3

A Critical Juncture

3.1 Introduction

In Chap. 1, we explored the benefits of sustainable housing for individual households and for society. We also discussed why, as a global community, we need to transition to sustainable housing for a low carbon future. As Chap. 2 outlined, many jurisdictions have made improvements to the design, quality, and performance of new and existing housing over recent decades, primarily driven by the creation of minimum performance standards.

Despite this progress, we are at a critical juncture for what type of future we are creating. If low carbon and broader sustainability outcomes are to be achieved by the middle of the century, we know that the time before 2030 is going to be critical, with potentially even less time than this. The most pressing issue in the wider sustainable housing debate relates to climate change and the ability of the housing sector to contribute to a low carbon future. This is not the only reason why there is an urgency for change though, with an increasing range of social and financial drivers challenging traditional thinking, policy, delivery, and use of housing.

This chapter explores why we are at this critical juncture where we need to make urgent changes (Sect. 3.2). This applies to both new housing and the need to address existing housing. If done right, a transition to

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sustainable housing will not just be about improving design, materials, technologies, and construction methods, but will also be a way to help address a range of other social justice and equity issues that have been exacerbated by rapidly worsening housing unaffordability and access issues around the world. We discuss this through innovations in sustainable housing as pertaining to the wider sustainable housing transition (Sect. 3.3). We return to the ideas and case studies of sustainable housing innovation in Chaps. 6 and 7.

3.2 An Urgency for Change

Globally, there has been increasing tension between the impact that humans are having on our natural climate and the way we are responding (or need to respond). While, for many decades, the housing construction industry and some policy makers have expressed intentions to deliver 'sustainable development' (as defined by Brundtland in 1987), there has been very little change to overall practices in many jurisdictions. This is especially concerning given that there has been a significant increase in population and consumerism since these ideas emerged, as well as related ideas from the 1970s (e.g., Limits to growth report and the establishment of the United Nations Environment Program), that makes the challenge of achieving a U-turn on relatively unchecked emissions growth a significant challenge. Cohen [1, p. 174] states there is 'growing recognition that the greenhouse gas reduction targets of the Paris Agreement and the objectives of the United Nations 2030 Agenda for Sustainable Development will be unachievable if policy initiatives continue to be predicated on incremental adjustments that only superficially mollify the most egregious aspects of contemporary norms'.

While there have been a range of mechanisms, such as minimum building performance requirements, introduced over recent decades, they have tended to be incremental and have been generally disconnected from what is considered best practice by the community of sustainable housing researchers and advocates [2]. The type of sustainable housing that will be required to achieve a low carbon future is housing that achieves significantly improved environmental, social, and financial outcomes. In this book, we define sustainable housing as dwellings with a zero carbon impact that, where possible, contributes to regeneration initiatives that support wider sustainability. Sustainable housing is housing which significantly reduces its life cycle impacts and engages with concepts of the circular economy (e.g., design for disassembly). However, it is more than just physical elements; sustainable housing improves health and well-being, reduces living costs, and connects to other sectors such as transport, food, and energy networks. Sustainable housing draws on a variety of design, material, technology, and construction innovations to build housing that will perform well now and into the future. This is not just performance from a technical perspective but also in terms of resiliency against a changing climate (e.g., resilient to extreme weather events).

These elements should be the minimum considerations for sustainable housing moving forward and we can achieve them right now (see Chaps. 6 and 7 for case studies). Innovations will likely mean our definition of sustainable housing will change in future years but will also likely lead to improvements in how sustainable housing can be provided. This dynamic consideration of sustainable housing means it is hard for a global definition, and a definition will also be dependent on context specific factors such as local climatic conditions. An increasing number of examples over the past two decades have demonstrated that there are no design, material, technological, and construction method reasons why we are not delivering these types of dwellings already.

While much of the broader policy discussion around the world has been on how the housing sector can achieve low carbon outcomes by 2050, the transition could happen much faster if the housing construction industry and other key stakeholders voluntarily engaged. We can see this voluntary change currently happening with electric vehicles. Since 2017, there has been a plethora of car manufacturers announcing their plans to transition to only selling electric vehicles. These manufacturers are setting even more ambitious timeframes than many government policies and pathways for increasing the uptake of electric vehicles, demonstrating that change can happen quite quickly when there is a desire to do so.

3.2.1 Locked In

Housing is infrastructure with a long life, lasting many decades if not 100 years or more. In relation to sustainability, the decisions made around design, materials, technologies, and construction methods are critical for determining a dwelling's quality and performance outcomes and the way it will be used by occupants. An old rule of thumb suggests that 80% of a dwelling's impacts are locked in during the first 20% of the design process, but the early considerations around land use and planning can also impact the future opportunities for improving design, quality, and performance. Once a dwelling is built, it can be costly to retrofit to improve design, quality, and performance and the options to improve outcomes are limited by the existing building. For example, if the dwelling is not orientated the right way there is little that can be done to improve orientation, potentially reducing the benefits that could be achieved via passive solar design.

Data from the UK indicates that it is likely to cost £20,000 or more to retrofit many existing dwellings to achieve a low carbon future [3]. Housing performance in the UK is arguably starting from a higher base level than many other countries given the high uptake of some more costly retrofits for various sustainable housing elements such as double-glazed windows (over 80% uptake) [4]. Conversely, in Australia, there has been a low uptake of double glazing meaning that any retrofit becomes significantly more expensive with the need to undertake more disruptive work. Research from Australia has found the cost of deep retrofits to be in the range of AU$25,000–$50,000 [5–8].

As noted by researchers across several countries, the housing that already exists will make up most of the residential building stock in 2050 [7, 9, 10]. Addressing the existing housing stock will take a significant effort and there are different challenges to achieving sustainability outcomes compared to new housing (e.g., ease of work). Therefore, we must make sure that whatever new housing we add to the current stock is delivered to the highest design, quality, and performance standards possible to ensure we are not locking in future housing and households to poor sustainability outcomes and the need to undertake expensive retrofit in the coming decades.

The challenge for the housing sector is how to provide the type of housing that is required now and into the future. This is not a straightforward proposition when what we want from housing, or the way we use it, may change. We have seen this occurring over recent decades with some developed countries, such as the USA and Australia, seeing rapid increases in the average floor area of detached housing as part of the perception that consumers wanted more (more bedrooms, more bathrooms, more hobby rooms). However, this increase in floor area occurred while average occupant numbers were decreasing, creating an odd paradox. Incremental improvements to energy efficiency technology are often being outstripped by a rapid overall increase in energy consumption. This is referred to as the rebound effect and it occurs because of the increasing number of appliances and changes to their use [11, 12]. These changes have created mixed results related to the sustainability of new and retrofitted housing, even though minimum performance requirements have steadily been improving.

What we want, or need, in our housing can shift quite quickly. For example, the emergence of COVID-19 resulted in many cities experiencing periods of lock down to try to control the spread of the virus. This meant people spent more time in their homes. For those who could work from home, the home became a blurred line between where people worked (or studied) and where they lived. It also resulted in people creating makeshift work-at-home spaces that were not designed for such use. Many people who had to spend more time at home realized that their housing is hard and expensive to heat and cool, or that there are a range of defects that impact liveability [13]. This is for those who are lucky: renters or those on low incomes have found that the pandemic exacerbated many of the pre-existing issues around housing quality and affordability. Additionally, during COVID-19, people who were homeless, who were in shared housing, or who lived in informal housing faced far more serious problems which were exacerbated by their access (or lack of access) to safe and reliable housing.

Because of climate change, we have seen more frequent and more extreme weather events such as extreme heat, flooding, and bush/forest fires since the early 2000s. These climate change impacts and related events inevitably impact housing. Higher temperatures lead to increased use of mechanical cooling systems to stay cool. Flooding can seriously impact the structural integrity of property and can damage homes and their contents. Bush and forest fires can completely decimate homes and infrastructure. This kind of weather related property damage impacts housing affordability and household finance. Research in the USA found that homes in California sold for an average 3.9% lower in wildfire prone areas compared to lower risk regions [14]. The cost of insurance has also gone up, and in some locations, homes have become uninsurable due to increased risk of flooding or fires. For example, between 6–10% of homes in Canada are not eligible for flood insurance because the locations have been deemed too high risk by insurance companies [15].

Every year that a sustainable housing outcome is delayed, it will continue to lock in households and the housing sector into less efficient housing. Research in Australia has calculated that the cost for delaying regulatory minimum performance requirements for new housing from 2019 to 2022 would impact 500,000 new dwellings built across the three years and result in AU$1.1 billion of unnecessary energy bills for households by 2050 [16]. The impacts were found to be wider than just individual households, with research estimating that the delay in improving minimum performance requirements would lock in AU$530 million of unnecessary energy network investment. If these figures are extrapolated to other jurisdictions, the global cost for inaction in delivering sustainable housing will run into many tens of billions of dollars each year, if not hundreds.

3.2.2 Timeframes and Targets

In relation to broader sustainability goals, there is global consensus that we are facing a climate emergency and must achieve greenhouse gas emission reductions of at least 80% by 2050, if not sooner [17]. Many countries have, after decades of avoiding significant action, set out interim targets to ensure a pathway towards this goal. This 2050 greenhouse gas emissions reduction target is considered the minimum of what must be done by many in the scientific community, and even if it is achieved, it does not guarantee that there will not be significant changes to our climate. Realizing the urgency, an increasing number of countries have revised their time frames and targets in recent years. This has also been seen in the business space where a number of companies have announced their own environmental targets. However, there remains a significant number of countries who have been reluctant to make such commitments or to adhere to calls for higher targets across a shorter time frame, making global progress towards a low carbon future challenging.

As discussed in Chap. 1, the built environment is a significant contributor to overall greenhouse gas emissions. This is both through the consumption of materials during the construction and through consumption of energy during the dwelling's use. As a reminder, the housing sector is responsible for 17% of the world's greenhouse gas emissions and 19% of its final energy consumption [9, 18]. This impact is even wider if we include transportation impacts from housing location.

However, the good news is that the housing sector has been identified as low hanging fruit by a range of researchers, industry stakeholders, and policy makers. This means we can cost-efficiently deliver sustainable housing right now. This is demonstrated in established and emerging examples of new housing from all around the world. This is also the case for retrofitting existing housing where significant improvements in performance can be achieved cost-effectively, such as through sealing all gaps and cracks and installing insulation, delivering improved sustainability and social outcomes, not just for the occupants but for society.

Prior to climate emergency declarations, in 2015 the UN announced their Sustainable Development Goals which are also driving change in the housing sector. These 17 goals aim to address a range of inequity and justice issues across the world. Several relate specifically to energy and the built environment such as goal 7 (Affordable and Clean Energy), goal 11 (Sustainable Cities and Communities) and goal 13 (Climate Action). These Goals demonstrate that a transition to sustainable housing is not just about housing in developed countries switching from fossil fuel to renewables. There are significant parts of the world where even the provision of basic housing is an ongoing challenge such as the 1 billion people who currently live in slums or informal settlements [19]. A transition to a more sustainable, affordable, and safe housing future for these populations means the provision of safe and decent housing, with quality and sustainability outcomes helping to improve a range of financial and social impacts. The timeframe set by the UN to achieve these outcomes is 2030, which at the time of writing this book is less than a decade away.

Typically, the development of minimum design, quality, and performance requirements has happened in small increments. This ensures that progress is being made but that the change is not so large that it adds unreasonable costs or burdens to consumers or the housing construction industry. However, there have been several examples where there has been a shift to longer term policy development as it relates to housing performance regulations. As discussed in Chap. 2, there are several jurisdictions that have made more significant progress towards sustainable housing by setting out longer term policy pathways for how it can be achieved. In California, policy makers set out a ten-year pathway to improve housing design, quality, and performance requirements in stages. This provides an example of how long it can take policymakers, and the construction industry to transition to a sustainable housing outcome. In British Columbia, the government introduced the BC Energy Step Code, a voluntary tool that provides an incremental approach to obtaining energy efficient buildings that go above the base requirements of the BC Building Code. The Energy Step Code also provides a pathway for ensuring all buildings province-wide are Net-Zero Energy Ready by 2032. Most countries, however, have not yet introduced requirements to achieve such housing outcomes, with current minimum performance still falling short of what is required for a transition to a sustainable housing future. Even when such outcomes are intentionally set, there is still a lack of pathway development to achieve them [20–22].

Several other locations, such as Australia, have recently developed, or are in the process of developing, longer term policy pathways to deliver sustainable housing and wider low carbon outcomes. These longer term pathways are important for a range of reasons, including that they provide more certainty for the housing construction industry and associated stakeholders about what the future holds. This provides an incentive for the housing construction industry to find a way to innovate and deliver the improved performances, while also providing time between each step to allow the industry to adapt. It also helps provide a clear reason for those who want to innovate to do so.

While globally there is a range of longer term sustainability goals relating to reducing greenhouse gas emissions by 2050, there has been a lack of specificity around housing's role in reducing these emissions in many jurisdictions. As a global society, we must aim to address this and move to delivering sustainable housing outcomes as soon as possible.

The jurisdictions that are already doing this, or are close to, are showing that this is not a pipe dream and that it can be done now if the political and industry will is there. While some jurisdictions will be coming from a low base for housing quality and performance, it is not unrealistic to think that the majority of new housing (and buildings more broadly) can be delivered to such outcomes no later than 2030. This would not only align to the wider UN Sustainable Development Goals, but would help to reduce the impact of all new housing from 2030 onwards to try and achieve the 2050 sustainability goals.

The retrofit of existing dwellings is more challenging [3, 7, 23, 24]. As part of the push towards a low carbon future, the UK Climate Change Committee stated that the residential stock needed to be nearly completely decarbonized by 2050 [3]. Based on their dwelling performance rating scale of A (best) to G (worst) in 2018–2019, there were around 19 million dwellings across the UK that had a rating of D or worse. With calls to lift these dwellings to at least a performance of C over 10–15 years, this would mean that homeowners would need to complete almost 2.5 retrofits every minute for 15 years [3]. To achieve this, it has been estimated that retrofitting existing housing would require more than £70 billion in total investment, although different estimates put the costs at 3–4 times this amount depending on the level of retrofit and the number of hard-to-treat homes [3, 23]. To achieve the nearly zero emission outcomes would require even deeper retrofits and include more of the housing stock. Similarly, high numbers of retrofits will be required in other jurisdictions, presenting a major challenge for how this will be delivered.

3.2.3 Green New Deals

The issue of how to deliver sustainable housing is not just about the design, materials, technology, and construction methods; it is also about having a housing construction industry that can deliver these outcomes. There are concerning labour shortages in both the new and existing dwelling sectors in many jurisdictions [25, 26]. This has been a bubbling issue in many countries for several years, resulting in constraints over the number of new dwellings that can be constructed, dwellings that can be retrofitted, and the capacity to scale up changes. It also limits the opportunities for any additional industry requirements, such as training for how to deliver improved design, quality, and performance, given the industry is already over stretched. While we generally have the knowledge to deliver sustainable housing, there is still a need to educate the vast majority of the industry about the practices they would need to change or modify in order to deliver sustainable housing.

The ongoing labour shortage issue has led to a chronic undersupply of housing in countries like Australia, which has contributed to worsening housing affordability due to less supply than demand. This in turn plays a role in discussions around design, quality, and performance. As the argument goes, improving design, quality, and performance will add costs to a dwelling which makes it even less affordable. This kind of thinking prevents improvements from happening, locking in the poor sustainability performance of a dwelling for decades (or until the household or homeowner undertakes a costly retrofit), creating a perpetual cycle where key housing issues are never properly addressed.

In response to the global financial impact of the COVID-19 pandemic, there has been an increasing number of research and policy analysis reports that have outlined how economic recovery should have a greater focus on sustainability. In fact, this research argues that more jobs will be created through a sustainability focus than any attempts to return to a business-as-usual approach. It should be noted this is not the first time such a plan has been put forward, with similar calls made after the Global Financial Crisis in 2008–2009.

In their Sustainable Recovery Plan analysis, the International Energy Agency outlines how a focus on a green recovery would save or create more than 9 million jobs a year from 2020–2023 [27]. The report estimates that 9–30 jobs would be created for every million dollars invested in energy efficiency measures for buildings. The report, as with others noted below, takes a more holistic approach to the call for a green recovery, highlighting the significant benefits related to lower energy bills, reduced energy poverty, and improved health and well-being outcomes. This is not just about improving housing quality and performance of developed countries, with the plan identifying a need to provide access to clean cooking to the more than 2.5 billion people that still have to cook with inefficient and polluting fuels like biomass and coal. This is about addressing polluting energy sources as well as improving health outcomes for such households. The broader impacts would not just be from providing jobs but also from a recovery that would be better for the environment. The recovery from the 2008–2009 Global Financial Crisis saw greenhouse gas emissions rebound as the global economy started to grow again. In contrast, the Sustainable Recovery Plan aims to reduce greenhouse gas emissions by 5% while creating jobs.

Major research in other parts of the world has identified similar benefits. McKinsey estimates that a green recovery will not only reduce emissions by up to 30%, but also create 3 million more jobs over the coming years than traditional employment would [28]. The authors estimate that for every million dollars in spending, 7.5 renewable energy jobs or 7.7 energy efficiency jobs would be created, compared to only 2.7 jobs in the fossil fuel sector. In total, they estimate up to 1.7 million jobs could be created to retrofit housing for energy efficiency.

In the UK, Greenpeace estimate that for every million pounds invested in the sustainable building sector, 23 jobs would be created for a total potential of 400,000 new jobs [29]. These jobs are to be created across the entire sector, but the retrofit of existing housing and provision of new sustainable housing is noted as a key driver of these jobs.

The retrofit of existing housing is a key theme in these green recovery plans. In France, there are plans to scale up retrofit to undertake 500,000 energy efficiency retrofits per year, half of which will be low-medium income households [30]. To achieve this outcome, funding will be provided by the government to train new and existing housing construction industry employees. Similar benefits from a green recovery have been put forward in Australia where a significant focus on retrofit of existing housing could make 2.5 million existing homes more energy efficient across a 5-year period [31]. At an estimated cost of AU$25,000 per home, the deep retrofits delivered would significantly reduce utility bills and improve liveability outcomes for occupants. This retrofit programme would create up to 500,000 jobs across the five years and help kick-start a longer term retrofit programme in Australia. In addition, there could be another 440,000 jobs in the new housing space through a focus on delivering an increased number of social housing units. This programme would also lead to significant environmental improvements with an estimated 20 million tonnes of greenhouse gas emissions avoided.

3.3 Innovations in Sustainable Housing

We are at an urgent junction in time where significant steps must be taken by 2030 if the housing sector is to address a number of critical issues: not just the broader environmental challenges, but also those relating to equity and justice in the housing space. In Chaps. 6 and 7, we will explore some case studies of what is currently being done in different regions of the world as it relates to sustainable housing. Below is an overview of some examples of innovations that have emerged in recent years that show us what we could be doing in relation to sustainable housing.

Related to rapid improvement of sustainability outcomes at the dwelling scale, one of the most widespread examples we have seen around the world is the uptake of residential solar PV since the early 2000s. Countries like Germany, Spain, and Australia have seen residential uptake of PV skyrocket. In Australia, in just over a decade, the percentage of dwellings that now have PV went from less than 1% to around one third of all dwellings [32]. While very much a technical sustainability fix, and arguably, not the first priority to consider when delivering sustainable housing, the fact is PV has shifted ideas and thinking around energy and housing. This shift has helped create a narrative around high cost of living and the options to address it (i.e., sustainable housing) with households able to make a direct link between having PV and the impact on their energy bills.

The success of PV has been created through various policy developments, government rebates, and industry innovation which have resulted in higher performance at a lower cost. Once the financial tipping point was reached, the floodgates opened in some countries and PV panels went from being a niche sustainability item for hippies living off the gird, to being normalized across the wider housing public [32]. PV panels have shown what can be achieved in a relatively short period of time. This rapid uptake has also laid the groundwork for future technology development and roll outs such as battery storage and electric cars, which are attempting to draw on the successful pathway of PV panels.

PV and battery storage are not without issues. These include questions on the environmental and social impact of mining the raw resources used in the technologies, poor quality products, dodgy PV retailers and installers, issues with intermittent energy loads on energy networks, and ongoing arguments about why governments are continuing to provide financial support (through rebates for capital costs and/or feed-in-tariffs). Despite these challenges, PV continues to grow in popularity as evidenced by evidenced by the ongoing uptake in countries like Australia when financial rebates have been removed[1] [32].

PV panels are seen as an easy "bolt on" sustainability solution, which means households get the benefit of reduced energy bills without having to change the way they use their housing. Outside of environmental and affordability benefits, PV panels are also critical to rapidly improving quality of life for the 733 million people without access to electricity or the 2.4 billion people who still use inefficient and polluting cooking systems [34]. The provision of even a small number of PV panels can not only improve quality of life for people, but can improve wider financial markets for communities [35, 36].

Double-glazed windows are another example, where in select regions of the world there has been significant uptake. In the UK, Europe, and

[1] While the topic of rebates to help deliver sustainability technology or to shift the industry is often a political tension point, often overlooked is the US$5900 billion of subsides provided to fossil fuel energy generators each year [33].

Canada, performance requirements mean most new housing has double glazing at minimum, with trends moving towards triple glazing. In British Columbia, the use of double or triple glazing is often dependent on the region; the south coast uses double glazing more regularly while colder regions are more likely to look for higher performance outcomes and choose triple glazing. As stated earlier, more than 80% of housing in the UK now has double glazing [4]. The uptake of double-glazed windows began in the 1970s when the industry started to establish itself. However, the role of policy and performance regulations is clear with government analysis stating that 'This [recent uptake] is mainly because, since 2006, Building Regulations have stipulated that all windows in new dwellings and most of those that are replaced in older dwellings should be double-glazed' [37, p. 30].

Policy makers have generally struggled with how to deal with existing housing in terms of how much direction governments can impose onto households and their dwellings, especially if such dwellings have been built, bought, or rented prior to the introduction of any sustainability improvement requirements. In addition to regulations for double-glazed windows, there are other examples of where regulation has been able to create improved outcomes. For instance, in 2014, the City of Vancouver introduced Canada's first bylaw with energy upgrade requirements for existing buildings. The City required housing renovation projects to acquire a demolition permit with obligations to re-use and recycle some of the materials. There have also been other notable developments in the retrofit space including the German Energiesprong programme, which now operates in Germany, France, the Netherlands, and the UK and leverages private financing to deliver affordable zero energy retrofits with the borrowed money repaid through the energy savings [22].

For rental units, an increasing number of countries are setting various improved minimum performance requirements any time a dwelling is listed for rent. For example, since 2019, the UK has required landlords to invest up to £3500 in rental properties that have Energy Performance Certificate ratings of F or G in order to improve the quality and performance of the dwelling to at least an E rating when it is next up for lease [38]. It is estimated that this requirement will impact just over 6% of dwellings in the UK. If this approach is successful, it is likely that these minimum requirements could be lifted to capture a wider proportion of the housing market, much like how new housing requirements have been periodically increased. This type of policy aims to address the issue that rental housing tends to be in poorer quality, older, and less sustainable. This is not true for everywhere but is prevalent in countries that have lower amounts of rental stock and do not have incentives for landlords to improve the performance and quality of rental housing (e.g., Australia).

In recent years, there has been more development of alternative mechanisms to improve design, quality, and performance of housing that goes beyond minimum building code requirements. These include "good design guidelines" that set minimum requirements for elements not typically considered within the building code. In Australia, there has been ongoing challenges with delivering good quality design, usability, and performance in the higher density dwelling space. Examples of poor design in apartments in Australia include bedrooms with no windows and poor ventilation. In an evaluation of recently built apartments in Melbourne, researchers found that no high rise apartments (over 16 storeys) met good design requirements, and only 11% of medium rise apartments (6–15 storeys) did [39]. In response to wider issues with apartment design and quality, New South Wales introduced the State Environmental Planning Policy No 65—Design Quality of Residential Apartment Development and associated Apartment Design Guide, and Victoria introduced the Better Apartment Design Standards. These standards set out requirements for things such as minimum requirements for certain room types, minimum amounts of storage, access to certain number of hours of daylight, and even things such as requirements for communal spaces.

Additionally, good design guidelines and regulations are increasingly engaging with requirements around life cycle thinking. This is reshaping how we consider the materials used within our dwellings, moving it away from just the construction phase and towards thinking about designing for longer life, ease of maintenance, and disassembly and re-use at the dwelling's end of life. For example, prefabricated housing is a newer construction technique that is improving material efficiency through precision construction and the ability to have greater control across the construction process. It has been reported that prefabricated housing can reduce the amount of materials/waste in a dwelling and result in shorter construction times which can potentially help to address the undersupply of housing [40].

As part of this increased focus on design, there is a section of the housing market that is demonstrating that you can get improved function from housing without having to increase a dwelling's floor area. At the extreme, the tiny house movement is demonstrating what can be done with very little space. While this is not for everyone (with spaces as small as $7m^2$ and up to $40\ m^2$), it does demonstrate what a focus on design and function can do to help deliver improved functionality in a smaller footprint. This has many benefits such as reducing initial construction costs and the costs from ongoing maintenance and use (such as reducing the need for heating and cooling a larger area). Part of the challenge is that the housing construction industry in many locations is not required to engage with people who have the skills to be able to deliver these types of outcomes. Architects in particular have a critical role to play in a transition to a sustainable housing future [41, 42]. For example, an architect in Melbourne presented a case study of two similar detached houses that were built for a single client on two similar blocks of land in the same location [43]. One of the houses was designed by a draftsperson with the other designed by the architect. The architect argued that their own design improved the function of the dwelling and reduced construction costs; they reduced "wasted" hallway space by 5% which resulted in reduced construction and labour costs by around AU$18,000. Another benefit of using the architect was that the house received approval for construction quicker than the draftsperson's design.

Another trend emerging to improve the design, quality, and performance of housing is smart homes [44–46]. A smart home typically will use a range of internet and wireless connections between devices and appliances to control certain things within the home. This could range from delaying the start of a washing machine until there is sufficient sun to cover the energy required for operating the machine, through to automatically opening/closing windows and blinds and turning on/off heating and cooling systems. Smart homes promise a range of benefits, such as improved energy and indoor air quality performance, lower energy costs, extending the life of appliances, automatically organizing maintenance, and identifying and fixing issues of underperformance [47, 48]. For example, if a PV system is not working or underperforming, a smart home can alert the owner to have the PV system checked. There are examples where people have not realized their PV system was not connected or working for multiple months due to not having the ability to access performance information in real time (or being unable to interpret the data of information they could access) [49]. Some reports cite people missing out on six months or more of renewable energy because they (or someone else) only realized their system was not working after several quarterly energy bills had been issued.

But the potential benefits implications of a smart home go beyond the boundary of the home itself. Energy policy makers in particular are increasingly looking towards what opportunities there may be to control energy loads at a household and neighbourhood scale during certain energy events such as peak energy during a heatwave. By regulating how many air conditioners are operating, energy network operators believe there will be less costs associated with generating peak energy and a reduced amount of blackouts. It is also potentially a way to distribute energy restrictions more evenly across a larger range of households for a smaller period of time, which could avoid rolling blackouts. Recent years have seen notable energy challenges with large scale energy network blackouts during extreme weather events (e.g., Texas, USA). However, there are technical and ethical issues around the smart home (e.g., how does a house operate if the internet go down? or, what happens to your data?) and around allowing energy companies control over what you do, or do not do, within your home. As Maalsen [44, p. 1545] states '[t]he increasing ways in which smart is reconfiguring housing and home means that we need to pay greater attention to the smart home's political, material, social and economic mechanisms and the way these produce and reshape the world'.

In contrast, some innovations are directly pushing back on more technology or a smart home driven approach, and are re-engaging with older ideas of housing design, quality, and performance. For example, the shift towards mechanical heating and cooling has been a more recent shift, with occupants previously taking a more active role in managing heating and cooling on their own. Practices such as opening and closing windows and blinds or sleeping out on porch on a summer evening were key methods to managing warmer months in many parts of the world [50–52]. As we move from active to passive housing, we are losing many of these ways for managing our homes. Oral history research has shown how peoples' practices, especially as they relate to heating and cooling, have changed over time; however, this research also shows that there are increasing examples of occupants re-engaging with active home management practices [53]. Additionally, research has shown that ideas like adaptive thermal comfort show people can be quite comfortable in a much wider range of temperatures [50–52, 54]. There are an increasing number of examples where these more passive thermal comfort options are being prioritized over more active systems. General improvements to design, quality, and performance allow for these types of outcomes.

The role of sustainable housing is starting to move beyond traditional framings of housing and is engaging in the social benefits which such housing can provide. For example, in the UK and New Zealand, there have been various programmes where doctors were able to prescribe energy efficient retrofit to address health and well-being issues for vulnerable people [55]. Or Finland's housing first principle which argues that you give a homeless person a contract to a home, a flat, or a rental flat, with no preconditions. This is arguably a more holistic way of thinking not only about health and well-being but also about housing. For housing, we are increasingly able to measure the social and health improvements such as reduced trips to doctors, less sick days off work, or the ability to tackle chronic conditions. Once measured, we can include these social and health improvements in the wider analysis on the costs and benefits of sustainable housing.

3.4 Conclusion

As a global society, we are facing a critical juncture. Not only do we urgently need to address the climate emergency, there is also a range of growing societal challenges that are negatively impacting a growing percentage of the population. Sustainable housing offers an opportunity to not only make a significant contribution to a low carbon future but also address issues such as poverty and health inequities.

For too long, the push towards sustainable housing has been diluted and challenged by vested interests within current housing regimes around the world. The industry has largely been wanting to continue business-as-usual operations, and would prefer less government intervention and for the "market" to decide what design, quality, and performance outcomes are desired. However, this approach has largely failed, and a new approach is needed if we are to avoid locking in millions more households, and our wider society, into a sub-optimal housing future.

While there are a range of challenges in trying to deliver sustainable housing, the innovations and examples presented in this chapter, and the increasing number of real-world case studies, demonstrate that we have the design, materials, technologies, and construction methods to be doing much more related to improving the design, quality, and performance for new and existing housing. In the next three chapters, we will explore the idea of a sustainable housing transition in more detail and present a range of case studies demonstrating various sustainable housing outcomes.

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