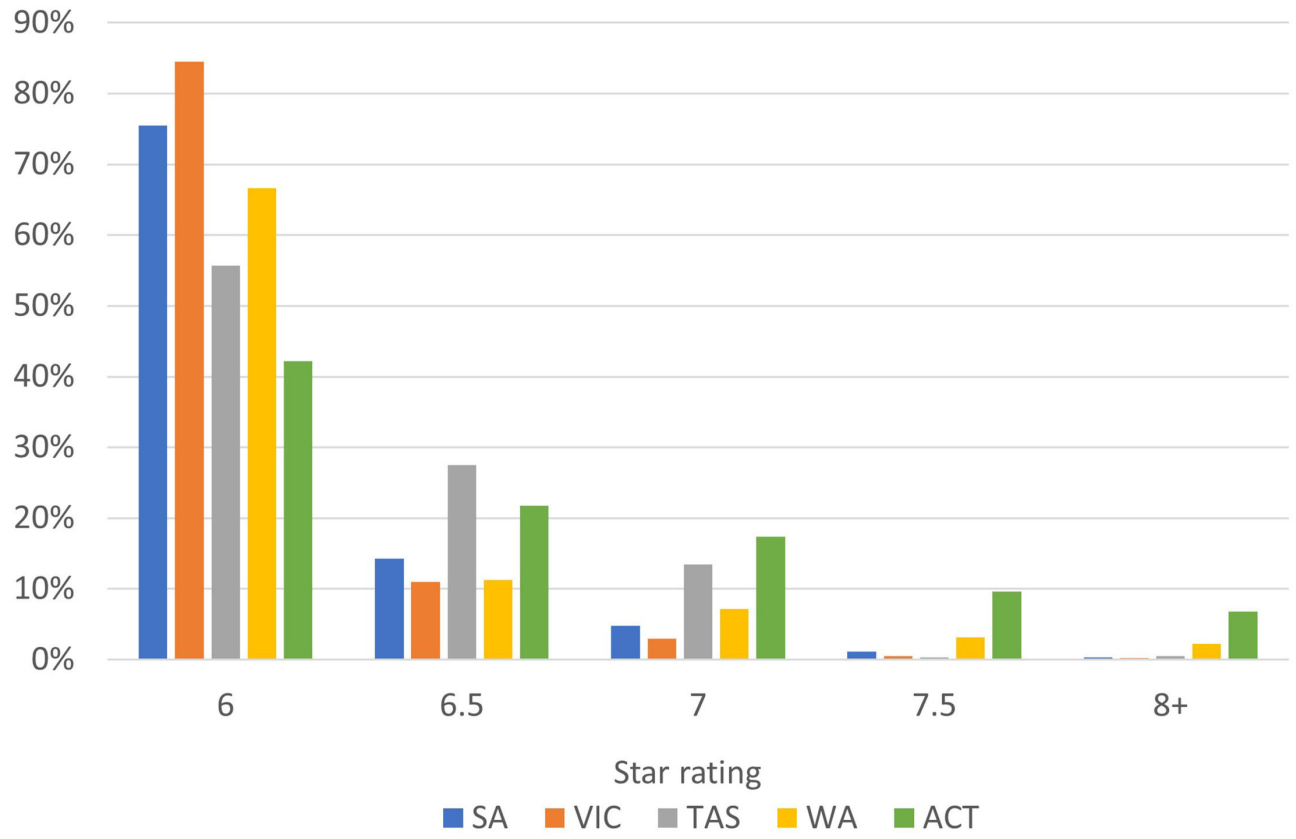

FIGURE 1 | NatHERS rating by 0.5 Star bin for new Class 1 dwellings in the ACT, Victoria, Western Australia, South Australia, and Tasmania May 2016–June 2021.

any Australian State (Australian Bureau of Statistics, 2016), has the next highest distribution at 6.5 and 7.0 Stars, those factors are unlikely to be significant compared to the influence of complementary mandatory energy disclosure requirements although further research is required to explore this. Therefore, although it is unreasonable to claim a causal relationship from this data, there is a suggestion from the data that complementary housing energy disclosure policy may deliver outcomes above that delivered solely by implementing mandatory minimum performance standards. As we push toward a more sustainable built environment future, this combination of policy mechanisms may be critical for shifting markets and housing performance (Doyon and Moore, 2020).

The evidence of complementary housing regulation in delivering greater net energy savings than individual policy instruments is similar to that found for household appliances and equipment. For example, Harrington and Brown (2007) note that complementary regulation (minimum standards and labeling) for appliances had achieved much greater savings compared to labeling alone. The evidence from the housing energy design data in this paper shows that complementary regulation achieves greater average energy performance than minimum standards alone. By addressing multiple market barriers in parallel the complementary policy instruments achieve additional market change.

More than 33% of all new homes in the ACT are designed at least 1.0 Star above the minimum standard, and ∼7% are reaching 2.0 Stars above the minimum regulatory requirement. No other State has a similar distribution of ratings, and factors such as local climate do not appear to shape the distribution. For example, Tasmania which also has a cool temperate climate has a relatively short distribution tail reaching to 7.0 Stars but does not have the long tail reaching toward 9.0 Stars found in the ACT data. The evidence shows that irrespective of whether the local climate is warm temperate, temperate or cool temperate, without the complementary regulatory requirement of mandating energy performance disclosure to address the information market failure, the market is overwhelmingly dominated by the minimum regulatory standard.

If the improved energy performance outcomes from the ACT were replicated in other states it would lead to a reduction of energy required for heating and cooling of ∼17% for new Class 1 dwellings across Australia compared to if there were not complementary regulations. The benefits of this are not just for the individual dwelling which would have reduced energy bills and improved thermal comfort but accumulates

across the broader community when considered at scale. For example, the performance improvement in Victoria would result in a reduction in energy for heating and cooling of ∼800 kWh/year/dwelling based upon an average conditioned floor area of 154 m^2 (CSIRO, 2021). At the typical average electricity price in Victoria of AU$0.25/kWh this would result in a reduction in energy bills of $200/year for households. If the ∼50,000 new Class 1 dwellings per year in Victoria (see **Table 1**) achieved this improved performance, it would result in a reduction in energy consumption of 40,000,000 kWh/year compared to if there were not complementary regulations. In 2018–19 Victoria consumed 48,333,333,333 kWh (174 PJ) of energy in the residential sector (DISER, 2020), meaning the potential energy reduction would equate to 0.8% of residential consumption, although as new dwellings are added to the total housing stock the overall energy consumption will continue to increase.

Previous research into the effect of mandatory disclosure in the ACT has shown a market premium of about 3% per each additional NatHERS star improvement (Department of the Environment Water Heritage the Arts, 2008), and often above the actual cost for construction of achieving an additional star. Therefore, actions such as installing additional insulation or maximizing glazing orientation are likely to be profitable for knowledgeable builders, encouraging some to deliver thermal performance beyond the minimum requirement. Further research is needed to identify whether the pull toward higher performance is driven by builder profit motive or is mainly a result of explicit consumer demand. While the majority of households will see market premiums as a beneficial outcome, there is also a need to ensure that any financial increase from improved dwelling performance does not exclude opportunity and access for those who are most vulnerable (e.g., low income households). Additional policies or support will be required to ensure these households are not pushed into older, poorer quality and performing housing.

The evidence can also be interpreted as a similar push-pull process to that of household appliance complementary regulation (Energy Efficient Strategies, 2006, 2016; Harrington and Brown, 2007; Yilmaz et al., 2019), where minimum standards push the industry to a particular societal minimum housing requirement, and mandatory labeling encourages consumers to pull the product toward higher energy efficiency performance levels. The ACT results suggest that complementary regulation is equally valid for high value, long-life housing assets as it has proven effective for lower value, short-life household appliances and equipment.

While it is evident that complementary regulation facilitates some pull of the market toward higher performance, this does not mean that all homes are designed at a level that is economically optimal for owners and the broader community, or at levels that reflect the environmental aspirations of society. While ∼33% of the new ACT housing stock is designed above the regulatory minimum, the vast majority of houses are still designed below the economically optimal performance level. Regulatory certainty is delivered by minimum energy performance standards (Moore et al., 2019), and the complementary disclosure instrument is useful but only addresses a specific information related market failure. It is clear from the evidence that the addition of a complementary disclosure instrument will not replace the need to continually review minimum standards to ensure that all homes meet the desired societal performance minimum and contribute to cost effective carbon abatement. However, jurisdictions that rely solely on minimum building performance standards may be missing out on a market opportunity to improve performance outcomes by not having complementary regulations.

While this paper has focused on new dwellings, a transition to a low carbon society will need to include large scale retrofit of the existing housing stock. A significant percentage of existing housing in Australia was built prior to the introduction of minimum performance standards. Future research should explore how building performance regulation *and* mandatory disclosure could support the transition of the existing housing stock to a lower carbon outcome. Improving the performance and sustainability of new and existing housing will be required to reduce the total energy consumption and wider environmental impacts of the housing sector.

CONCLUSION AND POLICY IMPLICATIONS

Climate change is a key driver for nations to seek cost effective means to limit greenhouse gas emissions by improving energy efficiency. The built environment has been recognized as having substantial and cost-effective carbon emission mitigation opportunities, and the suite of policy options available is large and diverse.

A number of countries have used the twin policy instruments of minimum energy standards and mandating the disclosure of energy efficiency information to reduce energy demand and transition to lower built environment carbon emissions. While this two-pronged approach has a long track record of success for household appliances and equipment, real estate purchases are generally more complex, higher cost and longer-life decisions, and until now there has been little evidence to confirm the power of combining these policy instruments for housing. The unique dataset available in Australia provides an important insight into the effectiveness of these policies in combination, and should guide future house energy policy development in Australia and globally.

Whilst we recognize the limitations of the data set and research methodology, the evidence from Australia suggests that both market push and pull measures can work in synergy to drive higher average energy performance for the new housing sector than would be achieved by a single minimum performance policy instrument. When used concurrently, these policy measures which address different market failures, appear to deliver a better overall housing energy efficiency outcome.

With more than 20 years of continuous regulation for both minimum building energy performance targets and mandatory energy performance disclosure, the ACT housing market is exhibiting significantly different behavior to that of other Australian States with just the minimum energy performance

requirement. The addition of the disclosure policy instrument is potentially informing consumers of otherwise relatively invisible performance attributes, and empowering them to demand higher energy efficiency performance.

The energy and environmental benefits of complementary regulation for long-life, higher cost housing appear to be consistent with that of shorter-life, lower cost household appliances and equipment. The use of complementary policy instruments on the same product type delivers greater energy savings than the use of a single policy instrument, irrespective of the expected product life or relative cost.

The evidence from Australia suggests that complementary regulation is effective in addressing a wider range of market failures than single policy instruments, and combined can be a powerful policy set to deliver energy and carbon emission savings. But policy makers should be careful not to use complementary instruments as an excuse to avoid delivering greater certainty from economically optimal minimum building energy performance standards. Complementing minimum energy performance standards with a mandatory disclosure policy instrument provides some material energy and carbon emission benefits, but does not replace the importance of maintaining minimum standards at a level that reflects optimal societal benefits.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

All authors contributed equally to the conception of the paper, data analysis, and writing of the paper. All authors contributed to the article and approved the submitted version.

REFERENCES

ACIL Allen (2021). *National Construction Code 2022. Consultation Regulation Impact Statement for a Proposal to Increase Residential Building Energy Efficiency Requirements*. Canberra, ACT: Australian Building Codes Board.

Aune, M. (2012). Making energy visible in domestic property markets: the influence of advertisements. *Build. Res. Inform.* 40, 713–723. doi: 10.1080/09613218.2012.696784

Australian Bureau of Statistics (2016). *Census of Population and Housing: Reflecting Australia 2071.0*. Canberra, ACT: Australian Bureau of Statistics.

Aydin, E., and Brounen, D. (2019). The impact of policy on residential energy consumption. *Energy* 169, 115–129. doi: 10.1016/j.energy.2018.12.030

Berry, S., and Davidson, K. (2015). Zero energy homes – Are they economically viable? *Energy Policy* 85, 12–21. doi: 10.1016/j.enpol.2015.05.009

Berry, S., and Marker, T. (2015). Residential energy efficiency standards in Australia: where to next? *Energy Efficiency* 8, 963–974. doi: 10.1007/s12053-015-9336-4

Berry, S., Marker, T., and Chevalier, T. (2008). "Modelling the relationship between energy efficiency attributes and house price: the case of detached houses sold in the Australian Capital Territory in 2005 and 2006," in *Paper presented at the World Sustainable Buildings Conference*. Melbourne, VIC.

Berry, S., Moore, T., and Ambrose, M. (2019). Flexibility versus certainty: the experience of mandating a building sustainability index to deliver thermally comfortable homes. *Energy Policy* 133, 110926. doi: 10.1016/j.enpol.2019.110926

Bouzarovski, S. (2018). *Energy Poverty: (Dis)Assembling Europe's Infrastructural Divide*. Cham, Switzerland: Springer Nature.

Brounen, D., and Kok, N. (2011). On the economics of energy labels in the housing market. *J. Environ. Econ. Manage.* 62, 166–179. doi: 10.1016/j.jeem.2010.11.006

Cajias, M., Fuerst, F., and Bienert, S. (2019). Tearing down the information barrier: the price impacts of energy efficiency ratings for buildings in the German rental market. *Energy Res. Soc. Sci.* 47, 177–191. doi: 10.1016/j.erss.2018.08.014

Council of Australian Governments (2009). *National Strategy on Energy Efficiency*. Canberra, ACT: Commonwealth of Australia.

Council of Australian Governments Energy Efficiency and Greenhouse Working Group (2003). *Towards a National Framework for Energy Efficiency: Issues and Challenges Discussion Paper*. Canberra, ACT: Commonwealth of Australia.

CSIRO (2021). *Australian Housing Data*. Commonwealth Scientific and Industrial Research Organisation. Available online at: https://ahd.csiro.au/ (accessed August 09, 2021).

Daniel, L., Baker, E., and Williamson, T. (2019). Cold housing in mild-climate countries: a study of indoor environmental quality and comfort preferences in homes, Adelaide, Australia. *Build. Environ.* 151, 207–218. doi: 10.1016/j.buildenv.2019.01.037

de Ayala, A., Galarraga, I., and Spadaro, J. (2016). The price of energy efficiency in the Spanish housing market. *Energy Policy* 94, 16–24. doi: 10.1016/j.enpol.2016.03.032

Department of Climate Change and Energy Efficiency. (2012). *National Building Energy Standard-Setting, Assessment and Rating Framework*. Canberra, ACT: Commonwealth of Australia.

Department of the Environment Water Heritage and the Arts (2008). *Energy Efficiency Rating and House Price in the ACT*. Canberra, ACT: Commonwealth of Australia.

DISER (2020). *Australian Energy Update 2020*. Canberra, ACT: Australian Government. Available online at: https://www.energy.gov.au/publications/australian-energy-update-2020 (accessed January 12, 2022).

Doyon, A., and Moore, T. (2020). The role of mandatory and voluntary approaches for a sustainable housing transition: evidence from Vancouver and Melbourne. *Urban Pol. Res.* 38, 213–29. doi: 10.1080/08111146.2020.1768841

Edwards, J., and Pocock, B. (2011). *Comfort, Convenience and Cost: The Calculus of Sustainable Living at Lochiel Park*. Adelaide, SA: Centre for Work + Life, University of South Australia.

Energy Efficient Strategies (2006). *Greening Whitegoods - A Report Into the Energy Efficiency Trends of Major Household Appliances in Australia From 1993 to 2005 (E. E. E. Committee, Trans.)*. Warragul: Equipment Energy Efficiency Committee, Ministerial Council on Energy.

Energy Efficient Strategies (2014). *Energy Standards and Labelling Programs Throughout the World in 2013*. Warragul, VIC: Energy Efficient Strategies.

Energy Efficient Strategies (2016). *White Goods Efficiency Trends: A Report Into the Efficiency of White Goods in Australia 1993 to 2014*. Canberra, ACT: Commonwealth of Australia.

Enker, R. A., and Morrison, G. M. (2020). The potential contribution of building codes to climate change response policies for the built environment. *Energy Efficiency*. 13, 789–807. doi: 10.1007/s12053-020-09871-7

European Commission (2010). *Directive 2010/31/EU of the European Parliament and of the Council on the Energy Performance of Buildings*. Brussels: European Commission.

European Commission (2015). *Securing Energy Efficiency to Secure the Energy Union: How Energy Efficiency meets the EU Climate and Energy Goals*. Ispra: Joint Research Centre.

Evans, M., Roshchanka, V., and Graham, P. (2017). An international survey of building energy codes and their implementation. *J. Clean. Prod.* 158, 382–389. doi: 10.1016/j.jclepro.2017.01.007

Franke, M., and Nadler, C. (2019). Energy efficiency in the German residential housing market: Its influence on tenants and owners. *Energy Policy* 128, 879–890. doi: 10.1016/j.enpol.2019.01.052

Fuerst, F., McAllister, P., Nanda, A., and Wyatt, P. (2013). An Investigation of the Effect of EPC Ratings on House Prices. London: Department of Energy & Climate Change.

Fuerst, F., Oikarinen, E., and Harjunen, O. (2016). Green signalling effects in the market for energy-efficient residential buildings. *Appl. Energy* 180, 560–571. doi: 10.1016/j.apenergy.2016.07.076

Fuerst, F., and Warren-Myers, G. (2018). Does voluntary disclosure create a green lemon problem? Energy-efficiency ratings and house prices. *Energy Econ.* 74, 1–12. doi: 10.1016/j.eneco.2018.04.041

Geller, H., Harrington, P., Rosenfeld, A. H., Tanishima, S., and Unander, F. (2006). Polices for increasing energy efficiency: thirty years of experience in OECD countries. *Energy Policy* 34, 556–573. doi: 10.1016/j.enpol.2005.11.010

Gerarden, T., Newell, R., and Stavins, R. (2017). Assessing the energy-efficiency gap. *J. Econ. Literat.* 55, 1486–1525. doi: 10.1257/jel.20161360

Gower, A. (2021). Energy justice in apartment buildings and the spatial scale of energy sustainable design regulations in Australia and the UK. *Front. Sustain. Cities* 3, 1–12. doi: 10.3389/frsc.2021.644418

Hårsman, B., Daghbashyan, Z., and Chaudhary, P. (2016). On the quality and impact of residential energy performance certificates. *Energy Build.* 133, 711–723. doi: 10.1016/j.enbuild.2016.10.033

Halverson, M., Johnson, J., Weitz, D., Majette, R., and LaLiberte, M. (2002). "Making residential energy codes more effective: building science, beyond code programs, and effective implementation strategies," in *Paper presented at the ACEEE Summer Study on Energy Efficiency in Buildings* (Pacific Grove, California).

Harrington, L., and Brown, J. (2007). "Energy consumption of whitegoods - what is improving and what is not," in *Paper presented at the ECEEE Summer Study* (La Colle sur Loup, Côte d'Azur, France).

Harrington, P., and Hoy, V. (2019). "The trajectory to a net zero emissions built environment: the role of policy and regulation," in *Decarbonising the Built Environment: Charting the Transition*, eds P. Newton, D. Prasad, A. Sproul and S. White (Singapore: Palgrave Macmillian), 193–207.

Horne, R. (2018). *Housing Sustainability in Low Carbon Cities*. London: Taylor & Francis Ltd.

Horne, R., and Hayles, C. (2008). Towards global benchmarking for sustainable homes: an international comparison of the energy performance of housing. *J. Housing Built Environ.* 23, 119–130. doi: 10.1007/s10901-008-9105-1

Horne, R., Hayles, C., Hes, D., Jensen, C., Opray, L., Wakefield, R., et al. (2005). *International Comparison of Building Energy Performance Standards*. Melbourne, VIC: RMIT Centre for Design.

Hurlimann, A. C., Browne, G. R., Warren-Myers, G., and Francis, V. (2018). Barriers to climate change adaptation in the Australian construction industry – Impetus for regulatory reform. *Build. Environ.* 137, 235–245. doi: 10.1016/j.buildenv.2018.04.015

Intergovernmental Panel on Climate Change (2014). *Working Group III - Mitigation of Climate Change: Technical Summary*. Geneva: Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change (2018). *Summary for Policymakers: Global warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the tHreat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. Geneva: World Meteorological Organization.

International Energy Agency (2013). *Modernising Building Energy Codes to Secure Our Global Energy Future*. Paris: International Energy Agency.

International Energy Agency (2014). *Capturing the Multiple Benefits of Energy Efficiency*. Paris: IEA.

International Energy Agency (2018). *Energy Efficiency 2O18: Analysis and Outlooks to 2O4O*. Paris: IEA.

International Energy Agency (2020). *Building Envelopes Tracking Report - June 2020*. Paris: International Energy Agency.

James, M., Ambrose, M., Lane, B., and Wright, A. (2017). The NatHERS dataset: an exploration of its content, provenance, and usefulness in the characterization of new residential building. *Energy Proc.* 121(Suppl. C), 142–149. doi: 10.1016/j.egypro.2017.08.011

Janda, K. (2009). "Worldwide status of energy standards for buildings: a 2009 update," in *Paper presented at the European Council for an Energy Efficient Economy, Summer Study* (La Colle sur Loup, Côte d'Azur, France).

Kearns, A. (2020). Housing as a public health investment. *BMJ* 371, m4775. doi: 10.1136/bmj.m4775

Kok, N., and Kahn, M. (2012). *The Value of Green Labels in the California Housing Market*. Los Angeles, CA: UCLA Institute of the Environment and Sustainability

Martek, I., Hosseini, M. R., Shrestha, A., Edwards, D. J., and Durdyev, S. (2019a). Barriers inhibiting the transition to sustainability within the Australian construction industry: An investigation of technical and social interactions. *J. Clean. Prod.* 211, 281–292. doi: 10.1016/j.jclepro.2018.11.166

Martek, I., Hosseini, M. R., Shrestha, A., Edwards, D. J., Seaton, S., and Costin, G. (2019b). End-user engagement: the missing link of sustainability transition for Australian residential buildings. *J. Clean. Prod.* 224, 697–708. doi: 10.1016/j.jclepro.2019.03.277

Martínez-Montejo, S., and Sheinbaum-Pardo, C. (2016). The impact of energy efficiency standards on residential electricity consumption in Mexico. *Energy Sustain. Dev.* 32, 50–61. doi: 10.1016/j.esd.2016.02.010

Meyers, S., McMahon, J., McNeil, M., and Liu, X. (2003). Impacts of US federal energy efficiency standards for residential appliances. *Energy* 28, 755–767. doi: 10.1016/S0360-5442(02)00188-3

Mills, B., and Schleich, J. (2010). What's driving energy efficient appliance label awareness and purchase propensity? *Energy Policy* 38, 814–825. doi: 10.1016/j.enpol.2009.10.028

Moore, T. (2014). Modelling the through-life costs and benefits of detached zero (net) energy housing in Melbourne, Australia. *Energy Build.* 70, 463–471. doi: 10.1016/j.enbuild.2013.11.084

Moore, T. (2018). "Strategic niche management and the challenge of successful outcomes," in *Urban Sustainability Transitions. Australian Cases - International Perspectives*, eds T. Moore, F. de Haan, R. Horne and B. Gleeson (Singapore: Springer).

Moore, T., Berry, S., and Ambrose, M. (2019). Aiming for mediocrity: the case of Australian housing thermal performance. *Energy Policy* 132, 602–610. doi: 10.1016/j.enpol.2019.06.017

Moore, T., and Holdsworth, S. (2019). "The built environment and energy efficiency in Australia: current state of play and where to next," in *Energy Performance in the Australian Built Environment*, eds P. Rajagopalan, M. M. Andamon and T. Moore (Singapore: Springer).

Moore, T., Horne, R., and Morrissey, J. (2014). Zero emission housing: Policy development in Australia and comparisons with the EU, UK, USA and California. *Environ. Innovat. Soc. Transit.* 11, 25–45. doi: 10.1016/j.eist.2013.12.003

Moore, T., Ridley, I., Strengers, Y., Maller, C., and Horne, R. (2017). Dwelling performance and adaptive summer comfort in low-income Australian households. *Build. Res. Inf.* 45, 443–56. doi: 10.1080/09613218.2016.1139906

Murphy, L. (2014). The influence of the energy performance certificate: The Dutch case. *Energy Policy* 67, 664–672. doi: 10.1016/j.enpol.2013.11.054

Nadel, S. (2019). Focusing and improving traditional energy efficiency strategies. *Electricity J.* 32:106620. doi: 10.1016/j.tej.2019.106620

NatHERS (2017). *Nationwide House Energy Rating Scheme (NatHERS)*. Available onlien at: http://www.nathers.gov.au/ (accessed August 12, 2017).

Newton, P., Prasad, D., Sproul, A., and White, S. (eds.). (2019). *Decarbonising the Built Environment: Charting the Transition*. Singapore: Palgrave Macmillian.

O'Neill, K., and Gibbs, D. (2020). Sustainability transitions and policy dismantling: Zero carbon housing in the UK. *Geoforum* 108, 119–129. doi: 10.1016/j.geoforum.2019.11.011

Population Australia (2021). *Australia Population 2021*. Available online at: https://www.population.net.au/ (accessed November 28, 2021).

Shim, J., Song, D., and Kim, J. (2018). The economic feasibility of passive houses in Korea. *Sustainability* 10, 1–16. doi: 10.3390/su10103558

Sustainability House (2013). *Assisting NatHERS Compliance: Literature Review*. Edwardstown: Sustainability House.

Thonipara, A., Runst, P., Ochsner, C., and Bizer, K. (2019). Energy efficiency of residential buildings in the European Union – An exploratory analysis

of cross-country consumption patterns. *Energy Policy* 129, 1156–1167. doi: 10.1016/j.enpol.2019.03.003

Warren-Myers, G., Bartak, E., and Cradduck, L. (2020). Observing energy rating stars through the Australian Consumer Law lens: how volume home builders' advertising can fail consumers. *Energy Policy* 139, 111370. doi: 10.1016/j.enpol.2020.111370

Wiel, S., Egan, C., and della Cava, M. (2006). Energy efficiency standards and labels provide a solid foundation for economic growth, climate change mitigation, and regional trade. *Energy Sustain. Dev.* 10, 54–63. doi: 10.1016/S0973-0826(08)60544-X

Wiese, C., Larsen, A., and Pade, L.-L. (2018). Interaction effects of energy efficiency policies: a review. *Energy Efficiency* 11, 2137–2156. doi: 10.1007/s12053-018-9659-z

Willand, N., and Horne, R. (2018). "They are grinding us into the ground" – The lived experience of (in)energy justice amongst low-income older households. *Appl. Energy* 226, 61–70. doi: 10.1016/j.apenergy.2018.05.079

Willand, N., Maller, C., and Ridley, I. (2019). Addressing health and equity in residential low carbon transitions – Insights from a pragmatic retrofit evaluation in Australia. *Energy Res. Soc. Sci.* 53, 68–84. doi: 10.1016/j.erss.2019.02.017

Yilmaz, S., Majcen, D., Heidari, M., Mahmoodi, J., Brosch, T., and Patel, M. K. (2019). Analysis of the impact of energy efficiency labelling and potential changes on electricity demand reduction of white goods using a stock model: the case of Switzerland. *Appl. Energy* 239, 117–132. doi: 10.1016/j.apenergy.2019.01.137

Yu, H., Tang, B., Yuan, X., Wang, S., and Wei, Y. (2015). How do the appliance energy standards work in China? Evidence from room air conditioners. *Energy Build.* 86, 833–840. doi: 10.1016/j.enbuild.2014.09.072

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