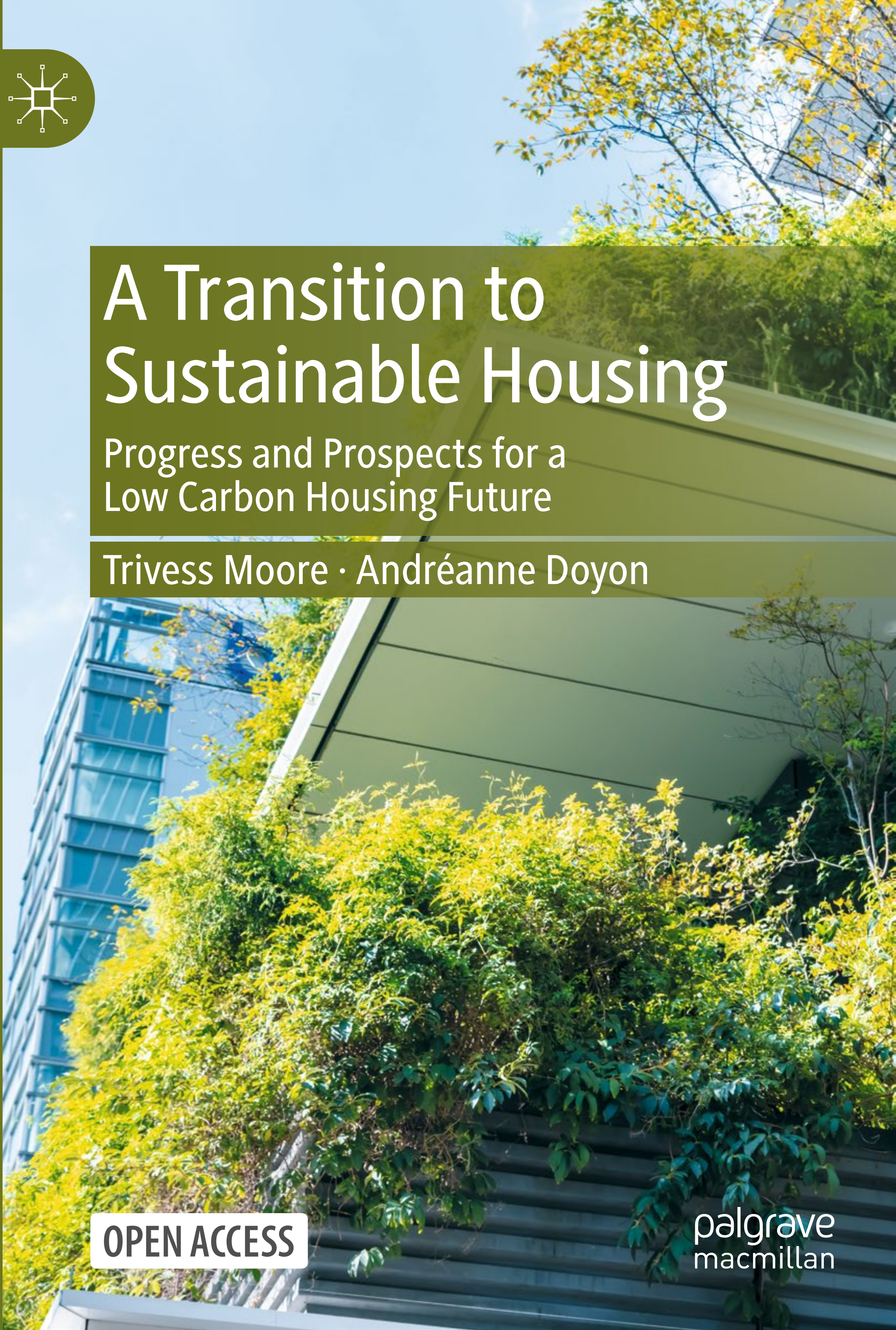
A Transition to Sustainable Housing

Progress and Prospects for a Low Carbon Housing Future

Trivess Moore · Andréanne Doyon



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Trivess Moore
RMIT University
Melbourne, VIC, Australia

Andréanne Doyon
Simon Fraser University
Burnaby, BC, Canada

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Foreword

A transition to sustainable housing makes for accessible, important reading as we face into the climate emergency. The authors, based on contrasting climates and global regions, methodically set out a consistent and well-argued call to action, sprinkled with examples that illustrate the urgency about what needs to be done. Thorough referencing throughout makes this a go-to text, not only for academics and students, but also for a wide range of actors, policy makers, commentators, and interested publics.

The book posits a set of contrasting and often competing/oppositional observations as explanations for (a) why the sustainable housing crisis is even greater than it often appears and (b) why responses are inadequate. Thus, Chap. 1 articulates the juxtaposition of the housing and climate crises and sketches some key elements of the predicament. Chapter 2 draws upon the concept of housing markets, and, specifically, ways in which they fail to deliver on human needs. Alluding to the disconnect between the theory of utility and the idea of sustainable housing as a basic right, the authors explore through the language of building codes, planning systems, and related regulatory mechanisms how markets mediation has largely failed to deliver sufficient shifts towards sustainable housing.

Drawing on the observation that housing occupies (unique) land parcels, and often lasts for 100 years or more, Chap. 3 outlines some ramifications of this for the housing sustainability agenda. Namely, housing might better be seen as social infrastructure rather than private asset, and decisions made around design, materials, technologies, and construction methods are critical for determining a dwelling's quality and performance outcomes and how it will be used by multiple households over a long life. Moreover, putting things right once dwellings are hastily built for an initial occupier is expensive or even impossible. For example, poor dwelling orientation is hard to fix.

Drawing upon their extensive experience working on practical projects evaluating energy efficiency retrofit, the authors present a reasoned case explaining how energy efficient retrofit seems feasible and logical and yet has not happened and is not happening at anything like the necessary rate. They also point to the ways in which housing sustainability presents different problems at varying scales, including the dwelling scale, neighbourhood and city scale and the state, national, and international scale. Another focus for the book draws on the authors' previous work on the rapidly growing corpus of work on socio-technical transitions. Adopting a neutral position, they probe concepts of transitions by expanding on key aspects of the housing and climate emergency debate. The non-linearity of change is a particular focus, as is the multiplicity of competing and often conflicting priorities facing a transition to sustainable and universal housing.

The final chapters together act as a prelude for a call to action, with directions and initiatives set out for guidance. Chapter 7 examines contemporary issues in housing and the climate emergency—technologies of high performing housing, the tiny house movement, shared housing, neighbourhood-scale housing, circular housing, and innovative financing. The prospects for their growth and development are examined in the frame of socio-technical transitions.

In sum, this book is richly referenced, well-informed, replete with case studies, and arranged as an accessible, reasoned call for carbon inequality and provision to be urgently addressed in our housing systems. The vantage point is the edge of the fossil fuel era precipice, overlooking decades of Nero fiddling while Rome is enveloped in the flames of market-based housing systems.

Melbourne, VIC, Australia
3rd March 2023

Ralph Horne

Acknowledgements

Many of the ideas we have explored in this book have been shaped and informed by a lifetime of curiosity around sustainability and the way the world works. However, we largely draw upon the research we have undertaken and discussions with our colleagues over the past decade.

As such, we wish to acknowledge that this book would not have been possible without the support of our current (and in the case of Andréanne—past) place of employment and organizations who have funded our research. In particular, we have had the opportunity to work with some amazing colleagues and we are thankful for their support and the contributions they have made to our research journeys to date.

We are also indebted to Emeralde O'Donnell as our copy editor who not only improved the clarity of our writing, but also challenged us to refine and elevate the key messages of the book. We are also thankful to Palgrave Macmillan for this opportunity and support to publish such a book, and for their patience through various delays in completing the book.

Finally, we are grateful to our families for their support, not only during the writing of this book, but more generally across the various challenges that academic life presents.

Expert Quotes on Book

"*A transition to sustainable housing: Progress and prospects for a low carbon housing future* is a powerful call to action for a global transition to sustainable housing. The authors skilfully lead readers through the current landscape of housing systems, policy, and research, providing the theoretical and empirical guidance—deftly illustrated by a variety of exemplars and precedent studies—to pursue sustainable housing. The book provides beautiful explanations of complex systems and concepts, accessible to anyone approaching the topic for the first time, while also being a brilliant, comprehensive resource for seasoned researchers."

—Dr Lyrian Daniel, *Associate Professor in Architecture University of South Australia; Deputy Director University of South Australia AHURI Research Centre*

"Trivess and Andréanne provide a much needed stocktake of current progress in the transition to sustainable housing. In addition to providing valuable insights on new approaches to buildings and technologies, they also remind us that it's not only about the hightech boxes we live in, but also where we live and how we live. They do not shy away from drawing attention to the limitations of allowing the market to lead housing and construction and they caution against new approaches that could deepen inequalities. They conclude with some insightful recommendations, of which we should all take note."

—Dr Graeme Sherriff, *Reader, University of Salford; Chair, Fuel Poverty Research Network*

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About the Authors

Trivess Moore is a Senior Lecturer in the Sustainable Building Innovation Lab (SBiLab) in the School of Property, Construction and Project Management at RMIT University in Australia. His research relates to housing quality and performance and focuses on the intersection between technical performance, liveability, social impact, and policy. Trivess is also a Trustee of the Fuel Poverty Research Network. Further information about his work and previous publications can be found here: https://bit.ly/3gZ3pAL

Andréanne Doyon is an Assistant Professor and Director of the Planning Program in the School of Resource and Environment Management at Simon Fraser University in Canada. Her current research focuses on urban governance and planning for resilient and climate just cities, sustainable housing, and questions of justice in sustainability transitions. Through her work, she is interested in advancing new approaches and narratives around sustainability. Andréanne is also a Registered Professional Planner and a Member of the Canadian Institute of Planners. Further information about her work and previous publications can be found here: https://bit.ly/3B105Mj

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Housing for a Sustainable Future

1.1 Introduction

As a global society, we find ourselves at a critical juncture: after decades of fragmented and limited action, we are experiencing a climate emergency [1]. In the face of this crisis, our global and individual responses will shape the future, not only for the current generation but also for generations to come. The built environment, which includes the housing sector, is a significant contributor of greenhouse gas emissions and wider environmental impact [2–4]. Globally, the housing sector contributes around 17% of total greenhouse gas emissions and consumes around 19% of total energy demand [2, 3]. Additionally, the housing sector consumes 30–50% of raw and recycled materials for building new housing and retrofitting existing housing [4]. The impact from materials occurs through the use of materials and the generation of waste during construction, through-life (maintenance), and at end of life.

Any transition to a low carbon future must include the housing sector and prioritize provision of sustainable housing [1, 5, 6]. The transition should also acknowledge the disparate outcomes at play for housing with

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some jurisdictions[1] over consuming energy, water, and materials and other jurisdictions struggling even to provide enough basic housing. Furthermore, sustainable housing is about more than reducing environmental impacts; it has a range of benefits including improving occupant health and well-being and reducing living costs at the individual dwelling scale and reducing the need for energy infrastructure at an urban scale [5, 7–9]. Given there are increasing numbers of sustainable houses and communities around the world, we know that we have the technology and knowledge to make sustainable housing possible.

In this book, we use the term housing to mean any type of building or unit that provides shelter or lodging for one or more people. Housing provides people with a place to sleep, eat, relax, be safe, and conduct their daily lives. Throughout the book, we discuss different types of housing, such as detached, semi-detached, and apartments, as sustainable housing is relevant for all housing types. We define sustainable housing as housing with a zero carbon impact that, where possible, contributes to regeneration initiatives that support wider sustainability. Sustainable housing is housing that significantly reduces its life cycle impacts and engages with concepts of the circular economy (e.g., design for disassembly). Our focus on zero and low carbon performance outcomes aligns with the wider international research that argues for significant greenhouse gas emission reductions of 80% or more from key sectors [1, 3]. We use the term low carbon throughout the book to reflect significant performance improvements of sustainable housing compared to a business-as-usual approach. However, it is more than just physical elements or specific technical outcomes; 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).

[1] In this book we use the term 'jurisdiction' to refer to a country, region, or territory over which an authority (e.g., government) can make and enforce policy. While jurisdiction will often be a single country (e.g., Australia), it also refers to a larger collective of countries in some instances (e.g., the European Union).

This book examines the role sustainable housing must play in the transition to a low carbon future. We begin by identifying where we are currently situated in the sustainable housing transition and then explore the opportunities for moving forward, both as individuals, and as a global housing society. There is a significant amount of research on sustainable housing, but much of it is focused on small parts of the wider picture (i.e., single developments or sector-specific data). In this book, we aim to bring together a more holistic picture of sustainable housing and encourage readers to think beyond traditional considerations of housing. The book focuses largely on developed countries due to the similarity of environmental overconsumption of resources, government intervention, and industry scale in the housing sectors, as well as wider social and financial housing issues prevalent throughout these countries. However, we do acknowledge different challenges that developing countries face with their housing and include examples from a variety of contexts. The opportunities for a transition to sustainable housing are relevant for all. While written by academics, we hope that this book is accessible to a wide audience, from researchers, to policy makers, to those in the housing industry, and to households themselves.

This chapter begins by exploring the changing world we face, largely from a changing climate, and what that means for the built environment (Sect. 1.2). We then discuss why housing is important (Sect. 1.3) and what benefits and opportunities sustainable housing can provide (Sect. 1.4). In Sect. 1.5, we reflect on why, given the benefits of sustainable housing, we find ourselves facing ongoing challenges with changing the housing industry around the world. We conclude the chapter (Sect. 1.6) with an overview of each chapter in the book.

1.2 A Changing World

Human activities are creating a climate crisis which will worsen without significant and urgent changes to the way we live as individuals and as a global society [1]. The Intergovernmental Panel on Climate Change

(IPCC),[2] continues to warn that time is running out as we speed towards irreversible outcomes triggered by changes to our natural environment [1, 10–12]. Average global surface temperatures between 2011 and 2020 were found to be 1.09 °C warmer than temperatures between 1850 and 1900, and we are seeing an increase in frequency and severity of natural disasters and weather events (e.g., fires, floods, storms) [1].

The impacts of a changing climate are wide ranging and will likely impact every aspect of our lives. Of increasing concern is not just the damage being done to the natural environment, but the social and financial implications this will have on us as individuals and as a global society, particularly because those most vulnerable in our communities face unequal impacts [13]. This includes the impact on our children and future generations who will bear the brunt of any impacts despite not contributing to the decisions that created the climate crisis. A report released by Save the Children International[3] found that, even under proposed environmental protection and carbon emission plans as set out within the Paris Agreement from 2015 [14], a person born in 2020 compared to a person born in 1960 would experience on average [15]:

- 2 times as many wildfires,
- 2.8 times the exposure to crop failure,
- 2.6 times as many droughts,
- 2.8 times as many river floods, and
- 6.8 times more heatwaves across their lifetimes.

Despite the climate emergency being the most significant environmental, social, and financial challenge of our time, governments, companies, and individuals around the world continue to hesitate on taking the urgent action required to transition to a low carbon future. Most climate and environment scientists have stated that we will need to reduce our global carbon emissions by 80% or more by 2050 to avoid catastrophic climate change [1]. While we have the technology and knowledge

[2] The IPCC is the world's peak body on climate change.

[3] Save the Children International is an aid and development agency dedicated to helping children around the world. It is an independent and not-for-profit organization with 30 national members.

available to move towards and achieve this outcome, governments and other key stakeholders continue to delay making the necessary decisions to do so. The limited outcomes from the 26th United Nation Climate Change Conference of the Parties in Glasgow in November 2021, and the 27th United Nation Climate Change Conference of the Parties in Sharm El-Sheikh in November 2022, demonstrate the inability to deliver a global consensus on a way forward. The lack of consensus also demonstrates that there are still powerful, vested interests involved in key decision making with many embedded stakeholders from the current regime[4] (e.g., fossil fuel industry) having undue influence.

While addressing climate change and greenhouse gas emissions has been a significant focus of many researchers and policy makers, our need for improved sustainability goes beyond just reducing greenhouse gas emissions. We are increasingly consuming goods and materials at faster rates than the world can replenish. Due to both an increasing population and increasing consumption from this larger population, World Overshoot Day[5] is occurring earlier each year. In 1972 the overshoot day occurred on December 25; 50 years later, in 2022, it occurred July 28 [17]. However, this impact is not equal around the word. In 2022, Qatar (10th February), USA and Canada (13th March), Australia (23rd March), and Denmark (28th March) were among the earliest overshoot dates, whereas Indonesia (3rd December), Jamaica (20th December), and South Sudan (25th December) were among the latest. As a global society, we are currently consuming at the rate of 1.75 planets per year, highlighting the challenge we face not only in reducing greenhouse gas emissions but also in living within the means of our planet [17].

Without a strong global agreement to address climate change and other sustainability challenges, there are increasing numbers of individuals, companies, and jurisdictions pursuing actions to move towards what is required for a low carbon future. However, more must be done across the globe to ensure this is a fair, equitable, and efficient transition, and that it does not leave those who are most vulnerable behind.

[4] A regime is defined as the articulation of the paradigm sum of current practices, beliefs, methods, technologies, behaviours, routines and rules for societal functions [16].

[5] World Overshoot Day is a measure of what day we exceed the earths biocapacity.

It is critical that any plans for a low carbon future incorporate the built environment (including our buildings, infrastructure, transport, and cities) [18, 19]. This is not just about what we add to the built environment (e.g., new buildings, roads), but also about what already exists. Sustainability retrofits of our existing built environment will be critical for a low carbon future [20–23].

The need to better consider the design, quality, and performance of our built environment is not a new concept [24]. For example, ideas around sustainable development were popularized in the Our Common Future report [25], which defined sustainable development as 'development that meets the needs of the present without compromizing the ability of future generations to meet their own needs' (also known as the Brundtland definition). This definition considers both limited resources and intra- and inter-generational equity. This definition of sustainable development also tries to balance the potentially competing pillars of the environment, society, and economy. However, this type of development has been difficult in practice within a neo-classical capitalist market that prioritizes financial growth over environmental and social outcomes. Outcomes of sustainable development have not yet matched what is required for a low carbon future.

While the Brundtland definition of sustainable development has been useful for guiding discussion and actions towards sustainability, we argue, as others have over recent decades, that this definition is no longer fit for purpose and will not help us achieve the type of low carbon future we urgently need. When considering that the global population of more than 8 billion (2023) is expected to increase to almost 10 billion by the middle of the century, that natural resources are rapidly decreasing, there is growing disparity of inequity, and that there is the urgency of the climate crisis, it is clear that sustainable development as previously defined and applied is falling short of current and future needs.

Sustainability needs to go beyond the idea of 'sustaining' or limiting environmental impact. Given the current context, sustainability must be regenerative, where we actively work to undo much of the damage we have already created. One simple way to think about this is to look at a tree: a tree provides fresh air, nutrition, habitat, and shade, among other attributes, but it also needs soil, water, and other nutrients to survive and grow. A low carbon future is not only a future that produces significantly less carbon, but also a future in balance with the world's resources so we can achieve a one planet outcome.

In addition to declaring the climate emergency, there have been several other critical global policy developments in recent years. These policies aim to address both environmental and social-equity issues which have been exacerbated in recent decades as the gap between jurisdictions and individuals with and without wealth continues to grow. Chief among these is the United Nations Sustainable Development Goals (SDGs). In 2015 the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development which included 17 SDGs covering a range of issues facing vulnerable populations [26]:

- GOAL 1: No Poverty
- GOAL 2: Zero Hunger
- GOAL 3: Good Health and Well-being
- GOAL 4: Quality Education
- GOAL 5: Gender Equality
- GOAL 6: Clean Water and Sanitation
- GOAL 7: Affordable and Clean Energy
- GOAL 8: Decent Work and Economic Growth
- GOAL 9: Industry, Innovation, and Infrastructure
- GOAL 10: Reduced Inequality
- GOAL 11: Sustainable Cities and Communities
- GOAL 12: Responsible Consumption and Production
- GOAL 13: Climate Action
- GOAL 14: Life Below Water
- GOAL 15: Life on Land
- GOAL 16: Peace and Justice Strong Institutions
- GOAL 17: Partnerships for the Goals

While many of these have some overlap with the built environment, key SDGs for the housing sector include Goals 7, 11 and 12. Many jurisdictions and companies have adopted these goals and are aiming to achieve outcomes by 2030.

What is clear is that a transition to a low carbon future must be about more than environmental outcomes. We must use this opportunity to re-orient our global society to improve social and financial outcomes and close, or even eliminate, the gap in inequities that have continued to grow as the sustainability transition starts.

1.3 The Importance of Housing

Housing is imperative to meet our basic human needs. It plays an important role in providing households with a safe, secure place to live, and it creates opportunities for enhancing social capital outcomes like health and well-being. The importance of housing and the right to adequate housing is enshrined in the United Nations 1948 Universal Declaration of Human Rights. The United Nations states that [27, pp. 3–4]:

> *Adequate housing must provide more than four walls and a roof. A number of conditions must be met before particular forms of shelter can be considered to constitute "adequate housing." These elements are just as fundamental as the basic supply and availability of housing. For housing to be adequate, it must, at a minimum, meet the following criteria:*
>
> - *Security of tenure: housing is not adequate if its occupants do not have a degree of tenure security which guarantees legal protection against forced evictions, harassment and other threats.*
> - *Availability of services, materials, facilities and infrastructure: housing is not adequate if its occupants do not have safe drinking water, adequate sanitation, energy for cooking, heating, lighting, food storage or refuse disposal.*
> - *Affordability: housing is not adequate if its cost threatens or compromises the occupants' enjoyment of other human rights.*
> - *Habitability: housing is not adequate if it does not guarantee physical safety or provide adequate space, as well as protection against the cold, damp, heat, rain, wind, other threats to health and structural hazards.*
> - *Accessibility: housing is not adequate if the specific needs of disadvantaged and marginalized groups are not taken into account.*
> - *Location: housing is not adequate if it is cut off from employment opportunities, health-care services, schools, childcare centres and other social facilities, or if located in polluted or dangerous areas.*
> - *Cultural adequacy: housing is not adequate if it does not respect and take into account the expression of cultural identity.*

Despite housing being a human right, there remain ongoing global issues with the delivery of 'adequate' housing as defined by the United Nations, and housing remains precarious for a large percentage of the global population. For example, the absence of adequate housing has negative consequences for both the overall rates of poverty and the ability to move out of poverty. The United Nations and others report that the number of people living in extreme poverty (living on less than US$1.90 per day) declined from almost 2 billion (or just over 35% of the global population) to 645 million (7.1% of the global population) between 1990 and 2019 [28]. However, this number increased to 738 million (9.5% of the global population) in 2020, the first year of the COVID-19 pandemic, and was predicted to increase as the impact of the pandemic unfolded [28–30]. While the number of people living in extreme poverty has declined over recent decades (notwithstanding the impact of COVID-19), it is estimated that 3.3 billion people around the world still live below the poverty line of US$5.50 per day [30]. It is also reported that climate change is predicted to push more than 100 million additional people into poverty by 2030 [30].

There is a significant overlap between people in poverty and their housing situation. Globally, there were more than 1.03 billion people living in slums or informal settlements in 2018 [31]. The dwellings in these settlements typically do not meet the United Nations definition of adequate housing. Furthermore, there are more than 100 million people without homes [32]. Such outcomes are not limited to developing countries. For example, in Australia, around 3.24 million people (13.6% of the population) are living below the poverty line of 50% of the median income (AU$457 per week for a single adult), including 774,000 children under the age of 15 [33]. In the USA, there were 37.2 million people in poverty (11.4% of the total population) in 2020, which had increased by more than 3.3 million from 2019 [34].

It is not just the provision of housing that has impacts for households, but also the design, quality and performance of the dwelling. For example, a growing body of evidence demonstrates relationships between housing design, quality, and performance and the impacts on the social and economic well-being of households [7, 35–43]. Good dwelling design, quality, and performance can elevate a range of social benefits, while poor design, quality, and performance can lead to significant negative outcomes for households. This is not just an issue in developing countries but also in developed countries. For example, in New Zealand [44] it was found that:

- around half of dwellings lacked adequate insulation in the roof space,
- around half of dwellings do not have mechanical extract ventilation in the bathroom,
- over half of dwellings have no heating in bedrooms,
- 1 in 5 people said their homes were always or often colder than they would like in winter,
- around 1 in 4 people heated their bedroom every or most nights in winter, and
- around 1 in 3 people reported problems with damp and mould in their homes.

These negative outcomes are not just problematic for the individual household, but also have implications for policy makers and the wider community. For example, the cost of people living in the bottom 15% of United Kingdom (UK) housing costs the National Health Service £1.4 billion per year [45]. In many cases, vulnerable households have housing impacts exacerbated by a legacy of poor quality housing [46]. Furthermore, housing contributes to the accumulation of larger scale issues such as air quality. The United Nation reported that in 2016, 90% of urban residents were breathing polluted air that failed to meet World Health Organisation air quality guidelines [31]. Low- and middle-income countries are more severely impacted.

The design, quality, and performance of housing also impact how affordable a dwelling is to live in. Housing affordability is increasingly becoming a global issue. In many jurisdictions, the cost of both purchasing and renting a home has increased rapidly in recent years, an increase that is faster than the increase in wages. The wider housing research and policy community define housing affordability using the 30% threshold where housing is considered unaffordable when a household is spending more than 30% of their income on a mortgage or rent. Globally, there in an increasing percentage of households struggling with housing affordability and in many cities low to middle-income households can no longer afford to buy dwellings [47–50]. However, the traditional way of thinking about housing affordability as capital costs is likely masking a range of other housing and financial challenges, such as the cost of maintenance and daily living. The design, quality, and performance of a dwelling influence how much energy and other resources are required. Poor design, quality, and performing housing uses significantly more energy, water, and other resources compared to sustainable housing (see Sect. 1.4).

The cost of energy, for example, has rapidly increased in many locations making housing costs increasingly unaffordable. This has resulted in a growing number of households being in or near fuel (or energy) poverty [43, 51–58]. Fuel poverty is where a household cannot afford to pay for energy to meet basic living requirements (such as maintaining thermal comfort within a health range) or where the household self-rations energy consumption or makes other trade-offs to ensure energy bills can be met [55, 59]. This is not just an issue confined to developing countries or housing slums, but is a growing issue in jurisdictions like Australia, Europe, and the UK. Fuel poverty is not only about the economics of paying for energy consumption, but if a household is not able to consume sufficient energy to meet their basic needs such as heating and cooling, it has implications on their health and well-being. Research has found that renters and low-income households are predisposed to experiencing issues of fuel poverty, but it is an issue increasingly impacting other socio-economic groups [57, 58, 60].

Not only do we need to address the critical social issues touched on above, we need to do so within the context of a growing population. How and where to house people is a pressing issue for policy makers, planners, and wider communities. It is not just a matter of providing more housing, but making sure we do so in a way that is equitable, just, and ethical [61, 62]. The promise of sustainable housing not only addresses the climate emergency and resources used for construction, it also addresses wider social and financial issues.

1.4 The Promise of Sustainable Housing

The good news is that the housing sector is considered 'a low hanging fruit', which has the potential to improve environmental, social, and financial outcomes significantly for little, if any, additional costs. This is why the housing sector has been identified as a key sector within a range of local, national, and international strategies to move towards a low carbon future [3, 63–68]. There is an increasing number of examples from around the world that demonstrate the critical role that sustainable housing will play in an equitable and low carbon future. This will be discussed further in Sect. 1.5 and case studies can be found in Chaps. 6 and 7.

These real-world case studies, and an emerging body of research, demonstrate there are significant benefits for households, the wider community, the construction industry, and policy makers that can be delivered through significantly improving the design, quality, and performance, and sustainability of our new and existing dwellings. Such benefits include reducing environmental impact (during the construction, occupation, and end of life phases), reducing costs of living, improving occupant health and well-being, improving household and community resilience, creating a more stable energy network, and mitigating some of the social issues noted earlier [8, 47, 69–71].

For example, researchers have found that poor design, quality, and performance of a dwelling can significantly reduce occupants' liveability, health, and well-being, and that improved design, quality, and performance can significantly enhance it [5, 8, 42, 43, 45, 60, 69, 70, 72–83]. Health benefits from improved design, quality, and performance include a reduction in respiratory disease, improved sleep, and a reduction of the severity of issues like arthritis, colds, coughs, and other milder ailments [7, 8, 37–39, 70, 72, 81]. Those who are most vulnerable, such as children, the elderly, or those who are low income, are often disproportionately impacted by negative health outcomes from housing. However, these groups also gain the most from significant design, quality, and performance improvements. Research from Boston (USA) found that a cohort of public housing tenants in sustainable housing experienced a reduction of 57% in self-reported health issues compared to standard public housing [84]. As noted earlier, this links to wider community costs and benefits, such as the cost implications for the health care system [45].

Improvements to the design, quality, and performance of a dwelling also results in reducing the need and usage of mechanical heating and cooling [9, 85]. There are some sustainable houses in certain climate zones that can provide year-round thermal comfort with no mechanical heating and cooling. A reduction in heating and cooling requirements has multiple benefits, including reducing energy consumption and therefore operating costs. This helps improve affordability outcomes for households. In an increasing number of examples, the reduction of energy requirements for heating and cooling, combined with other design and sustainable technology inclusions (e.g., renewable energy), has eliminated day-to-day bills related to energy and water costs. The 'smart' homes innovation is promising to elevate these benefits of more energy and water efficient homes. Integrating technologies and appliances places the household at the centre of a dynamic two-way interaction with the wider urban and energy environment and maximizes environmental, financial, and social outcomes [86–88].

By reducing living costs, sustainable housing can save households hundreds, if not thousands, of dollars each year. Research in Australia, for example, found that households in a high performing zero energy dwelling could save more than AUD$90,000 in energy bills over the assumed 40-year life of that dwelling [6]. This potential economic saving is likely to be even greater with the price of energy increasing more rapidly than previously predicted. The economic benefits do not just stop there. If owners re-invested energy savings into their mortgage payments, they could offset any additional capital costs associated with sustainable design which would reduce the interest paid on the home loan by more than AUD$50,000 across the loan's life and result in paying off the house up to four years sooner. Research from the UK found that households in energy efficient housing were less likely to be in mortgage payment arrears than those in energy inefficient housing [89].

These types of benefits are also available when undertaking a largescale sustainability retrofit of existing housing. Even small retrofits such as draught sealing, installing ceiling fans, and other internal changes can reduce the requirement for mechanical heating and cooling and significantly reduce energy costs for households [21, 90, 91].

Sustainable housing also adds financial value at the point of sale or lease. Research from around the world finds that improving design quality and performance can result in an added sale value of 15% (or more) [7, 9, 92–97]. Some research has found that the added resale value from sustainable design and technology elements is greater than the cost of investment, such as with the case of heat pumps in the United States of America (USA), which were found to have an installation cost of around US$8000 but result in an added resale value of US$10,000–$17,000 [97]. In addition, research has found that houses with improved design, quality, and performance were on the market for less time [98]. There are also financial benefits when a sustainable dwelling is part of a wider sustainability focus. For example, access to local amenities such as parks or having a view can add a further 15% (or more) to resale value [99–103]. Recent research from Sydney, Australia, even found that an increase of tree canopy on the street could increase sale values of property by AUD$33,000–$61,000 [104].

The importance of what is around the outside of a dwelling is key for any discussion, not only for how to deliver sustainable housing, but also as part of a wider urban push towards improved sustainability. For example, increasing tree coverage and other natural features around dwellings can significantly reduce heat island impact (where excess heat is trapped within the built environment). An urban area with high coverage of trees or nature can reduce ambient air temperatures during extreme weather days by 15 °C or more [105–108]. A reduction in wider air temperature will keep dwellings cooler which reduces the need to use air conditioning and the associated costs for energy consumption. This can then have wider financial, social, and environmental benefits for the energy network by reducing the need to provide energy in peak weather events (which can be costly) and reducing issues such as energy blackouts due to high demand. It also impacts on peoples well-being. Research from Canada's heat dome event in 2021 found there was an increase of community deaths by 440% due to the extreme conditions and that those who died had lower greenness within 100 m of their dwellings [109].

The good news is that an increasing amount of research and real-world examples of sustainable housing have demonstrated that it is possible to significantly improve the design, quality, and performance outcomes of new and existing housing within our current building practices and existing design, materials, technologies, and construction techniques (see Chaps. 6 and 7 for case studies). Notable case studies which have emerged over recent decades include the Vales Autonomous house and BedZED in the UK, Circle House in Denmark, Nightingale Housing, Lochiel Park and Cape Paterson ecovillage in Australia, and zHome in the USA [110–116].

Many of these examples, and those presented in later chapters, show that sustainable housing has a range of benefits beyond just improving environmental outcomes and it has the capacity to address a number of the wider social equity and justice concerns touched on earlier in the chapter [8, 47, 57, 70, 117]. However, delivering these sustainable and ethical outcomes is currently easier said than done. Barrett et al. [61, p. 3] state that 'ethically oriented cities will ultimately be the ones that succeed in enhancing resilience, improving quality of life, creating productive economics and reducing the environmental burden for all residents'.

1.5 The Current System

While the benefits of sustainable housing are clear within a research context, there is only a small percentage of the housing market that currently achieves design, quality, and performance outcomes in line with what is required for a low carbon future. The low uptake, despite the benefits such housing provides, points to market failures [118]. With a 'perfect' neo-classical market, the belief is that if housing consumers or the housing construction industry sees value in improving the design, quality, and performance of the housing stock, consumers or building stakeholders will drive such improvements [6]. However, this is not occurring. For example, more than 80% of new dwellings in Australia are built to only meet minimum standards and only 1.3% of all new housing in the UK was built to the Energy Performance Certificate rating 'A' between 2020 and 2021 [19, 119]. This wider market structure has been challenged within the environmental economics and broader social and sustainability literature [1, 3, 6, 9, 19, 62].

Due to these market failures, governments have introduced, and then periodically revised, minimum design, quality, and performance requirements for new and existing dwellings. The housing construction industry is often resistant to the introduction or improvement of these regulations, claiming that such requirements create 'red tape' that adds time and costs to construction or renovations which is then passed onto consumers and further adds to affordability issues [6, 120]. They also often state that they are delivering the type of design, quality, and performance of housing that consumers want.

The introduction of minimum building design, quality, and performance requirements by many jurisdictions over recent decades has been shown to be effective at lifting the bottom of the market and improving sustainability outcomes [65]. A range of studies has found that building energy codes have improved energy performance in housing by up to 20% (or more) [121, 122]. Despite the argued lack of progress towards the type of sustainable housing we will need to ensure a low carbon future, there has been a surprisingly long policy history in some jurisdictions with minimum performance requirements introduced into building codes as early as the 1940s [123, 124]. In many cases, these minimum requirements do not yet require outcomes that align with a low carbon future or with our earlier definitions of sustainable housing [125, 126]. There are a small, but increasing, number of jurisdictions who have made more significant progress in this space (e.g., California, the European Union), as will be discussed in more detail in Chap. 2.

There is also a range of other policy mechanisms which have been implemented in different jurisdictions in recent years. Of note is the mandatory disclosure policies that require dwelling owners to provide the energy or sustainability information of their property to be provided at point of sale or lease [127]. The intent of such a policy is to provide potential purchasers or renters with more information about their housing choice, and an incentive for the current owner to consider and undertake retrofit activities that would improve the rating and (ideally) realize increased financial value.

Additionally, planning schemes in many jurisdictions have also been important for driving sustainable housing outcomes, either when minimum building code requirements fall short or as complementary measures to help deliver enhanced outcomes [128–131]. For example, design guidelines at the dwelling or neighbourhood level and other mechanisms such as creating 'zones' have been used to some success in various jurisdictions.

Despite these approaches, there is an urgent need to do more to transition to a low carbon future. This book unpacks many of the ideas touched on in this chapter and explores them in more detail with a key focus on how we can equitably scale up the delivery of sustainable housing as part of that low carbon transition.

1.6 Overview of the Book

Clearly, as a society, we find ourselves at a critical juncture in relation to many critical environmental, social, and financial issues. How we address these issues over the coming decades will determine what type of future we create and what type of world we leave for future generations. This book starts from the position that we must urgently transform our housing to become more sustainable, not only from an environmental perspective but also to enhance social and financial outcomes for households. If we delay in making the changes necessary, we will be locking in substandard housing and impacts on households for decades to come.

A transition to low carbon housing is going to require more than just incremental change to housing design, quality, and performance. This book aims to challenge policy makers, planners, housing construction industry stakeholders and housing and urban researchers to rethink what housing is, how we design and construct our housing, and how we can better integrate impacts on households to wider social policy development.

In Chap. 2 we explore how we are broadly providing housing currently around the world and look at how multiple market failures have resulted in housing design, quality, and sustainability being undervalued by policy makers, the housing construction industry and housing consumers. We discuss how building codes, planning systems, and a range of alternative mechanisms have attempted to address these market failures.

Chapter 3 further explores a number of the key points raised in Chap. 1 and focuses on why we are at a critical juncture where we need to make urgent changes if we are to provide sustainable housing to help achieve that low carbon future. We explore how this is not just about addressing environmental issues but also an opportunity to address a range of other social justice and equity issues which have been exacerbated by rapidly spiralling housing unaffordability and design, quality, and performance issues around the world.

Following this, Chap. 4 presents the sustainable housing challenge and presents a number current and future challenges preventing a sustainable housing transition. We look at these changes across a number of different scales include the dwelling scale, neighbourhood and city scale and the state, national and international scale and discuss what these mean in the context of a sustainable housing transition.

In Chap. 5 we present an overview of sustainability transitions theory as a framework which could help us facilitate a transition to a sustainable housing future. We explore the theory including recent sustainable housing transitions research. In doing this, we identify a number of socio-technical dimensions which we argue are important for addressing if we are to create deep structural changes to enable a wider sustainable housing transition.

These socio-technical dimensions are then discussed in detail in Chap. 6 where we define the dimensions and explore the contrast of how they are addressed by the current housing regime and sustainable housing niche. We provide short examples to demonstrate how these dimensions are being addressed in practice.

Building upon this, Chap. 7 presents six key sustainable housing themes: high performing housing, small housing, shared housing, neighbourhood-scale housing, circular housing, and innovative financing for housing. We highlight how these themes are challenging the existing regime and discuss how the theme and specific case studies are demonstrating the socio-technical dimensions.

We then reflect in Chap. 8 upon these case studies, and the key discussions and evidence from the earlier chapters of this book, to discuss the sustainable housing transition including where we are placed in that transition, potential pathways forward and challenges that still need to be addressed. We then reflect on the types of innovation across policy, practice, and research required to help facilitate the sustainable housing transition.

In Chap. 9, the final chapter of the book, we go back and revisit the core ideas woven throughout and summarize the current situation we find ourselves in relation to the provision of housing which is not going to meet our environmental or societal needs moving forward. We discuss the prospects for change and explore where that change needs to occur. We finish the chapter with some concluding reflections.

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2

Current Housing Provision

2.1 Introduction

In Chap. 1, we explored the climate emergency and the role the housing sector plays as a significant contributor to greenhouse gas emissions and other environmental impacts (e.g., material consumption). We also talked about the importance of sustainable housing for environmental, social, and financial benefits it can provide. The evidence is clear that sustainability can improve several critical issues facing the housing sector, households, and policy makers. We also presented an overview of the current system of housing provision, discussing that addressing deeper structural issues within this system is important if we are to transition globally to a low carbon future.

In this chapter, we explore current housing provision in more detail and outline how we have arrived at the current way of 'doing' housing, including the governing, financing, planning, designing, building, and habitation of housing. We start the chapter by discussing the market failures of housing and neo-classical market approaches that are not suitable for providing the type of sustainable housing required for achieving a low carbon future (Sect. 2.2). To address this, the use of policy by various levels of government has been a critical driver of housing design, quality,

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and performance. However, many sustainability advocates argue that these policies have been slow to improve and do not go far enough, given the current climate emergency and other housing issues seen around the world. We discuss some of these key policy mechanisms, including setting and improving minimum performance requirements in building codes (Sect. 2.3), using planning systems to require additional sustainability standards (Sect. 2.4), and developing financial and other alternative mechanisms (Sect. 2.5). This sets the context for later chapters where we explore the range of challenges facing the housing sector and discuss current best practice in sustainable housing and policy.

2.2 The Market Failure of Sustainable Housing

Globally, the housing construction industry largely operates under a neo-classical economics framework—a framework which has guided societies and industries around the world for many decades [1–4]. Neo-classical economics theory states that competition in the market benefits both consumers and industry which ensures efficiencies between supply, demand, scarcity, and cost [5–7]. Thereby, this competition reduces the requirement for government intervention as industry and consumers will determine what the best outcomes are including what products, materials, and services are valued and desired. This idea of 'competition' and the need to innovate to find cost efficiencies has reinforced the narrative the housing construction industry uses to advocate for fewer (and certainly not more) regulations.

Opponents of regulations that set requirements for quality and sustainability (among other outcomes) claim that these regulations create 'red tape' which adds time and cost to developments which are passed onto consumers and create further financial challenges in an already unaffordable housing market [8–11]. It is also argued that regulation does not only impact the bottom end of the housing market, but also stifles the ability of companies to innovate when the innovation does not conform to regulations. Therefore, in these arguments, consumers miss out on two fronts: it adds costs but also constrains what the industry can delivery.

Instead, opponents of regulation suggest that consumers will use the competition of the free market to decide what types of housing they want built, where they want it built, and at what quality and sustainability level. This means that if someone wants a large house, they can have a large house as long as they have the money. If they want granite benchtops in their kitchen, they can have them. And if they really want extra insulation, solar panels, double-glazed windows, and passive solar performance, they can have it. But consumers must ask for these things *and* be able to pay for them.

This thinking is based on three critical assumptions about consumers: (1) that consumers make rational decisions, (2) that consumers make decisions that maximize the outcome for themselves, and (3) that consumers make these decisions independently, based on complete information [2, 12]. These assumptions are contested within the environmental economics and broader social and sustainability literature [13–16].

We know that consumers often have other motivations distinct from self-interest and profit maximization, which are part of the choice process, or have a range of constraints impacting their decision making. Yet, these realities are not captured in the above assumptions and consumers rarely have complete information when making choices [17–21]. For example, the decision to buy a dwelling is limited to the existing dwellings available for purchase at that point in time or finding land to build a new dwelling (or via knock-down rebuild), which itself is limited to what is available or already owned. This decision is also constrained by budget. Similar constraints apply for renters. In many countries, there is currently an undersupply of housing, making it even more competitive or challenging for those wanting to buy or rent property [22, 23]. All this means that housing consumers face a constrained choice, even before other factors like improved sustainability are considered and therefore the market is not operating as the theory about the free market suggests.

This neo-classical market framework has enabled significant wealth accumulation by key stakeholders in the housing construction industry at the expense of housing quality, affordability, sustainability, and social outcomes (see Chap. 3). It is not just key stakeholders in the housing construction industry who have made significant profits from construction, but also governments. Governments are heavily dependent on construction in many parts of the world. The health of the housing construction industry is intrinsically linked to different levels of government, as it is a key determinant of economic measures like Growth Domestic Product and provides significant income for governments via development fees and property and land taxes. We have seen evidence of this with governments' responses around the world to the Global Financial Crisis in the late 2000's and COVID-19 recoveries (from 2020 onwards) where infrastructure and building projects have been key pillars of economic and social recovery. However, this can also be seen as a catch-22, where governments have found themselves wanting to make housing more affordable and accessible to all, but knowing that any decrease in housing value will impact their property income and the broader health of the economy. It is a tightrope that governments have been walking for decades and the loser is often the consumer; we are seeing the price of housing for purchase or rent rapidly increase in many jurisdictions around the world, often faster than the increase in wages and often without any measurable improvement in housing quality, sustainability, or even access to nearby amenities.

As explored in Chap. 1, sustainable housing has a clear range of benefits. In addition to providing more basic safety and security that housing entails, sustainable housing can reduce environmental impacts, reduce living costs, and improve health and well-being [24–26]. If we accept the 'rational' consumer assumed by the industry and many policy makers, we should expect to see consumers demanding improved sustainability outcomes for new and existing housing. However, around the world, we have seen that consumers are generally not engaging with sustainability beyond what is set in minimum performance standards unless there is significant financial incentive for them to do so (e.g., residential solar rebate programmes, mandatory disclosure of building performance programmes). For example, research of the Nationwide House Energy Rating Scheme in Australia found that from 2016–2018 almost 82% of new detached housing was built to meet only the minimum building code requirement, with only 1.5% built to the economic and environmental optimum (higher) performance [27]. From 2019 to July 2022, this had fallen to 1.4% of new housing [28] despite it corresponding to the period of time where significant public, industry, and policy discussion was occurring about a likely increase to minimum building performance requirements that were announced in August 2022.

Some jurisdictions are delivering a much higher percentage of new dwellings closer to the technical performance outcomes required for a low carbon future. For example, data from the UK found that, while there was only around 1.3% of all new housing built to the Energy Performance Certificate rating A across 2020–2021, most new houses are achieving an Energy Performance Certificate rating B (Fig. 2.1). While this might seem like a good outcome, especially in comparison to Australia, the design, quality, and performance of new housing in the UK is still being criticized for being insufficient to respond to the climate emergency [9]. Additionally, with new dwelling construction only representing a small percentage of the overall stock in the UK, the more significant issue is the poor design, quality, and performance of existing housing which primarily have ratings of D or worse (Fig. 2.2).

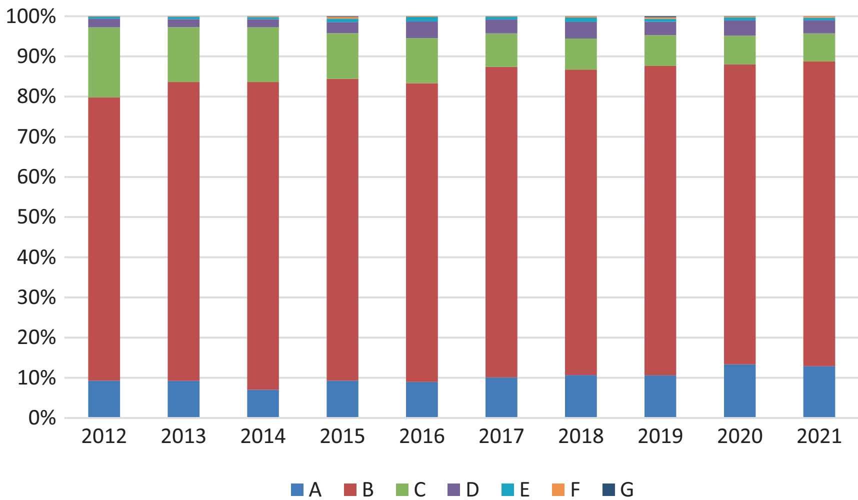

Fig. 2.1 Energy Performance Certificate ratings for new housing in the UK from 2012–2021. Energy efficiency grades from A (best) to G (worst) [29]

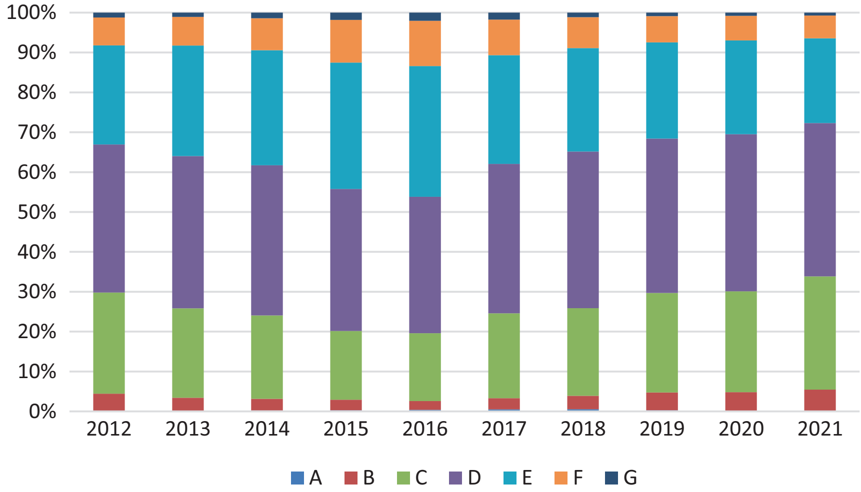

Fig. 2.2 Energy Performance Certificate ratings for existing housing which undertook an Energy Performance certificate in the UK from 2012–2021. Energy efficiency grades from A (best) to G (worst) [30]

The push by some key housing construction industry stakeholders and policy makers to leave housing quality and performance 'to the market' assumes that consumers can access and understand the design, quality, and performance information of dwellings. This has largely been found to not be the case, both in terms of access to such information as well as the understanding of what it means [21, 31].

There are some notable attempts to provide housing customers improved information about the design, quality, and performance of housing to address market information gaps [32]. For example, mandatory disclosure of building performance, which typically requires all houses being sold or rented to have an energy or performance rating, are among some of the longest running housing information programmes. Such programmes include the Energy Performance Certificates across the European Union (EU) and UK and the Civil Law (Sale of Residential Property) Act 2003 in the Australian Capital Territory (Australia) [33, 34]. In some of these jurisdictions, there is now more than 20 years of data and research is increasingly focusing on understanding the influence of the provision of information in these jurisdictions. Largely, the evidence suggests that the provision of easy to understand, verifiable and independent information results in positive outcomes across a range of different metrics for housing consumers such as driving the uptake of energy efficiency retrofit.

Improved information for housing consumers is translating into an improved willingness to pay for sustainability in some jurisdictions. For example, housing consumers across different jurisdictions put a sale or rental premium of up to 15% or more on higher quality and performing dwellings [35–44]. However, positive sale or rent value is not universally found in the research. For example, in Northern Ireland, researchers found that dwellings with higher Energy Performance Certificates were not more likely to increase in sales price [45]. In Chile, consumers associated higher ratings with higher prices which resulted in an unwillingness to pay for improved outcomes [46].

Beyond the impact on sale or rent price, improved information about dwelling quality and performance has been found to enhance opportunities for consumers to undertake retrofit activities or seek out higher performing dwellings which would reduce their cost of living and improve other outcomes such as thermal comfort [47–50]. For example, Sweden is one jurisdiction with an early introduction of the EU Energy Performance Certificate requirement where owners of multifamily dwellings were required to obtain a certificate before the end of 2008. With the certificates lasting ten years, there has been a significant number of dwellings in Sweden that have had a second rating completed. Von Platten et al. [51] analysed the first and second round certifications and found that energy performance in existing housing had improved and that improvement was greater in rental (private and social) rather than owner-occupied dwellings. In a study surveying homeowners across 12 EU countries, Charalambides et al. [50] found Energy Performance Certificates played a role in renovation decisions as well as rent/buy decisions, but the results of the influence varied significantly across jurisdictions. The authors found that, for those who had already renovated their homes, 59% said the information played a very important role in undertaking the renovation and 20% said the information was somewhat important. Across the emerging body of research there seems to be a positive association with improving housing quality and performance and understanding the value of this.

There has also been research exploring the role language and key intermediaries, such as real estate agents and builders, play in educating consumers [52, 53]. Hurst [19] explored how the language used by real estate agents advertising houses for sale in Melbourne (Australia) engaged, or did not engage, with sustainability. Analysing more than 150,000 advertisements from 2008–2015, Hurst found that only around one in five houses had some mention of sustainability. While this percentage slightly increased across the analysis period (up to one in four), Hurst was critical of the way sustainability terms were being used. Often, sustainability was used to elicit a feeling of 'home' rather than have more meaningful discussions. For example, 81% of the advertisements contained no key words about energy efficiency and another 15% only contained one key word. Hurst [19] also found that, where sustainability was discussed, it was often placed in the middle of the text, while consumers are more likely to remember the first and last parts they read. He argues that the lack of emphasis placed on energy efficient characteristics 'has the potential to dilute the importance of reducing energy consumption in housing and retard market acceptance'. (p 196).

It is not only real estate agents who have a critical role to play in disseminating sustainability information; the practices of the housing construction industry itself are just as critical [54]. Warren-Myers et al. [21] analysed the 30 largest builders of detached homes operating in Australia to see how they communicated on their websites about housing energy efficiency and performance. Only two thirds of builders mentioned energy rating requirements, while half stated that the regulated 6 star minimum (0 worst–10 best) was part of their individual standard despite it being legally required. Furthermore, the researchers found that, in many cases, the builder's communicated information about the 6 star minimum in misleading ways. For example, there were multiple examples where websites presented a visual representation of stars, but with only 6 stars rather than 6 out of 10 (the maximum). This was deemed as misleading 'due to semantic confusion' and was arguably in breach of Australian consumer laws. In earlier research, it was noted that, 'the lack of information relating to sustainability provides evidence for why consumers demonstrate little engagement in the sustainability agenda when entering the building process' [52, p. 35].

This lack of consumer and stakeholder understanding about sustainable housing is not just limited to the dwelling itself, but also broader considerations of how the house is impacted by, and impacts, wider sustainability. For example, research by Ambrose [55] finds that many people do not think about how the energy they use in their home is generated.

While these information programmes and intermediaries have been recognized as playing an important role in trying to improve understanding and engagement with sustainability in housing, there is an ongoing challenge that many consumers are not responding, or are unable to respond, to what improved performance of their housing means for them, society, or the environment. Consumers are responding to what is being provided or what they have known or experienced previously (i.e., social norms). Clearly, there continues to be a market failure occurring in relation to sustainable housing. Research that has asked what consumers look for in housing continues to identify elements such as price, location, number of bedrooms and bathrooms, and the quality of the kitchen above considerations of sustainability [19].

This market failure is not new. To address this issue, governments around the world have been trying different policy levers to improve the quality and performance of housing, including the aforementioned mandatory disclosure schemes. By far, the most common policy approach has been the setting of minimum performance requirements within building codes. There has been a long policy history in some jurisdictions with energy efficiency and performance requirements in an attempt to improve the bottom of the market, while other jurisdictions have only engaged with this approach in more recent years [56]. This is explored in the following section.

2.3 Building Codes

The first building codes emerged in the 1940s and they were slowly introduced in many developed countries over the following decades. They are now a critical mechanism for addressing dwelling quality and performance [56–59]. Early iterations of building codes for housing were developed to address minimum levels of safety, quality, and performance for both the construction and occupation phases of the dwelling [60, 61].

Building codes are regulatory documents developed by governments, often in conjunction with peak housing construction industry stakeholders. The codes outline what can, and cannot, be done in relation to design, materials, technology, and construction methods. Typically, building codes are either prescriptive or performance-based. Prescriptive regulations involve a detailed requirement for each element (e.g., staples shall be not less than 1.98 mm in diameter), whereas performance-based regulations provide more overall requirements (e.g., residential buildings shall be equipped with heating facilities capable of maintaining an indoor air temperature of 22 °C). In recent years, there has been a shift away from prescriptive codes to allow for flexibility and innovation and to account for complexities within buildings and across different building sites [59, 62].

In locations with mandatory building codes, someone who wants to build a new dwelling, or undertake significant renovation of an existing dwelling, would need to demonstrate compliance with the codes as part of any planning and construction approval process. This is typically demonstrated through a 'deemed to satisfy' approach (essentially, a box ticking exercise to ensure key requirements are met and that evidence can be provided to support those requirements) or through computer modelling to demonstrate that overall performance outcomes are met.

Figure 2.3 shows the overall modelling energy loads required for heating and cooling across different cities in Australia. This is set through the Nationwide House Energy Rating Scheme, which is a framework for evaluating the thermal performance of housing on a scale from 0 star (worst natural thermal performance) to 10 stars (best natural thermal performance, requiring virtually no mechanical heating and cooling) and links to the National Construction Code to demonstrate compliance with minimum performance requirements. Since 2010, the minimum performance requirement was to achieve a 6 star standard, which was improved to 7 star from 2023.

The energy shortages of the 1970s were a key turning point for the consideration of energy and sustainability within building codes [56, 64]. Leveraging the wider focus on improving energy consumption and

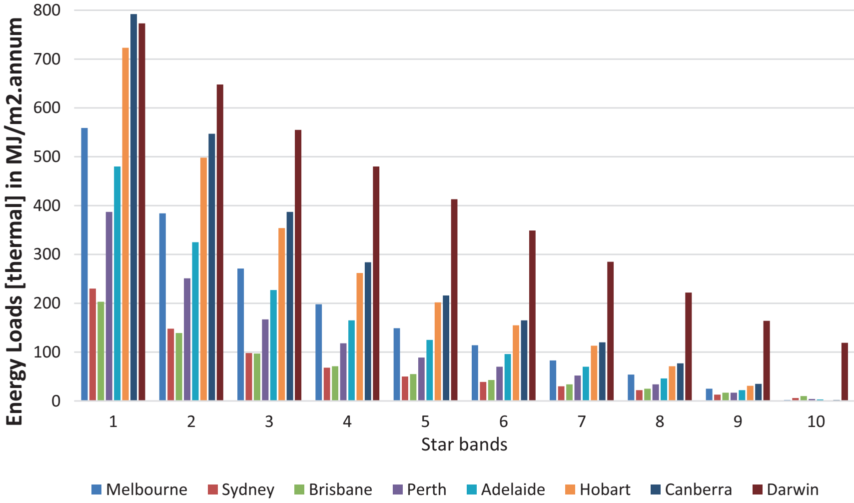

Fig. 2.3 The Australian Nationwide House Energy Rating Scheme star bands and energy load requirements [63]

efficiency, building codes started to expand beyond safety elements to include minimum performance requirements for elements such as energy, heating, and cooling (thermal performance), lighting, water, and other sustainability considerations. The use of regulation to improve sustainability in housing was, and still is, seen as a way to start to address broader market failures, ensure consistency, and reduce risks, uncertainties, and confusion over requirements [33, 65–68].

The inclusion of energy and sustainability elements within building codes (sometimes referred to as building energy codes) are increasing, but are still not universal. The International Energy Agency reported that, in 2020, there were 85 countries with mandatory or voluntary building codes that contained specific energy requirements and another eight countries with codes in development. There were also a number of other jurisdictions (i.e., states or provinces) with building energy certifications (either mandatory or voluntary) [59]. However, globally two in three countries lacked mandatory building codes with specific requirements for energy, with many of these being in developing countries where some of the largest growth in residential buildings is occurring [59]. Where they have been implemented, mandatory building codes with energy and sustainability requirements have been found to be a critical mechanism for reducing energy consumption and greenhouse gas emissions from the housing sector. A range of studies has found that building energy codes have improved energy performance in housing by up to 20% (or more) [59, 69, 70].

The introduction and development of building codes that address minimum performance requirements has happened sporadically and without international coordination. In most cases, each jurisdiction has developed its own requirements and this has resulted in significant variances in what is included, or excluded, from such codes. There have also been periods of more significant development (see examples below), but for the most part any revision of building code minimums has happened through subtle tweaks rather than significant steps forward. These requirements can also be quite challenging to change once set. In some locations like Australia, minimum performance requirements were changed in 2010 and were not significantly revised again until 2023, demonstrating how slow some jurisdictions have been to embrace or improve sustainable housing requirements.

While minimum dwelling design, quality, and performance requirements have been improving in many developed countries over recent decades, they remain short of what is required for a transition to a low carbon future and there are calls for further innovation that better aligns with the housing future we will require [31, 59, 67]. Some have also cautioned against the reliance on building codes as the only answer. For example, Cass and Shove [71, p. 1] argue that codes and standards are increasingly leading to outcomes that are 'disconnected from changing user needs'. They say that because the term 'standards' implies it is a good thing, it creates an industry norm and may result in stifling further innovation beyond the minimums.

There are, however, examples that have emerged over the past two decades which have aimed to go beyond the standard approaches to delivering housing performance.

2.3.1 Mandatory Codes

Collectively, the EU has developed a number of policies related to housing and energy efficiency that guide Member States, including *Directive on the Energy Performance of Buildings* (2018/844/EU) (initially Directive *2002/91/EC*, but updated several times since its introduction) [72]. The latest version of these policies sets regulatory requirements for Member States to ensure that all new buildings from 2021 (including residential) are nearly zero energy. There is also a significant focus on scaling up the delivery of cost-effective deep retrofits to existing buildings [72]. This regulatory approach is seen as a critical for the EU to achieve longer term greenhouse gas emission reduction targets, as well as a range of other outcomes such as improving energy resiliency and security. A review of the Directive's implementation found that, by the start of 2021, seven jurisdictions had performance requirements that were less energy demanding than the EU benchmarks, and only three jurisdictions had not implemented the requirement (Greece, Hungary, and Bulgaria); Greece and Hungary were noted as introducing the requirements by the end of 2022, while uncertainty over Bulgaria remains [73].

The UK has been an early leader in the space of sustainable housing with the introduction of their Code for Sustainable Homes policy that set out a ten-year pathway to increase minimum sustainability requirements at set periods and to deliver zero carbon new housing by 2016. While the policy was withdrawn in 2015 when there was a change in government, the ten-year plan was seen as an important way to deliver certainty for the housing construction industry and other key stakeholders regarding how a transition to sustainable housing would be delivered [31, 74]. However, the withdrawal of the policy has lasting impacts for households. Since 2016, the removal of the Code for Sustainable Homes requirements resulted in more than £790 million of additional cumulative energy costs paid by owners of almost 1.2 million new homes [75].

In 2019, the UK Government announced a Future Homes and Buildings Standard that would result in new housing reducing emissions by around 80% when implemented by 2025 compared to performance of the 2013 building standards [76, 77]. In preparation for achieving this outcome, a step change improvement of performance of around 30% was introduced in 2022 [77]. In an analysis of sustainable housing policy development in the UK, Kivimaa and Martiskainen [78, p. 93] found that low carbon housing policy development improved the opportunity for transitions intermediaries to engage 'through increasing needs and resources to pilot, scale-up and implement policy'. The introduction of these new short-medium term policy requirements in recent years is likely to further support opportunities for other stakeholders to innovate and be involved in the transition.

The establishment of short-medium term policy pathways has also been applied in several other jurisdictions to guide a transition to sustainable housing. For example, in 2008, the state of California established a medium-term energy efficiency policy plan to require new housing from 2020 be built to a nearly zero energy standard [79]. Since 2008, the plan has undergone several revisions. At the time of writing, the 2019 California Energy Efficiency Action Plan is the latest version of the plan [80]. The 2019 update seeks to double energy efficiency by 2030, remove and reduce barriers to energy efficiency in low income or disadvantaged communities, and reduce greenhouse gas emissions from the building sector. Specific performance requirements for housing are established within the 2019 Building Energy Efficiency Standards [80] which now include requirements for renewable energy technology and a range of other efficient technologies.

This approach, where a short-medium term policy plan is put forward, is becoming more common: several other jurisdictions have announced plans to transition to low carbon or energy buildings by 2030. This includes an announcement by the Canadian Federal Government in 2022 which stated a goal of net-zero energy ready buildings by 2030 [81]. Some jurisdictions within Canada have already started taking steps towards this outcome. For example, British Columbia enacted the BC Energy Step Code in 2017 to show the Province's commitment to taking incremental steps to increase energy efficiency requirements for making buildings net-zero ready by 2030. The BC Energy Step Code is a voluntary provincial standard, giving municipalities the option to implement the Energy Code and either require or encourage builders to meet one or more steps as an alternative to the BC Building Code's prescriptive requirements. The code does not specify the construction of a building, but simply identifies energy efficient targets that must be met in a way that the design and construction team choose.

It is not always about achieving a zero energy or carbon goal. For example, Wales has set out their own requirements to reduce carbon emissions from new housing by 80% by 2025 [82]. The requirements are not only about improved environmental performance and energy efficiency but they are linked with broader social goals like improving occupant health and well-being and ensuring a resilient housing stock in the face of a changing climate. The importance of integrating broader environmental or social goals into housing performance policy has been identified elsewhere as being critical for strengthening housing performance outcomes in the face of a resistant housing construction industry [74].

2.3.2 Voluntary Codes

In addition to regulating minimum performances in building codes, there has been the emergence of voluntary energy rating tools which aim to help drive housing performance forward through systematic and robust frameworks. These voluntary tools have been developed for jurisdictions where regulations do not exist or where they are not sufficient to deliver the types of housing required for a low carbon future.

One prominent example is the Passive House standard, which originated in Germany but is now spreading internationally [83]. Passive House aims to deliver low energy, thermally comfortable, and affordable housing. Achieving a Passive House standard is up to 90% more energy efficient than typical housing [83]. This high performance outcome is achieved through strict requirements for thermal energy loads in the design, materials, technologies, and construction methods applied, as well as through rigorous compliance checking at multiple points throughout the construction process. It is the attention to detail during the build which is a key difference to many other sustainable housing approaches.

Another example is the Living Building Challenge standard which emerged in 2006 and aims to address several criteria including more traditional elements like energy, water, and materials as well as other criteria such as place, health and happiness, equity, and beauty. Unlike other standards, the Living Building Challenge aims to be a regenerative performance, requiring the building to do more than just meet net-zero. For example, the Living Building Challenge requires dwellings to meet 105% of their energy needs through renewable sources. It also goes beyond the technical focus of the building to include how the building adds value to the occupants and surroundings. These voluntary tools have had varying success but are increasing in popularity around the world, especially regarding shifting the focus to improving health and well-being for occupants.

2.4 Planning

The introduction of building codes and the shift from a focus on safety to minimum performance requirements (such as energy efficiency) have resulted in improving housing design, quality, and performance. However, some researchers and policy makers argue that there has been an overreliance on building codes to deliver improved sustainability given the lack of compliance with them, tension they create with the building regime, and the often long lag times to amend to the codes [84, 85]. Over recent decades, this has led to attempts to influence sustainability outcomes in the housing sector through planning systems in different parts of the world, at both the individual block development and larger urban scale.

Planning is concerned with shaping cities, towns, and regions by managing development, infrastructure, and services. Strategic land use planning (also known as physical planning or spatial planning) 'refers to planning with a spatial, or geographical, component, in which the general objective is to provide for a spatial structure of activities […] which in some way is better than the pattern existing without planning' [86, p. 3]. Statutory land use planning is also responsible for approving developments as all formal developments need permission from the government [87]. When it comes to the role of planning in housing, strategic planning is responsible for the location of housing; housing type, mix, and diversity; location of transport, jobs, and services; urban growth; and urban consolidation. Strategic planning takes a macro approach and creates area-wide policy plans that map general policy districts such as conservation, rural, or urban areas. It also creates communitywide land use design plans and is responsible for small-area plans such as transportation corridors, business districts, and neighbourhoods. Statutory planning is responsible for land use regulations, zoning, density, residential growth boundaries, and planning approvals and permits. There are several mechanisms employed by governments and urban planning departments to control land use. These include zoning, development controls, design guidelines, and building codes, among others.

Zoning is a system for developing various geographic areas that are restricted to certain uses and development. It is a tool for governments and urban planning departments to guide future developments and to protect areas and people. While the exact terms differ around the world, common zones include industrial, commercial (retail and office), agricultural, residential, mixed use, parks, and schools. Within each category of zones, each city will provide further definitions and restrictions. For example, in the City of Vancouver, housing can occur in several different zoning districts such as multiple dwelling districts, two-family dwelling districts, one-family districts, as well as in other areas such as comprehensive development districts, historic area districts, and light industrial districts. In addition to zoning, other approaches include subdivision regulations, which are used to convert land for greenfield suburban developments; tax and fee systems, including development contributions, which are employed to generate revenues needed to provide certain services or for infrastructure improvements; geographic restraints (growth boundaries) that control growth and limit development in specific geographic areas; and official mapping which provides the public with maps of proposed future facilities and their locations.

Architectural or urban design reviews are another method to control land use and the type and appearance of developments. Some jurisdictions have an urban design panel made of design professionals who advise the local government about development proposals or policies, including major development applications, rezoning applications, and other projects of public interest. Another instrument is design guidelines which are illustrated design rules and requirements that provide either prescriptions or strategies on the physical development of an area. Design guidelines have been successful in delivering a range of benefits, for instance, 'quality, certainty, coordination, land and property values' [88, p. 276]. These design guidelines go beyond the performance and design requirements found within building code requirements.

Planning operates within a multi-level governance context. In Canada, planning is a provincial matter but provinces defer their responsibilities to local governments. Provincial governments provide legislation and frameworks for how planning and associated activities must be carried out, as well as the structures for voluntary agreements with local governments. Whereas, in Australia, the state governments retain more control over planning with local governments responsible for implementing policies. In the USA, planning is mostly a local government exercise with literately thousands of different planning systems across the country. These governance contexts are even more complex with the addition of different systems such as building codes. For example, buildings codes fall under provincial/state jurisdiction in Canada and the USA, but national jurisdiction in Australia.

In different jurisdictions, the planning system has been used to intervene at the provincial/state and local level due to the limited ability to improve sustainability through the building code. In the state of Victoria (Australia), a number of local governments have had the *Local Planning Policy Clause 22.05 Environmentally Sustainable Design* incorporated into their planning scheme with approval from the state government. This clause allows local government to embed sustainability requirements into local planning policies. Most local governments have required planning applications be accompanied by a Built Environment Sustainability Scorecard which was designed to support the Sustainable Design Assessment in the Planning Process.

In British Columbia (Canada), the provincial government launched the B.C. Climate Action Charter in 2007; since then, the majority of local governments have signed on. Under the Charter, signatories commit to becoming carbon neutral in their cooperate operations; measuring and reporting their community's greenhouse gas emissions; and creating complete, compact, and more energy efficient communities. Local governments and planning departments use their Official Community Plans (strategic planning document) and tools such as Development Permit

Areas for Climate Action, which are designated areas for the purposes of supporting climate action through energy or water conservation and greenhouse gas emissions reductions, to ensure that planning decisions lead to more sustainable housing outcomes. Building examples include improved siting of building to capture solar energy, the provision of deep overhangs for shade, and the inclusion of rainwater collection systems or geothermal systems.

What can be seen from these examples is that the planning system in many jurisdictions can play a critical role in the provision of sustainable housing (new and existing), and where building codes fall short, planning requirements can push for improved outcomes. The planning system is especially important for addressing sustainability beyond the individual dwelling level, which is typically not considered within building codes, or by individual dwelling owners. Given the challenge in transitioning to a low carbon future, improvements will need to come at different scales, which will be discussed further in Chap. 3.

2.5 Alternative Mechanisms

Further to the approaches explored above, there are a range of complementary approaches that have emerged in recent decades to address and guide improved housing design, quality, and performance. These approaches typically aim to address consumer barriers around market failures.

For example, there has been a range of attempts around the world to provide consumer education around how to reduce energy and water consumption and improve energy and water efficiency within the housing sector [89]. These education campaigns, which are separate to the earlier discussion on mandatory disclosure of building performance, have provided basic energy and water literacy for how occupants influence and improve housing performance through their everyday lives. There have also been education programmes focused on providing information around key design, material, technology, and construction method considerations that can create a more sustainable home. These programmes recognize that, although housing can be complex, there are common approaches for improving outcomes.

These campaigns have had varying success: some programmes have demonstrated lasting change. Evidence from Melbourne (Australia) found that, during periods of draught, different education campaigns played a critical role in reducing water consumption. The voluntary 'Target 155 L' campaign, which was introduced in Melbourne in 2008, used a range of advertising and education to encourage residents to reduce their daily water consumption to under 155 litres per person (40% lower than average consumption of only a few years previous). Analysis found that the campaign was quite successful with consumption not only dropping to the desired level but also remaining at that level for several years following the campaign's formal end [90]. More than ten years after the campaign started, the average water consumption in Melbourne remains around 160 litres per person [91]. One of the ongoing challenges for education campaigns, as with any changes to practices or lifestyle, is that it can take a long time for people to develop new energy or water efficient practices and, unless the education campaign is sustained or repeated, the benefits can decrease over time.

There has also been a rise in open house style events for sustainable housing, which have both acted as a way educate consumers and demonstrate what is possible [92]. Or, as Martiskainen and Kivimaa [93, p. 28] put it, such events create a 'space for initial visioning by sharing experience from completed projects'. Seeing real life examples helps translate ideas and knowledge [94], so these open house experiences are important for both learning what has worked and identifying what has not, as well as learning how to improve the overall process.

In conjunction with raising awareness through education campaigns, product labelling programmes, such as Energy Star, have provided consumers with improved information to aid purchasing decisions. The Energy Star programme was developed in the USA in 1992 to address increased energy from appliances, particularly in dwellings, and it is widely regarded as one of the more successful government energy efficiency programmes [95]. Systematic improvements to the programme have seen minimum energy efficiency standards of appliances increase over recent years. Since its inception, the Energy Star programme has helped save more than 5 trillion kWh of electricity and reduced greenhouse gas emissions by 4 billion metric tons [95]. The programme has also seen significant financial savings with more than US$42 billion in 2020 and more than US$500 billion in avoided energy costs since the start of the programme. In addition to Energy Star for product labelling, there has been an Energy Star certification for homes which has seen more than 2.3 million homes certified to its performance level since 1995, resulting in housing that is at least 10% more energy efficient compared to building code requirements [96]. In 2020 alone, this programme (Energy Star) saved 3 billion kWh of electricity, avoided US$390 million in energy costs, and achieved 4 million metric tons of greenhouse gas reductions [96]. Similar benefits have been seen elsewhere; for example, energy efficient appliances are saving New Zealanders more than NZ$30 million a year, with estimated economic savings of NZ$1.5 billion since 2002 [97].

A further approach that has been used with varying success is the use of rebates or tax incentives for energy efficient technologies or building practices. For example, from 2007–2012, the UK offered significant stamp duty (land tax) reductions to encourage consumers to purchase new housing that exceeded minimum performance regulations in a bid to reward early adopters of the higher energy performance standards [98, 99]. This may have helped reduce costs to deliver zero carbon homes in the UK by around 8% across the first four years of the Code for Sustainable Homes programme [100].

In Australia, rebates (including upfront and as a credit for excess energy) have seen the rapid uptake of residential solar photovoltaics (PV) to the point where more than one third of homes now have a solar system—a change that happened in less than a decade. However, there have been challenges with the various financial support programmes, and when the rebates or other financial supports have been too high, the programmes have often seen an over-subscription of uptake which has led to issues around the quality of some systems being installed. The frequent changes to the amounts received for excess energy and the feed-in-tariff has fluctuated over the years and, depending on it if is higher or lower than the cost for consumers to purchase standard energy, it starts to change the way the systems should be used to maximize financial outcomes. For example, if the feed-in-tariff is high, then it benefits households who are out of the home during the day and can sell as much energy as possible; whereas, if the feed-in-tariff is low, it is better for that household to consume as much of the energy they are generating as they can.

Rebates, and other innovative finance options, have been identified as particularly important for the retrofit of existing dwellings. To date, much of the retrofit undertaken across the world has, outside a few key government programmes, largely been driven and funded by individual households. Typically, banks and other significant investors have been reluctant to drive this funding. Some examples of where this is occurring include the Property Assisted Clean Energy finance programmes in the USA and low cost loans delivered by the German KfW state bank [101]. Brown et al. [101] discuss how meeting future climate challenges will require significant alternate funding and easier access to funding for retrofits.

2.6 Conclusion

Sustainable housing offers significant opportunities to improve outcomes across a range of environmental, social, and financial metrics. There is increasing evidence that we can (and should) be delivering much higher design, quality, and performance for new housing and significant deep retrofits for existing housing. However, as we explored in this chapter, there have been significant market failures around sustainable housing. This is important to understand not only because it provides a context for how we have been addressing housing design, quality, and performance (largely through inadequate building codes), but also because it identifies the opportunity for change. We discussed some of these key policy mechanisms, including the setting and improvements of minimum performance requirements in building codes, the use of planning systems to require additional sustainability requirements, and the development of financial and other support. This sets the context for later chapters where we explore the range of challenges facing the housing sector and discuss current best practice in sustainable housing and policy.

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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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4

The Sustainable Housing Challenge

4.1 Introduction

In Chap. 1, we explored the broader context as to why there was an urgent need for the provision of sustainable housing as part of a wider transition to a low carbon future. We discussed what sustainable housing is and the range of environmental, social, and financial benefits that such housing can provide both at the individual household level and at larger urban scales. In Chap. 2, we outlined how housing design, quality, and performance has typically been addressed around the world, that is through the setting of regulations for minimum thermal and energy performance of new and existing housing. The introduction of such regulations has arguably been the biggest driver of improvements to dwelling performance over the past 30 years. However, despite the evidence on the benefits of sustainable housing and the role that such housing will play in a transition to a low carbon future, progress in improving the design, quality, and performance of new and existing housing around the world remains below where it should be and below where it needs to be to meet future sustainability goals such as the 2050 emission reduction targets. Building upon this, we discussed in Chap. 3 the critical juncture we are currently at, and the importance that the time leading to 2030 will play in shaping the direction of the sustainable housing transition to a low carbon future.

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In this chapter, we build upon the disconnect between what we know is required for housing design, quality, and performance and what we are currently providing. The chapter explores why this is the case by looking at historic, current, and future challenges that contribute to holding back a sustainable housing transition. The chapter is not intended to be an exhaustive list of challenges, but rather attempts to highlight the range of challenges across different domains (e.g., technical, financial, knowledge, practice). Naturally, not all these challenges will be relevant everywhere and every location will have a more nuanced set of challenges relating to things such as climate and the existing urban context. The intent here is to highlight some of the common challenges to help us develop an understanding of the types of things we need to address in order to scale up the provision of sustainable housing. Some of these challenges are deeply complex and play out differently at different scales. We structure the discussion in this chapter around the scales where decisions are typically made: the dwelling scale (Sect. 4.2), the neighbourhood and city scale (Sect. 4.3), and the state, national, and international scale (Sect. 4.4). We then discuss the wider residential market and the unwillingness to change (Sect. 4.5) and the interconnected complexity of such change (Sect. 4.6).

4.2 Dwelling Scale

There are well-established elements that contribute to providing a sustainable dwelling, including considerations around design, materials, technologies, and construction methods and the way the dwelling is used by occupants across its life [1–5]. When basic sustainable design principles, such as orienting the dwelling to maximize use of passive solar design and natural ventilation are included in the initial design of a dwelling (or even before that, in the planning for property lot layouts) sustainable housing outcomes can be maximized for little (<10%), if any, additional financial cost [6–9]. However, despite the technical understanding of how we can provide sustainable housing in different climate zones, and the increasing number of real-world case studies of how to do this (see Chaps. 6 and 7), challenges remain at the individual dwelling and site level in many jurisdictions, which can make it difficult to provide improved sustainability.

4.2.1 Planning and Design

In many developed countries, there is some form of planning process involved in the provision of housing (see Chap. 2). In addition to the ability to set local requirements for design, quality, and performance, planning systems have a critical role in deciding how land is used and where development should occur [10–13]. The decision of what land can or cannot be used for has important implications for environmental, social, and economic outcomes for a range of stakeholders. For example, the planning system can set parameters for areas that are to have higher, or lower, density development which then immediately influences the type of housing that can be provided, as well as its affordability. In other areas, the rezoning of land from industrial or agricultural to residential can unlock significant financial value for the landowner. Furthermore, it is in the planning system where decisions on climate risk typically sit, such as determining if dwellings should be built in an area with a particular climate risk such as flooding or bushfire. These planning system decisions present opportunities for improvement of design and sustainability outcomes but can also create negative outcomes if not done properly. For example, after significant flooding events through urban centres on the east coast of Australia in 2022, it was revealed that many local planning authorities were using historical climate data to make decisions about flood risks. Some researchers suggested that this had led to some houses being built in areas we should not be building in, considering future climate changes [14, 15].

The planning system is typically also responsible for the design and layout of proposed development sites. This means that before any dwellings are designed, materials and technologies are selected, and construction methods are confirmed, that lot layout of vacant or underdeveloped land is done in a way that maximizes sustainability outcomes. For example, optimizing orientation can reduce the costs for design, materials, technologies, and construction methods to achieve improved performance outcomes. Conversely, if lot layout is done without considering orientation, it can negatively impact dwelling performance. Research from Australia shows that the difference between the best and worst orientations for a minimum regulated performance house in Melbourne was as much as 35% and that higher performing dwellings had less variance from worst to best orientations [16]. Research on the benefits of orientation in other locations has also found significant performance improvements. For example, Elnagar and Köhler [17] found thermal performance improved by 7% for a residential dwelling in Kiruna (Sweden), 15% in Stuttgart (Germany), and 22% in Palemo (Italy). In the UK, Abanda and Byers [18] modelled a house and found a 5% difference in thermal performance between the best and worst orientations and this translated this to an energy saving cost of about £900 over 30 years. Abanda and Byers [18] demonstrate that orientation is not just about reducing energy consumption but it has a wider impact on affordability and liveability, an outcome that is only likely to increase with a changing climate and increasing energy bills.

Additionally, planning systems address the question of density of housing. Arguments for density include the need to house growing populations close to amenities as well as for housing affordability outcomes. However, density should not be done at the expense of good design practices. In relation to environmental sustainability, there is disagreement across the research as to what is optimum in relation to density and diversity of dwellings. From a purely energy perspective, research has shown that detached housing is more energy intensive from dwelling operation compared to medium-higher density housing. However, this depends on what is under consideration, as higher density housing requires increased energy for things outside the dwelling such as elevators, communal lighting, and heating/cooling [19–23].

It also depends on what other considerations are included. Research undertaken in Adelaide (Australia) compared energy consumption and emissions across the life cycles of apartments within the city centre and detached homes in the suburbs. This research found that the total delivered energy consumption of apartment households was lower than the suburban households [24]. However, the authors found that, when looking at greenhouse gas emissions, the total per capita emissions typically exceeded those of the detached suburban households.

The challenge in the density discussion is that when housing gets built upwards, it often results in higher embodied energy[1] consumption due to the requirements of the structure and results in lower occupants/dwellings in comparison to lower density housing. Highlighting the complexity of this issue, Estiri [22], analysed more than 12,000 dwellings in the USA and found that lower density suburban households consumed 23% more energy than higher density inner city households. Again, depending on the metric, the data could be interpreted differently with the research showing that those living in the higher density city housing had a 22.6% higher energy intensity compared to the detached suburban homes. Roberts et al. [25] found that, with apartment occupants, it was not just the difference in energy consumption, but also how and when the energy was consumed which was different to detached housing. This could have broader implications for energy generation and energy grid stability. As we move towards consuming more renewable energy we are already seeing a need to better align energy consumption with when energy is being generated [4].

In an interesting analysis of more than 73% of housing in the USA, Goldstein et al. [26] explored the carbon footprint of housing across the country. They calculated that if cities were to meet Paris 2050 goals, there would need to be an increase in density of 19%. In some cities, such as Boston, the required increase in density was more than 50% (increasing to an approximate 5000 residents/km^2, which the study authors say is a critical threshold for residential energy sustainability targets). The authors also argued that densification has wider benefits for affordable housing, largely through the provision of more housing options in well-established areas.

The design stage is also critical for the sustainability of a dwelling. In many countries around the world, like the USA, Canada, and Australia, the floor area of new detached housing has been increasing for many years, although there are signs that this may have plateaued [27]. The

[1] Embodied energy is a calculation of all the energy that is used to produce a material or product, including mining, manufacture, and transport [1].

growth in floor area has not occurred equally around the world or across housing types; other jurisdictions, like the UK and Sweden, have much smaller housing [28]. Furthermore, while the average new detached dwelling size in Australia has grown in recent decades, the opposite was seen for Australian apartments with a rapid increase of small apartments entering the market and prompting some Australian states to introduce minimum design, space, and performance requirements.

The increase in the average floor area of new dwellings has been occurring at a time of declining average occupant numbers. It has also occurred across a period of increasing shifts in consumer expectations around housing quality and inclusions. As Ellsworth-Krebs [27, p. 22] states, the trends of 'increasing house sizes and floor area per capita undoubtedly impact expectations of home comfort and aspirations for the ideal home. Just as standardization and globalization has resulted in homogenization of indoor temperatures across the globe over the past forty years, so too can increasing floor area per capita shift norms and expectations of how much space is "enough"'.

Increasing floor area has an impact on the design, quality, and performance of dwellings [29, 30]. Research in the USA found that a 1000 square foot increase in dwelling size would result in a 16% increase in energy consumption for space heating/cooling [31]. In Australia, researchers estimated that each 2% increase in average new floor area would add 1 tonne to a household's total CO_2 emissions per year [32]. Although much of this growth in floor area occurred during the same time that minimum performance requirements were introduced, research has found that the growth of floor area of detached housing has largely nullified energy efficiency gains from these improve thermal performance requirements [33]. It is also not just the floor area that is an issue for sustainability, but that the growing floor area on decreasing lot sizes means there are less opportunities to optimize passive design and address wider issues such as the urban heat island effect [30].

There also needs to be a better match between occupant numbers and house size or number of bedrooms due to the impact on sustainability outcomes. In China, Wu et al. [34] found that removing one person from a household results in an increase of 17–23% per capita residential electricity consumption. In England, Huebner and Shipworth [35] found that if single occupant households with multiple bedrooms downsized by one bedroom, they could achieve an 8% energy efficiency saving, or a 27% saving if they downsized to a one-bedroom dwelling. The authors also note the range of benefits downsizing has beyond environmental benefits, such as social and financial ones like freeing up larger dwellings for growing families and releasing equity for those downsizing.

These benefits have not only been identified for small occupant households; in the USA, Berrill et al. [36] found that changing 14 million dwellings from family housing to multi-family housing would reduce energy demand by up to 47% per household and reduce total urban residential energy by up to 8%. Clearly, the benefits achieved just from ensuring appropriate household and housing balance will have significant implications for the environment. As McKinlay et al. [30, p. 146] state

> [g]overnment policies that attempt to address urban consolidation, green urbanism and housing affordability, seldom consider the dwelling size factor … The size of a dwelling has cumulative effects for sustainability at the scale of both neighbourhood, city and country. If these sustainability goals are to be met, the dwelling scale needs addressing. It can be speculated that neoliberal government attitudes avoid intruding in the private realm of the home, however policy documents need to reflect dwelling size as a fundamental aspect of sustainable housing.

This is echoed by Cohen [28, pp. 175–176] who writes, "the important insight is that size matters and if policymakers are serious about sufficiency – especially with respect to meeting climate targets and commitments embodied by the SDGs (Sustainable Development Goals) – it is imperative to devote serious consideration to shrinking floor area".

However, Huebner and Shipworth [35] pointed out a number of challenges in achieving these outcomes, including a limited number of options for such households to downsize into. Similar arguments are put forward by Ellsworth-Krebs [27, p. 22] who says any focus on restricting increasing dwelling sizes must be done alongside ensuring that alternative housing options "provide[s] adequate occupant satisfaction in terms of privacy and personal space as this is assumed to be a part of modernization and a driver towards smaller household sizes". Jack and Ivanova [23] echo these calls, arguing policy makers must think about new ways to encourage new forms of shared living and downsizing as part of an approach to reduce residential carbon emissions. Others like Berrill et al. [36] argue that there needs to be innovation in the use of taxes and subsidies to help guide the housing industry and consumers to build the type of housing we need in the future.

4.2.2 Materials, Construction, and End of Life

Many of the environmental impacts across the life of a dwelling are well known. These include the life cycle impacts from the extraction of raw materials; the manufacture and use of materials for construction; dwelling maintenance and the resources consumed, such as energy and water, by the people living in the dwelling across the building's life; and the impact from end of life of the dwelling (e.g., disposal or reuse of materials). Many of these impacts are locked in at the design stage and become costly to rectify once a dwelling is built. Elements such as material use, floor area, orientation, and thermal performance levels have been found to be key parameters for determining the environmental impact of a dwelling [37].

Globally, the housing sector consumes between 30–50% of materials with the total amount predicted to increase alongside the need for more housing and the increasing average floor areas in some countries [38]. In their analysis, Marinova et al. [38] identified that, by amount, concrete is the most significant material consumed within the housing sector at around 250 Gt in 2018. Other key materials include steel (12 Gt) and wood (10 Gt). It is not just the sourcing of raw materials that creates a significant environmental impact, but also the embodied energy required to source and manufacture the end products [1]. The use of these materials is not universal as dwelling designs, materials, technologies, and construction methods differ around the world and change over time based on a range of factors including historical, cultural, and climate [39]. In recent years, supply chain shortages for construction materials have been emerging in different regions around the world, highlighting how fragile the globalized material supply chain is and how significant of an impact this can have on local construction costs and other outcomes.

The impact from materials occurs through the generation of waste during construction, through-life (maintenance), and at end of life. Efforts have been made in some jurisdictions to reduce construction waste generated and increasing the amount of waste being reused or recycled. This is evident in the waste reduction and recycling targets and requirements being set in different locations around the world. It is also being driven through improved requirements in voluntary sustainable housing standards. For example, the LEED v4.1 Residential Single Family Homes rating sets out a minimum waste reduction requirement of 40–50% (depending on what option the project follows). This is low in comparison to international best practice for construction waste reduction and/or recycling; construction waste recycling is up over 90% in jurisdictions like Singapore [40], and is above 70% across the EU [41]. However, there is a gap between international best practice and what many jurisdictions are doing.

In terms of embodied energy, research has found that it can account for 5–35% of a typical dwelling's overall greenhouse gas emissions impact [1]. However, as we start to provide sustainable housing, this embodied energy impact could rise to 80% or more of the dwelling's greenhouse gas emissions total lifetime impact as the impact of zero carbon energy shifts where the environmental impact of a dwelling occurs [42]. To date, the focus on sustainable housing has often looked at reducing the environmental impacts during the different phases of a dwelling's use, but there is an increasing call to better incorporate considerations of material impact, and specifically embodied energy, in the provision of sustainable housing. The need to focus on materials will only grow with more improvements to building design and energy efficiency, and the increasing inclusion of renewable energy technologies [42]. This focus of materials also needs to be considered within planetary boundaries as we are consuming many resources faster than the earth can replenish them [43].

Material choices have primarily focused on environmental impacts, but there is increasing acknowledgement that we need safe materials and to consider social implications of material choices [44]. This is not only from an environmental perspective but also in relation to the safety of the dwelling and those involved in the process of producing the materials. Flammable cladding is an example that has emerged in recent years as a significant building safety issue in countries like the UK, Dubai, and Australia. This cladding which goes on the outside of a dwelling has certain properties which increases fire risks, and has been responsible for rapid spread of fire in building fire events such as Grenfell Tower in the UK where more than 70 people lost their lives [44]. While the cladding in question was developed partially to improve thermal performance, it is an example of unintended consequences. This has resulted in increased fire risks for thousands of impacted dwellings around the world and will likely cost billions of dollars and take more than a decade to mitigate the issue [44]. Furthermore, homeowners are experiencing substantial negative impacts to their finances and well-being [45, 46]. Similar environmental, social, and financial impacts were experienced during the leaky homes saga in New Zealand, leaky condos in Canada, and the global issues with asbestos and more recent materials such as engineered stone benchtops [44, 47, 48].

Recent policy developments at a global level have also moved beyond material safety on the construction site, introducing modern slavery laws that address safety across the supply chain [49]. This makes it clear that the stakeholders responsible for the housing provision process have a duty of care and responsibility for ensuring that social considerations are included throughout any decision making processes. The terms "ethical sourcing" and "responsible sourcing" are used to refer to choices that housing sector stakeholders make that support organizations and suppliers that value and demonstrate ethical working practices. Some voluntary sustainable building rating tools and systems, such as LEED and Living Building Challenge, provide purchasing guides or material requirements that meet sustainability and equity standards to encourage or ensure responsible choices. However, housing policies like building codes or land use planning generally have not included any equity requirements.

4.2.3 Use and Technology

A dwelling's impact on the environment is also influenced by how occupants are using the dwelling and what technology is (or is not) included in the dwelling's design. The International Energy Agency found that, in

2019, the housing sector contributed 17% of global greenhouse gas emissions [37]. This is primarily due to the amount of fossil fuel energy required to operate dwellings. The decisions made about the design, materials, technologies, and construction methods used can significantly reduce greenhouse gas emissions when they improve a dwelling's energy efficiency and reduce its energy consumption.

In many developed locations around the world, heating and cooling energy requirements make up the majority of energy consumed by a dwelling [37]. This has been driven by a rapid uptake of mechanical heating and cooling systems in recent decades as technology has become cheaper and changing social norms have resulted in expectations for year-round thermal comfort to be maintained through narrow temperature bands [50–53]. Energy consumed for heating and cooling varies around the world, largely influenced by climate but also by dwelling quality. Heating and cooling has been found to make up 55% of total residential energy consumption in Central and Eastern Europe, 52% in North America, 49% in Oceania, 46% in Western Europe, 40% in Latin America, 33% in South Asia, 24% in North Africa and the Middle East, and 20% in Sub-Sahara Africa [54]. We have the technology to construct housing that requires significantly less (or even zero) mechanical heating and cooling, such as through the thermal improvements of building envelope and making use of passive design features (e.g., the use of natural sunlight to support heating). This can significantly reduce the amount of energy a household consumes, and the generation of greenhouse gas emissions associated with it.

Some countries are also beginning to face challenges with the rapid uptake of renewable energy technologies and the use of battery storage at the individual dwelling scale. Many energy networks were not built with small-scale energy distribution in mind and they are now struggling to cope with the introduction of renewables such as solar PVs. In some jurisdictions, there are concerns around energy grid stability and, subsequently, for larger energy generators (typically fossil fuel generators). For this reason, certain locations in Australia are not allowed to instal additional residential renewable energy. While this might be rectified with improvements to energy network infrastructure, it is problematic for several reasons including that it locks out those who were slower to add renewables. This is of concern for those who experience housing vulnerability, with previous research finding that it has been the middle and higher income earners who have been the ones to take up residential solar PV while implementing these technologies presents a range of challenges for renters [55–57]. There are also instances where energy network providers are turning off renewable energy generation on houses for short periods of time when there is an issue with grid stability such as in South Australia in March 2021 [58]. So, even if a household incorporates sustainable technologies into their dwelling, factors outside of their control can impact how the dwelling performs and how it is used.

The issues presented above are largely developed country issues. In many developing countries, there are still challenges around providing energy of any generation type, as well as challenges in providing other critical requirements such as safe drinking water. The UN Sustainable Development Goals identify that, in 2020, 733 million people were without electricity connection to their dwellings, more than 2.4 billion still used inefficient and polluting cooking systems, 1.6 billion lacked safe drinking water, and 2.8 billion lacked safe sanitation. When considered alongside the fact that around 1 billion people are estimated to be living in slums or informal settlements, this highlights the depth of housing provision challenges in some jurisdictions.

4.3 Neighbourhood and City Scale

4.3.1 Where and How to House a Growing Population

Since 2007, more than 50% of the world's population has lived in urban regions. The UN predicts that, by 2050, close to 70% of the world's population will be urban [59]. The growth in urbanization is primarily due to population growth and migration/immigration. However, regions around the world have experienced this growth differently. In North America and Latin America and the Caribbean, more than 80% of the population lives in urban areas. This number is closer to 75% in Europe, just under 70% in Oceania, 50% in Asia, and just over 40% in Africa. These urban areas range in size, from tens of thousands to tens of millions. While most of the world is experiencing population growth, there are some regions that are experiencing decline, including Japan, South Korea, Eastern Europe, and parts of Germany.

The pressure from population growth has forced cities to find ways to house their growing populations; for many cities, this means going out (expanding the urban growth boundary through suburbanization and peri-urban developments) or going up (building medium and high-rise apartments). Growing outwards to accommodate an increase number of dwellings is most common in places like USA and Australia. This is largely driven by a need for cheap land to build on, with the perception that it helps with housing affordability, and that building new developments is easier and cheaper than urban infill[2] or urban renewal/regeneration.[3] This has caused a loss in natural environment as areas that were forests or agricultural land are now being consumed for the construction of new housing. This creates issues in relation to food security, biodiversity loss, and air quality, among others.

There is also an increase in jurisdictions around the world that have altered the natural environment to reclaim space for construction. Examples include land reclamation in Singapore to increase the size of the island and accommodate more development, and building over waterways on the Gold Coast (Australia) and over mangrove forests in the Niger Delta (Nigeria) for urban expansion. Reclaiming land can be costly and there are several examples of where it has, or could, cause issues longer term. For example, a significant number of developments on the Gold Coast are now at risk from rising sea levels, and the 2021 apartment collapse in Miami (USA) highlights the safety issues around building in such areas [44].

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[2] Urban infill refers to the development of vacant or underused parcels of land in otherwise built-up or developed areas.

[3] Urban renewal, or regeneration, is where an area of a city is targeted for unlocking under-utilized land and amenity. This may involve the redevelopment of existing buildings and infrastructure or the development of vacant land. It can often involve rezoning land, improving an area's amenity, and improving wider access.

Unfortunately, the design of urban regions in many parts of the world has largely been done in ways that are not optimized for sustainability. The challenge is that once our built environments are constructed, there are limitations to what can be done to improve outcomes. This applies to the micro and macro level. For example, the way streets and blocks are developed will determine how a dwelling can engage with principles of sustainable design, quality, and performance. While there are design options that can negate some of those challenges (such as access to a certain amount of sun during winter to reduce heating needs), this can add cost and complexity to housing delivery. At a larger scale, the way we have designed our neighbourhoods also creates lock in. For example, adding public transport in the form of trains or light rail to an already established urban area can be costly and limited to existing space and infrastructure, leading to costly and suboptimal outcomes.

4.3.2 Urban Climate Change

In addition to housing a growing urban population, many cities are facing unique challenges related to climate. It is not only the changes in climate that impact housing performance, but also how climate interacts with city design. Many cities have reduced permeable land surfaces due to increasing building numbers and the associated hard infrastructure like roads and paths. With these features, we are now creating our own microclimates in cities through the urban heat island effect. The urban heat island effect occurs when heat is trapped in our urban environments due to high amounts of heat-retaining structures such as concrete and asphalt relative to the amount of natural cooling features such as plants and open space [60]. Temperature increases of up to 15 °C have been found in urban areas due to this heat island effect [61]. This can be detrimental to the health and well-being of people living in these areas. In British Columbia (Canada), the 2021 heat dome event caused more than 600 heat related deaths, while the 2022 heat waves in Europe caused over 2000 deaths in Spain and Portugal [62]. Increases in temperature also mean that more energy is required for cooling. In Sydney (Australia), researchers found a 9 °C increase in summer temperatures which resulted in an additional residential energy load of 6.4% [63].

Fortunately, researchers and practitioners have identified and tested various strategies for reducing the urban heat island effect. These strategies range from increased vegetation, to the use of green roofs, to improved performance through passive design and insulation [63–65]. However, in their research across 48 states in the USA, Roxon et al. [66] find there are some cold climatic locations where the heat island effect can help improve thermal performance and reduce energy bills. This also translates to positive and negative impacts on mortality, with Lowe [67] finding that the heat island effect can increase heat related deaths by about 1.1 deaths per million people but reduce cold related deaths by about 4.0 deaths per million people. The above research highlights that specific heat island responses are going to depend on a range of factors.

Global climate change also impacts housing performance in urban areas. In many jurisdictions, historical climate data is used within regulations and support tools to design and build new housing. This means that new housing is unlikely to perform well in a future climate. However, like with the urban heat island impacts, this can have both positive and negative outcomes [68, 69]. Using future climate data, Wang et al. [70] found a mixed result for new housing performance in Australia with performance decreasing in some climate zones (e.g., Sydney, Darwin, and Alice Springs) but increasing in others (e.g., Melbourne and Hobart) with changes of up to 350% by 2100. However, even this increase was not consistent; beyond a certain increase in average temperatures, a negative performance would be seen. In other research, Chakraborty et al. [71] found that, based on likely climate change scenarios, there would be a global increase of cooling energy consumption of 15% for apartments and 37% for detached housing. If climate change is more extreme, this could increase cooling energy consumption by up to 121% for detached housing. In Canada, while energy for cooling in apartments is predicted to increase by about 40% by 2070, energy for heating is likely to decrease by 27% [68] which is similar to results for four USA cities studied by Shen [69].

What the above evidence points to is that we should be building for IPCC's mid scenarios for a future climate, with an assumed mid-range life of a dwelling. For example, if a dwelling was built in 2020 and expected to last 40 years, it should be built for a 2040 climate. This climate data should not just include temperature but also changes to other areas of the natural environment (such as sea level rise, flooding, and bush/forest fires), and be used to inform housing design, material and technology selection, construction methods, and use. When urban planners and other residential stakeholders are considering these things, they must consider where we are building and living.

4.4 State, National, and International Scale

4.4.1 The Social Challenges

Research has demonstrated that poor quality housing can exacerbate or create poor health and well-being outcomes, and conversely, that sustainable housing can improve these outcomes. As we spend most of our time indoors (up to 90%), the design, location, quality, and sustainability of our dwellings becomes increasingly more important for health outcomes, both broadly as well as during extreme weather events [72–83]. Unsurprisingly, the research typically finds that it is those who are already vulnerable that are impacted most by this issue.

Another social challenge is global population growth, resulting in more housing being needed. The UN has predicted that the population will grow from 8 billion in 2022 to 10.9 billion by 2100 [84]. However, assumed continued population growth is being challenged with the UN noting that a number of countries are experiencing population declines. Others such as Bricker and Ibbitson [85] and Vollset et al. [86] argued that the evidence suggests we are already facing a more rapid reduction in population growth and that we are unlikely to reach the numbers projected by the UN. In relation to housing, a smaller population is likely to help address some of the previously identified issues such as how and where we get materials from. However, there is still a significant challenge in how we improve the design, quality, and performance of existing housing and the significant numbers of new housing predicted to be built over the coming decades.

Additionally, policy making for a low carbon future must bring together the technical with the social. Research looking at the transition to low carbon housing requirements in the EU, UK, North America, and Australia found that the jurisdictions that had the strongest current and future housing performance requirements clearly communicated how those requirements were going to address a range of environmental and social issues (such as health and well-being, fuel poverty) and linked the outcomes of the policy to other key government policies [9, 87]. In some locations, there is a shift in the focus and language around sustainable housing, moving from one that is strictly about environmental impact (e.g., zero carbon) to include the wider social benefits (e.g., improved health through more stable and comfortable indoor air temperature). This is helping in broadening the benefits and appeal of sustainable housing and addressing some of the arguments put forward by those against the changes. While some people might still see improving sustainability outcomes as a “nice” to have element, it is harder for people to argue against improved health and well-being and reduced living costs!

4.4.2 Governance

There are also key governance challenges to delivering sustainable housing. As discussed in Chap. 2, the improvement to housing performance (or sustainability outcomes) has largely been driven by the introduction, and then revision, of performance requirements [88, 89]. However, these minimum performance regulations create tensions between policy makers, the housing construction industry, and those who argue they do not go far enough. Often when it is suggested that minimum performance requirements should be improved, and that longer term targets should aim to achieve zero or low carbon/energy outcomes, there is significant push back from key stakeholders who are opposed. The housing construction industry tends to be entrenched in the ways they operate and do not like anything they perceive to impact their productivity or ability to make money. This then turns the discussion into a political point scoring and support exercise and ignores why the discussion is required in the first place. The revoking of the Code for Sustainable Homes in the UK is an example where different politics played out to negatively impact the push towards more sustainable housing [90]. A change in government led to a change in priorities and, ultimately, a softening of sustainable housing performance requirements and the long-term policy pathway.

An issue which has had increasing attention in recent years is that, despite the use of minimum performance standards, there is significant evidence of a performance gap between what those standards require and what is delivered as the end product, especially with new construction [91–94]. This is problematic for several reasons. Firstly, consumers are not getting what they are entitled to in relation to minimum performance. Secondly, it is locking occupants and owners into poorer performance and higher living costs. Thirdly, it helps perpetuate a housing construction industry that already struggles with issues of quality and accountability in many parts of the world.

Researchers have found that buildings can consume up to 250% more energy than predicted in design, although the gap tends to be in the 10–30% range across larger data sets [91]. A study of a housing development in Italy found that there was a gap of 44% between predicted and actual performance but that, by updating various assumptions in the design model (such as the weather file, use profile, and heating, ventilation, and air conditioning features), they were able to close this gap to 7% [94]. Stellberg [95] translated the broader performance-design gap into an economic energy waste number by analysing studies from the USA that found there was a significant issue with high non-compliance against elements of building codes in most states, and as high as 100% in some jurisdictions. This represented reduced economic and environmental benefits of the codes by up to US$175 million a year (for both residential and commercial buildings), demonstrating significant financial waste.

One of the ongoing challenges with addressing housing performance through policy is that policy has historically only been applicable to new construction which only make up a small percentage of the overall building stock. For example, in Australia, new dwellings only make up approximately 1–2% of housing each year. Around the world, various reports highlight that the majority of the housing stock in 2050 has already been built [96]. If we are to deliver sustainable housing, we need to address the dwellings that already exist. The International Energy Agency estimates that up to 2% of the existing building stock undergoes energy renovations per year and that these retrofits lead to energy intensity reductions of up to 15% [97]. To meet future sustainability targets, there is a need to improve this both in terms of number of retrofits undertaken and the improvement in energy reductions. Minimum performance standards addressing existing dwellings are comparatively recent and not yet a requirement in all of the countries that have requirements for new housing.

As regulation implementation varies around the world, it is problematic to rely on regulations in their current form to improve sustainable housing outcomes. Some jurisdictions (like Australia) aim to set a nationally consistent approach, which often contains some subtle variances for different climate zones. Other jurisdictions (such as the USA, and the EU to some degree) have a more fragmented approach where the introduction or improvement of performance regulations is left to state or local governments to implement [9, 98]. There are arguments for and against both ways of delivering these regulations. On the one hand, a nationally consistent approach allows the housing construction industry to have more certainty when working across different locations and attempts to deliver a more collaborative approach to improving outcomes. The downside is, as Australia found out, that if you require the consensus of all stakeholders to lift minimum requirements, it can take just one State or stakeholder to delay the process or create weaker outcomes. When governments are responsible for developing and setting minimum requirements, it can lead to inconsistency in relation to what the targets and requirements are. However, this responsibility also allows the jurisdictions who want to lead or innovate housing to do so. This is what is happening in California, which has a long history of leading in the sustainable housing regulation space [99]. Where the federal or national government does not have authority to set performance requirements, these governments tend to use other levers to try and drive change including through the provision of rebates, subsidies, training, and other support [100].

There is also an issue of split incentives for rental housing where those responsible for paying energy bills (the tenant) are not the same as those who make capital investment decisions (the dwelling owner). A range of policy, economic, and sustainable housing researchers have found some landlords are unwilling to spend money on sustainability or quality upgrades. The tenant does not have control over changes that can reduce living costs, improve health and well-being, and increase the thermal comfortable of their housing [101–103]. Some jurisdictions have developed policies to try to overcome this split incentive. In the UK, the “How to rent a safe home” guidance states that landlords must ‘supply adequate heating in proper working order’, and that ‘a cold home is one that cannot be maintained at a temperature between 18°C to 21°C at a reasonable cost to the occupier’ [104]. In New Zealand, under the “Healthy Homes Standards”, ‘the landlord must provide at least one fixed (not portable) heater that can directly heat the living room to at least 18°C’ [105].

4.5 A Market Unwilling to Change

The broader housing market contains several structural challenges that prevent sustainable housing from being provided in larger numbers. Over recent decades, housing affordability issues have been growing more significant in many parts of the world [106–108]. The discussion on housing affordability has focused largely on the cost of purchase (ability to borrow and then service a home loan) or payment of regular rent [109]. Several factors have combined to cause housing prices (both purchase and rent) to rapidly increase in many cities around the world, a rise that has typically outpaced increases in wages. This has meant that people require an increasingly large deposit to purchase a property and that loan amounts are growing. It is now increasingly harder for aspiring first-time homeowners to enter the market without sufficient financial resources as well as impacting on those already in the market [110]. This also pushes lower-and middle income homeowners further out from the city centre in the search of “affordable housing” [109]. In the rental sector, increasing rental costs have meant that those who are renting, but want to own a home, are taking even longer to save for a down payment, and/or impacting where they can afford to rent.

This is leading to an increase in the number of people living at home longer or staying in other types of shared housing to save money or because it is all they can afford and this is reshaping a range of wider social and financial norms. For example, research from the UK shows that the increasing cost of housing has a significant impact on the social and financial well-being of individuals and society [111]. The research found that 21% of 18–44-year-olds without children were delaying starting a family due to the lack of affordable housing, and an increasing number of young adults were living with their parents longer which was negatively impacting that relationship. More than a quarter of people had made trade-offs to help pay for housing costs (such as reducing spending on food) and almost a quarter of people were continuing to live with a partner, or knew someone who was, because it was not affordable for them to live apart. There is also an increasing body of evidence emerging that relates to the negative health and well-being outcomes associated with unaffordable or precarious housing [112, 113].

Sustainable housing researchers and advocates have started to engage with affordable housing debates, arguing that sustainable housing is important for improving affordability outcomes [9, 114]. Affordable housing researchers and advocates have now started to reconcile that housing costs are more than just capital costs and are starting to call for inclusion of costs of location, transport, and energy within affordable housing discussions. As Haffner and Hulse [109, pp., 72, 73] states:

> *Explicating and measuring housing affordability inevitably involves norms about what is considered acceptable and what is not. Establishing norms for affordable, decent and adequate housing ideally must recognize the bundle of attributes that housing provides which include quality, security and location in relation to jobs, transport, facilities and services, with the latter having become increasingly important in the 2000s at least in large metropolitan areas. Households who hold different norms from societal/political norms may trade off some other essential consumption items to reach these housing norms or trade-off key dimensions of housing to ensure essential consumption to some degree. But there is a limit to the extent to which lower-income households can do this.*

Unfortunately, the broader housing market in many countries tends to focus on things that are perceived to increase the re-sale value of a dwelling. Elements such as location (close to amenity, places of work/study/schools, and prestige of area), number of bedrooms (and bathrooms), and what the kitchen benchtops are made of (e.g., granite) are typically the things that people are looking for [115]. While no doubt some of these things have practical benefits, some make little difference to the liveability or sustainability of a home. As a global society, we are preconditioned to want more and to "keep up with the Joneses". You only have to watch a few episodes from any of the new home or renovation TV shows to see the types of things that are being put forward as desirable. It was not so long ago that a family home might only have one bathroom [39], but these shows have many examples of people turning up their noses at ensuite bathrooms with 'only' one vanity.

Key stakeholders in the housing construction industry who are resistant to changes often perpetuated the idea that sustainability elements add cost to a dwelling. The argument often made is that housing is becoming increasingly unaffordable to a greater percentage of the population and that we must not do anything that adds additional costs. However, this argument has a number of flaws, including that we can deliver improved sustainability of housing for little or no additional costs as costs for sustainability elements have fallen significantly over the past decade [8, 9, 116–118].

Another challenge remains on how to engage the existing housing regime to embrace the requirements for improved sustainability. Research from around the world has consistently found significant tensions between the housing construction industry and regulators, and to a lesser extent consumers, as to who exactly should be responsible for housing performance [90, 119–124]. This resistance to change means that it is a difficult process to create broader structural changes required to deliver more sustainable housing.

4.6 The Complexity of Housing

So, what do the above challenges tell us? The role of governance is central to many of the challenges. To date, the introduction and use (or lack thereof) of policy mechanisms has been a key driver of progress towards improved housing performance. However, it is also acting as one of the key challenges that are hindering progress. Research from around the world has shown that the housing construction industry is often resistant to any type of change placed onto them via regulations, and there is an increasing desire to have partisan support for policy changes (or at least a package of support put in place to help with any transition to the new requirements). The current practices of much of the housing construction industry, who are intent on trying to maintain business-as-usual approaches, make it challenging for those niche actors who want to innovate and push boundaries. It does not help that building codes and planning systems around the world often do not allow for innovation.

As touched on above, any changes to design, material, and technology use, and construction methods or improvements to performance are seen as adding red tape, time, or costs to a project, and that this is pushed onto clients in the form of additional costs. In the housing sector where housing affordability is a global issue, anything that is perceived to add cost is a challenging political and public sell, even when there is limited evidence to support such claims. The narrative around the idea of cost and housing performance needs to shift from one of capital costs to through-life costs. The costs to live in housing can be substantial, not just from the operation of the home in relation to utility bills, maintenance, and impact on health and well-being but also the wider costs associated with location such as transport costs. Many new "affordable" houses get built in urban growth areas at the fringes of cities. This has a whole range of implications for liveability and affordability.

There are an increasing number of examples from around the world that have demonstrated that key proponents in the housing construction industry often overstate their own analyses, with costs and benefits more accurately aligning with government analyses [125]. The housing construction industry is more likely to innovate when asked to change which has resulted in any costs for compliance or performance changes rapidly falling away through improved design, material and technology selection, and construction methods. For example, minimum building code requirements changed almost overnight in Australia after the Black Saturday bushfires in 2009 where more than 2000 houses were destroyed and 173 people died. The building codes were strengthened for new housing in bush fire zones to require houses to be better protected against fires. While there were some concerns around this adding cost, houses have continued to be built to those higher standards. In the UK, analysis during the Code for Sustainable Homes found that costs to deliver zero carbon homes fell by more than 8% across four years, and that this was for a standard that was not yet mandatory so costs were expected to continue to fall [125]. Others have also predicted cost reductions around the world as more low or zero carbon houses enter the market and construction industries implement more efficiencies and learnings around the design, materials, technologies, and construction industries [126, 127].

While setting regulation is one thing, ensuring compliance is another. As touched on earlier, there has been an ongoing issue of actual performance not meeting building code requirements [91, 93, 94]. This lack of compliance is enabled by a lax system of checks and balances in many countries. This is not just in relation to sustainable housing performance, but it has also been seen in recent housing crises around flammable cladding (e.g., UK, Dubai, Australia), leaky condo crisis (Canada), and the leaky homes crisis (New Zealand) [44, 45, 47].

Another key consideration is the way we design and select materials, technologies and construction methods for our dwellings has significant implications for how occupants can use them, and in turn how sustainable, usable, and affordable they are. Also important is that these impacts go beyond the individual dwelling. There is a complex relationship between the design and use of our dwellings and how they have been shaped by hundreds of years of development and innovation. The design, use, and challenges of housing around the world have shifted over time. There is probably no better illustration of this than Bill Bryson's *At Home* book [39]. Bryson explores how some things we now take for granted in our housing (such as mechanical heating and cooling) are relatively recent innovations, and that housing continues to both influence the occupants as well as be influenced by them.[4] While Bryson's book does not directly focus on sustainable housing, some of the elements the book discusses are elements that we have seen contribute to sustainable housing (e.g., natural ventilation).

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[4] Indeed the shift in the ways we have changed heating and cooling practices has been a focus of various researchers [50].

Furthermore, the history of how our housing has developed cannot be considered in isolation from how our cities have developed. However, much of the focus of sustainable housing and sustainable cities from policy makers often looks at the present moment, without due consideration of how things have changed over time, or could change over the future. This often results in band aid solutions which are reactive to the situation rather than taking a wider consideration of the challenges and potential solutions. By this, we mean that governments have continued with business-as-usual approaches while paying lip service to sustainability or not exploring the deeper structures of what is happening and why. For example, as cities have expanded, people have become increasingly reliant on the car to get around. This is often because public transport is inadequate or is put into communities after they have been built and people have already established their transport practices. The solution to trying to improve mobility is often to build more roads and add more lanes to existing roads, often at great expense. While this might provide a short-term solution (although it rarely does), it does not address the question of why people drive. Providing work, recreation, and other amenities closer to homes (or providing homes closer to those amenities as advocated in transit-orientated development) will have a greater impact on transportation in cities than adding more roads [128, 129]. However, there are locations that deliver public transport and other non-car travel options (e.g., cycling, walking) in a much better way. We return to the need to challenge how we think about housing, and solutions for sustainable housing, in the later chapters of the book.

4.7 Conclusion

In this chapter, we have explored several historic, current, and future challenges that are contributing to holding back the provision of sustainable housing. While not an exhaustive list, the chapter highlights the range of challenges across different domains (e.g., technical, financial, knowledge), the way some of these challenges play out at different scales, and how they are impacted, and how they impact different stakeholders. We need to understand these common challenges, as well as location-specific challenges, if we are going to be able to provide a low carbon future. Many of these challenges are deeply complex and have been entrenched in the ways we have provided housing for decades; addressing these challenges will not be straight forward. As we will discuss in Chap. 5, we have potential transitions frameworks we can draw upon for guiding the sustainable housing transition.

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5

Providing Sustainable Housing through Sustainability Transitions

5.1 Introduction

Across the previous chapters, we discussed the current provision of housing and the need to transition to a sustainable housing future. We explored the benefits of sustainable housing, not just in terms of playing a critical role in achieving a low carbon future by 2050, but also the wider social and household benefits sustainable housing could provide such as reducing living costs and improving health and wellbeing outcomes. This was followed by a discussion on how we have been improving design, quality, and performance requirements of new and existing housing, largely guided by regulations. Despite some progress, we are now at a critical juncture. The decisions made over the coming years will have significant implications for decades to come. However, we have argued there are a range of policy and market failures and other contemporary challenges that need to be addressed in order to provide a sustainable housing future.

In this chapter, we explore the concept of sustainability transitions and how it offers a framework to change some of the deep structural elements and embeddedness within the current housing regime. Much of the focus in improving the design, quality, and performance of housing has resulted

T. Moore, A. Doyon, *A Transition to Sustainable Housing*,
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in minor tweaks rather than the more significant changes required to provide sustainable housing at the scale and rate required for a low carbon future. We begin this chapter with an overview of sustainability transitions theory and research, including exploring where sustainability transitions occur. Following this, we note emerging sustainable housing and transitions research and identify several important socio-technical dimensions for change which will be discussed in more detail in Chaps. 6 and 7.

5.2 Sustainability Transitions

Although technological innovation and ecological modernization[1] remain important for environmental outcomes, wider approaches to innovation are being argued for as a result of shifts in understanding and urgency to addressing issues such as climate change and the need for a transition to a low carbon future [1–4]. The field of sustainability transitions focuses on the trajectory of change towards sustainability and seeks to uncover the origins, patterns, and mechanisms that drive these transitions. Sustainability transitions theories build on an ecological modernization framing by requiring innovation while also questioning the need for technology by advocating for social considerations, environmental outcomes, and governance as well as generating deep structural change in order to achieve a transition to a low carbon future [5–7]. Sustainability transitions are co-evolutionary and involve a broad range of actors whereby innovations related to sustainability are adopted more broadly [7–10].

In this context, a sustainability transition is a process of structural, non-linear systems change in dominant practices (routines, behaviour, action), structures (institutions, economy, infrastructure), and cultures (shared values, paradigms, worldviews) from one state, stage, subject, or place to another [8, 10]. Such a transition typically takes place over a period of decades, although more recently there has been a focus on

[1] Ecological modernization is a technology-based approach to environmental policy and sustainability outcomes. It is often associated with efficiency-based initiatives.

trying to manage and accelerate these transitions given the urgency due to climate change and other social drivers [11–13].

The field of sustainability transitions emerged in the 1990s as a response to short-term policy making around the world. Its origins are in science and technology studies, complex systems analysis, and governance, but many more themes have since emerged. The early theory, policy, and practical applications of sustainability transitions emerged from the Netherlands, but other countries have embraced sustainability transitions research and/or policy development including the UK, Austria, Belgium, Finland, USA, Mexico, Spain, and Australia [1, 14, 15].

There are three core beliefs that differentiate the field of sustainability transitions from sustainability science or development:

1. The systemic fight picture
2. Non-linearity and dynamics in phases (s-curve)
3. Transitions as a solution to persistent problems

The systemic fight picture is where one or more alternative systems emerge to replace or transform a dominant system, leading to a better system overall. This concept is presented through the multi-level perspective (MLP), where transitions are conceived as the interference of processes at three levels: 'innovation (niche experiments), structure (the regime), and long-term, exogenous trends (the landscape)' [10, p. 4]. The MLP is a framework to understand socio-technical configurations and the processes by which niches displace existing dominant or mainstream technologies [7, 16]. The MLP is divided into three levels that form a nested hierarchy (see Fig. 5.1). This nested hierarchy demonstrates that regimes are embedded within socio-technical landscapes, and niches within regimes. Landscapes influence change both on niches and regimes; in return, niches (may) change the regimes and a new regime (may) change the landscape in the longer term. One of the strengths of the MLP is that transitions are viewed as non-linear processes [17].

Niches are generally thought of as protected spaces that are significantly different alternatives to the existing technological regime, where rules, behaviours, practices, and wider social elements can develop without typical market, competition, and innovation pressures [18, 19].

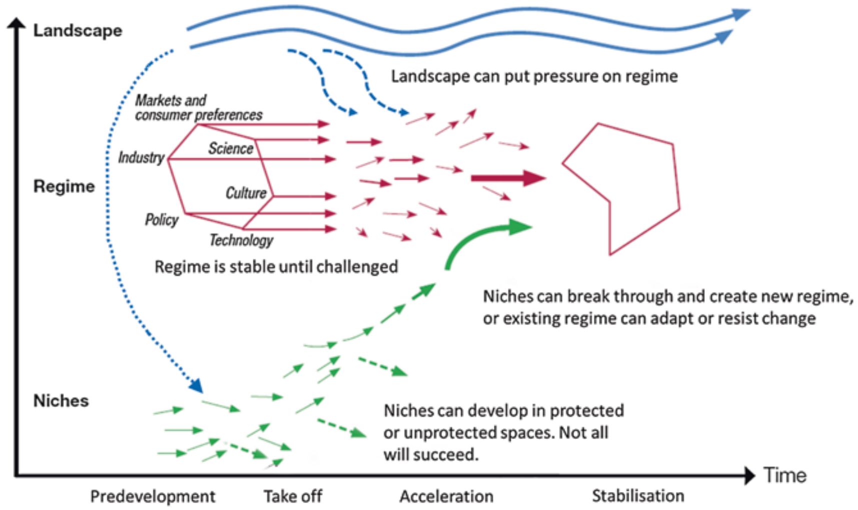

Fig. 5.1 The MLP and interactions between the three nested hierarchical levels [adapted from 7]

Strategic niche management [20–22] focuses on creating protective spaces for niches. This protection provides learning opportunities, creates more robust innovations, and allows for new networks to develop [20, 23]. This can help to address barriers including technological factors (such as a new technology not fitting into existing systems), a lack of support for development within government policy, and market challenges (such as high costs for consumers). To create protected spaces for niches, transitions researchers have identified the importance of shielding, nurturing, and empowering niches [23, 24].

The multi-phase concept or the s-curve (Fig. 5.2) represents the ideal transition: a transition where the system can adjust itself to changing internal and external dynamics [10]. The s-curve is useful for illustrating historical change, where the speed and acceleration of the transition helps to explain the trajectory of the change. While there are an increasing number of current transitions case studies, most empirical analyses that have informed the development of transitions theory are based upon historical case studies, including sailing ship to steam ship [7], coal to gas energy [25], modernization of Dutch agriculture [26], and industrialized

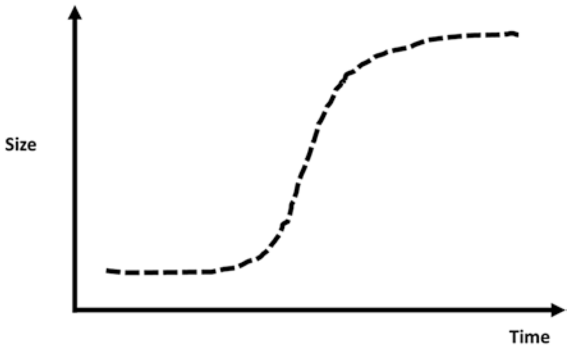

Fig. 5.2 S-curve development across time

to sustainable agriculture in Switzerland [27]. Conceptually, four different phases of transition have been distinguished [8]:

- Pre-development—There is limited visible change at the systems level; however, substantial experimentation and development in the niche level occurs to find a challenger/s to the current regime. Pressure for change starts to build on the current regime.
- Take-off—When enough pressure is exerted on the existing regime, the niche challenger can begin to destabilize it and increase its own diffusion.
- Acceleration—At a certain point, the existing regime will be destabilized enough for the niche challenger to make significant structural changes (socio-cultural, economic, ecological, and institutional) more rapidly and with less resistance.
- Stabilization—Once the speed of change decreases and deep structural changes have occurred, a new socio-technical regime is achieved.

Persistent problems are complex, uncertain, and hard to manage. The field of sustainability transitions is normative, as it believes in finding solutions to create a more sustainable future. These solutions should come from a place of co-design and learning [10], something that is more explicit in transition management and emerging theories that incorporate politics and power. Transitions management is a theoretical framework and a practical, collaborative process to support those that want to affect positive change towards a more sustainable future. The transitions management framework assesses how societal actors deal with complex societal issues at different levels but consequently, it can also be used to develop and implement strategies to influence these 'natural' governance processes [28, p. 168]. Transitions management can be applied to larger systems, as well as subsystems and specific projects. By 'bringing together frontrunners from policy, science, business, and society to develop shared understandings of complex transition challenges; [transitions management] develop[s] collective transitions visions and strategies; and experimentally implementing strategic social innovations' [29, p. 14]. Scholars have identified four types of governance activities that are relevant for sustainability transitions [30]:

- Strategic—problem structuring, envisioning, and the establishing a transitions arena
- Tactical—developing coalitions, images, and transition agendas
- Operational—mobilizing actors and executing projects and experiments
- Reflexive—evaluating, monitoring, and learning

Within the field of sustainability transitions, the transformation of a regime is typically the result of 'a particular power struggle between the current regime, upcoming niches and landscape pressures' [31, p. 545]. Researchers have been focusing on understanding the role of power in transitions, identifying who has the power (and who does not), and exploring if and how power dynamics can be identified during a transition [32–38]. Given our previous discussions around the housing construction industry and the attempts to improve outcomes through governance, power has been an ongoing challenge within the push for sustainable housing.

Despite the work on power within transitions, there has been a delayed but growing focus around ethics and justice in transitions [39–41]. This has emerged from the need to ensure that sustainability transitions are "just" and do not leave people behind, especially those people who are most vulnerable. Researchers have been exploring how ethics and justice considerations can not only help identify problems but also help shape and guide solutions and wider transitions processes [13, 40, 42–44]. This includes exploring the transitions dynamics that create, embed, exacerbate, or reduce issues with ethics implications like poverty, inequality, and access [13]. Ethics and justice in transitions have been applied across different jurisdictions, scales, and industry sectors, including mobility [44], energy [45, 46], and cities [47]. In this book, we will consider ethics and justice within housing transitions which has not yet received much attention.

5.3 Where Do Transitions Occur?

For a long time, considerations of place and scale were often overlooked in transitions theory. While it suited case study analysis to ignore these elements, contemporary transitions have increasingly been occurring beyond traditional geographic boundaries, especially as we face global environmental (and other) challenges where fixed boundaries no longer apply. Transitions researchers have become more interested in the role of place and scale and exploring things such as why a transition may occur in one place and not another, why transitions develop differently depending on the location, and what the importance of and implications are for spatial scales for the transitions process [48]. More explicit acknowledgement of place can support reflection and theoretical advancement as theories from transitions studies are used in different parts of the world [49]. Place and scale are particularly important for sustainable housing given that the construction of housing is increasingly reliant on global supply chains and involves the complexity of not only improving outcomes for new housing but also for existing housing within established environments. This places a sustainable housing transition at both the global and local scales.

In a review of geography and transitions, Hansen and Coenen [48] highlighted the importance of cities and urban regions within transitions research. Cities, and the municipal networks they belong to, play an increasingly vital role in climate change action [50–52]. Cities are also viewed as places of experimentation [53], and transitions scholars are now investigating urban experiments and living labs (conceptually and empirically) as processes and pathways to connect place-base experiments to systemic change [54–56]. Living labs offer a forum for innovation to develop new products, systems, services, or processes through co-creation to explore and evaluate new ideas in complex and real-world contexts [57], contrasting with the more deliberative “innovation spaces” approach of strategic niche management. In urban living labs, society becomes the laboratory rather than the technology or businesses that produce or adopt it. Urban living labs create the place where actors and organizations test new things to improve and re-shape systems and, most importantly, learn from their successes and failures as they go [58].

Transitions occur within and across many socio-technical systems, domains, and sectors, including energy, water, food and agriculture, finance, buildings, and transportation. Many of these sectors have experienced major shifts or transitions and are likely to do so again in the future [59]. Sector-focused transitions research tends to study past or ongoing transitions and the potential for (or barriers to) future transitions, or actively tries to facilitate transitions. Studying a specific sector provides researchers with boundaries to investigate complex problems, much like geographic scale or location. Sectors are comprised of networks of actors, which include be individuals, firms, and other organizations, institutions, which represent norms, regulations, standards of good practice, and material artefacts and knowledge [34].

One of the initial sectors that received significant attention within the sustainability transitions field was energy. This focus was largely on how previous and ongoing energy transitions occurred, as well opportunities for transitions from fossil fuel energy systems to renewable energy systems [15, 60–67]. Energy transitions research has explored issues around politics, policies, markets, actors, power, and lock-in of existing fossil fuel systems. In more recent years, the focus has started to shift from energy as one large isolated domain to acknowledge the smaller scales and decentralized nature of energy systems and that energy overlaps across domains such as the built environment and housing. As discussed in earlier chapters, for the past few decades, the focus of improving housing performance from an environmental perspective has really been on improving energy efficiency, reducing energy consumption, and (more recently) finding opportunities to shift away from fossil fuel to renewables.

Within the realm of energy transitions, there has been an increasing focus on the role of households and renewables as part of the broader sustainability transition. Bergman and Eyre [68] explored the role that small-scale renewable energy generation (microgeneration) could play in a transition to a low carbon future in the UK. What they found was that this shift in energy generation technologies had the potential to facilitate deep structural changes relating to energy consumption. For example, people who generate their own energy would go from being energy consumers to "energy citizens" that consume and produce energy, giving them new responsibilities, levels of awareness, and agency. This would be a significant departure from the existing energy regime and has a role to play in a transition to sustainable housing. This is already playing out around the world. For example, more than one third of dwellings in Australia now have solar PV on their roofs and this is fundamentally shifting the discussions around energy generation and what it means for sustainable housing [69].

There has also been a focus on the energy consumed to power the built environment. This includes the need to shift from fossil fuel energy to more sustainable energy alternatives (such as electric vehicles and bicycles charged by renewable energy technology) and the provision of more opportunities to move away from individual cars to improved active and public transport. Where a dwelling is built and how well it is connected to local amenities and services is important, but much of the focus on sustainability transitions for transportation has focused more on how transport can be made more sustainable. Discussions on transportation transitions have generally overlooked considerations of why people need to travel and how the provision of ideas like the 15- or 20-minute neighbourhood should be part of any solutions.

Across transitions studies, firms, businesses, and other industry actors are increasingly being recognized as playing important roles in sustainability transitions [13]. These institutions and actors are often part of the regime,[2] those who shape and influence societal elements such as policies, regulations, technologies, user practices, and cultural meanings. Transitions scholars have typically been interested in how these industries and businesses contribute to or slow down transitions [13]. New directions in this area of research include destabilization and decline of industries, change across industries such as the impact of information and communications technology, the role of finance capital and regulation, institutional dynamics, and business model innovation [13, 70, 71]. Businesses and industries also offer interesting perspectives for transitions research because they intersect with other areas of study, including politics, social movements, and geography [13, 70].

Another avenue of research commanding increasing attention is the need to better conceptualize different actors and their changing roles and interactions within sustainability transitions [38, 72–75]. Transitions scholars have emphasized that actors in supporting roles are important to the success of innovations and transitions processes [58, 76]. Identified as intermediaries and champions, these are individuals that create spaces for innovations to occur, facilitate innovation processes, and act as knowledge brokers and networkers [76]. Users are another set of actors that play an important role in transitions processes. Users are active players in these processes, championing change [76] and contributing to new innovations in technologies, products, and practices [77]. In addition to being consumers, users can also be voters within democratic institutions and participants in political and social movements [78]. Lastly, niche actors, those who develop or work on innovations, 'create a starting point for systemic change' by working within or against dominant systems [74, p. 6]; niche actors try to 'convince the wider social world that the rules of the game need to be changed' [23, p. 1033].

[2] A regime is defined as the articulation of the paradigm sum of current practices, beliefs, methods, technologies, behaviours, routines, and rules for societal functions [16].

5.4 Sustainable Housing Transitions

Recent years have seen an increasing focus on housing within sustainability transitions [6, 11, 12, 76, 77, 79–94]. Core to this research has been the recognition that incremental improvements or changes to housing quality and performance requirements are not sufficient for providing the type of housing required for a low carbon future. In response to market failures, researchers exploring housing through a transitions lens have argued that, in order to provide the housing we need both now and in the future, we need more than just a technical solution and will require deep structural changes to the way housing is provided and used [95].

An increasing number of researchers have attempted to explore these deep structural changes and impacts for sustainable housing. For example, research by Bergman et al. [6, 96] explored sustainable housing pathways in the UK with a focus on identifying deep structural changes that are critical to provide a sustainable housing transition. The researchers found that, if deep structural changes are to be achieved, significant pressure must be placed on the existing regime not only by niche actors but also by landscape elements (e.g., climate change). Further, they identified that significant support must be given to niche actors to allow them to develop and challenge the existing regime (protected space); the emergence of urban living labs (as discussed above) has been an attempt to try and facilitate this. Bergman et al. [6, 96] concluded that it is possible to achieve deep structural change on a pathway to sustainable low carbon housing, but that it will require radical changes to current housing and energy performance regulations.

In recent years, scholarship has further explored the role of policy and regulations within the housing space through a transitions lens including our own previous work [62, 79, 85, 91, 97]. Tambach et al. [62] concluded that several critical elements are missing from the current range of policies in the Netherlands hindering a transition to a sustainable housing future. These included a lack of a long-term policy agenda (and, in turn, short and medium-term goals and visions), a lack of upskilling industry in preparation for changes, and a requirement for financial reconfiguration (e.g., niche protection through rebates and low interest home loans). Edmondson et al. [91] adds that sustainable housing policies must include mechanisms to produce positive feedback early, that there must be adequate support and resources provided, and that clarity of information is critical. Without these elements, the authors argue that policies, even if they are well intentioned, can lead to uncertainty and inertia. In our own research, we have looked at the role of mandatory and voluntary policy approaches for driving a sustainable housing transition and found that voluntary approaches (e.g., non-mandatory sustainability rating tools) are critical for driving the top end of the market while mandatory requirements are important for lifting the bottom of the market [85]. However, Kivimaa and Martiskainen [97] analysis of sustainable housing in the UK demonstrates that the development of policies or support does not guarantee outcomes. In their analysis, they explored how, after a long period of pre-development followed by an initial take-off of sustainable housing policy, the policy commitments underwent a period of backtracking driven by the government watering down broader climate ambitions and rescinding a range of policy and support packages.

Beyond the policy focus, work by Smith [5, 82] has been important for understanding the context and practices of sustainable housing as a niche in comparison to the wider housing regime. Table 5.1 compares the clear socio-technical differences across the two housing types. As reflected by Smith, sustainable housing in the early part of the century was characterized through small scale, bespoke housing with a strong and connected community committed to an active sustainability lifestyle.

As discussed in earlier chapters, ideas and practical outcomes of sustainable housing have shifted in recent years compared to the characterization put forward by Smith. For example, no longer is sustainable housing only being provided as bespoke single dwellings but is starting to be provided at scale. The sustainable housing transition has also shifted from being more focused on new housing [5, 82, 98] to how to retrofit existing housing [12, 92, 99]. It is also broadening to consider connection and engagement with other sectors such as energy, transport, and justice. This means questions are being asked by researchers as to whether sustainable housing is (still) a niche or if it is something else.

Table 5.1 Contrasting socio-technical practices in sustainable housing niche and mainstream housing regime [adapted from 82, 86]

Socio-technical dimension	Mainstream house building	Sustainable housing in early 2000s
1. Guiding principles	Maximizing profit and minimizing financial loss; high external inputs	Ecology and one planet living; autonomous housing; minimizing ecological footprint within cost constraints
2. Technology and materials	Tried and tested technologies and materials; grid connected services; routine; bulk purchasing; established suppliers	Small-scale; off-grid services; natural/reclaimed materials; green supplies
3. Industrial structure	Speculative; volume building; subcontracted labour; construction costs; profit from contracted price; one fault on many dwellings—large liabilities; larger estates	Bespoke building; specialist builders; life cycle costs; premium for sustainable features; learn from correcting faults; single dwellings or small groups
4. User relations and markets	Passive and conservative consumers with limited input to design and construction	Active commitment to a green lifestyle; high-user involvement in design and construction or self-build
5. Policy and regulations	Land use planning and building regulations are met; lobbying to control and reduce the pace of environmental standards	Land use planning and building regulations can be a constraint; lobbying to accelerate the pace of environmental standards; delivering significantly beyond minimum regulatory requirements
6. Knowledge	Knowledge relevant to existing competencies and business practice; standard housing designs of developers' choosing	Knowledge relevant to reducing the ecological footprint of homes; site-specifics are important, e.g., passive solar orientation, wastewater treatment and recycling; learning by doing
7. Culture	Meeting market demand and minimum regulations	Sustainable housing

More recent research has also challenged the previous passive consideration of the household within transitions research and has called for greater focus on the role households will play in the transition [83, 100]. For example, Greene [101] writes about how household consumption practices are both shaped by, and shape, housing performance and outcomes. There has been a lack of consideration of this within the conceptualization and provision of sustainable housing to date. Further, Martiskainen et al. [90] explored the development of residential heat pumps from a niche to challenging the regime in Finland and the UK. The research drew upon the different users identified by Schot et al. [77]: user-producers, user-legitimators, user-intermediaries, and user-citizens. Martiskainen et al. [90] found that the role of users was important for shaping the heat pump transition in Finland and achieving an outcome where heat pumps were normalized. Conversely, in the UK, users had not been as actively involved and uptake of heat pumps in the UK was still considered a developing niche. The UK case also highlighted the challenge of the powerful regime with reports that government support for heat pumps was tempered due to concerns around push back from the powerful "gas mafia". This case also highlighted that the wider socio-financial contexts were important (e.g., the cost of gas heating in the UK was still quite cheap at the time and it had a strong regime).

What is clear within the emerging sustainable housing transitions research is that there is an increased focus on housing and how it can transition to a sustainable future. Further, as progress is made around the world to lift housing quality and performance outcomes, this continues to raise the bar for what a sustainable housing transition looks like and what could, or should, be looked at within this space in terms of mechanisms or approaches to provide a sustainable housing outcome. In our early work [86], we argued that the rapid uptake and normalizing of residential solar PV around the world has shifted the discussion around energy consumption and generation in housing, and reflected on what that means for what the benchmark was for sustainable housing. While the rapid uptake of solar PV in Australia was likely more influenced by rising energy prices than sustainable housing or wider sustainability considerations, it has led to significant outcomes for more than a third of the population. This means that the benchmark for sustainable housing is different to what it was a decade ago and will likely be different in another decade as battery storage and other technologies/materials enter the market and become cost efficient.

5.5 Conclusion

We feel that the sustainable housing research, both broadly and within the transitions space, has not taken the opportunity to question what housing is and where it is going. The housing market in many developed countries continues to provide very typical housing typologies without questioning if that really is meeting consumer needs not only now but also into a changing future. For example, in countries like Australia and the USA there has been a preference for increasing house sizes which has implications for sustainability and the cost of living. Small houses have had a stigma attached to them, but (as discussed in Chap. 7) the tiny housing and small space movement is showing what can be done with small spaces when careful design and construction is applied. We believe that researchers, policy makers, the building industry, and housing consumers must take the opportunity to critically question not only the quality and performance of housing, but also if it is meeting our needs. This questioning needs to occur at the same time as challenging the deep structural changes of the existing regime.

Sustainability transitions offer researchers, policy makers, and practitioners a framework or lens which may be able to address the limitations of current policy and market thinking. Of particular interest to transitions researchers over recent years has been how to enable and manage such transitions. While there are critiques over if a sustainability transition can be 'managed' there is increasing evidence that the more we can understand about current or potential transitions, the better placed we will be to help guide transitions as they emerge.

Sustainable housing has received increasing focus within the sustainability transitions literature and by policy makers looking at deeper structural changes. The work by Smith [5, 82] and others helped map out the existing housing regime as well as the emergence of the sustainable housing niche. However, developments in the sustainable housing space in recent years means sustainable housing has moved beyond a niche and finds itself at the core intersection of a range of sector, scale, and industry development. Drawing upon the recent sustainable housing transitions research we have identified a number of important socio-technical dimensions which we feel will play an important role in providing that sustainable housing future. We discuss these in more detail in Chap. 6.

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6

Socio-Technical Dimensions for a Sustainable Housing Transition

6.1 Introduction

In the previous chapters, we have made the case for why we need to urgently transition to a sustainable housing future for new and existing housing. This transition is needed both as part of the wider transition to a low carbon future and for the benefits such housing will provide occupants such as improving affordability and health and well-being outcomes. Our current way of providing housing has failed to sufficiently improve the quality and performance of housing in many regions of the world. As such, improving these outcomes has relied on setting and increasing minimum housing performance regulations. However, while there have been improvements in recent decades, the speed at which we need to transition to a sustainable housing future means more must be done to address a range of market failures. Every year we delay making the required changes, we continue to lock an increasing number of households into poor quality and performing housing which will be costly and (potentially) challenging to retrofit at a later stage. In the previous chapter, we explored the concept of sustainability transitions and of how this may offer us a frame to change deep structural elements and embeddedness within our current housing regime. We argued that this framing is

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required if we are to move beyond incremental sustainability improvements and unlock more significant change.

In this chapter, we explore key socio-technical dimensions that we have identified through the wider literature and our own sustainable housing research which we feel are important to address if a transition to sustainable housing is to be achieved. These dimensions build upon the dimensions identified by Smith [1] but have been updated and added to as informed by more recent research and developments across the housing and sustainable housing space [2]. Table 6.1 outlines and defines the ten socio-technical dimensions we cover in this chapter.

Table 6.1 Outline and definition of socio-technical dimensions important for a sustainable housing transition

Socio-technical dimension	Definition
Guiding principles	The embedded moral values that establish a framework for expected behaviour, practices, and decision making
Physical attributes	The individual and combined physical elements of a dwelling
Knowledge	The 'doing, thinking, and organizing' of housing
Geography	The location (specific place) and scale of housing
Industrial structures and organizations	The multiple actors and stakeholders across the traditional housing industry, including developers, builders, manufactures, amongst others
Markets, users, and power	Where and how housing is sold or exchanged (markets), the consumers or occupiers of housing (users), and the politics and regimes, including government and industry players, that dominate the housing sector (power)
Policy, regulations, and governance	The rules of engagement for the housing industry set by the government
Everyday life and practices	The activities that are typically and habitually performed in everyday life by individuals; these include cooking, showering, and going to work. For housing, we are interested in how dwellings are used, and how we might change those practices
Culture, civil society, and social movements	Individuals and organizations challenging and changing the status quo
Ethical aspects	Good governance practices and considerations of poverty, justice, and inclusivity

This chapter explores each dimension in turn by providing a definition, overview of how the current housing regime engages with it and how sustainable housing offers a different approach. We also provide a short example of how this is being provided or considered in practice. In Chap. 7, we explore these dimensions further through in-depth case studies.

6.2 Guiding Principles

For this book, we define guiding principles as the embedded moral values that establish a framework for expected behaviour, practices, and decision making. As discussed in earlier chapters, the existing housing regime in many regions of the world is dominated by entrenched guiding principles located within the frame of neo-classical markets and by stakeholders who use this approach to design, construct, and maintain housing in a certain way—low quality and low cost—with little consideration for the environment and follow the minimum building code and local planning system requirements [3–7]. There is a disconnect between this typical housing provision and what is required for a sustainable and equitable future for everyone.

Typical guiding principles for many (but not all) stakeholders in the housing industry are generally focused on refining the business model. This model was developed over many decades and is geared towards maximizing financial profit, often at the expense of improving housing quality and performance outcomes for households [3, 8–10]. This approach sees the provision of new housing and the renovation/retrofit of existing housing as primarily a business transaction, taking advantage of any opportunity to reduce costs, time, or resources to improve the financial bottom line. This approach is not overly concerned with the housing consumer experience or with what happens after the completion of the dwelling or renovation/retrofit project. The broader housing sector would likely challenge this point and argue they are providing housing that consumers want, even if that does not align with what we need in relation to addressing the environmental and social housing issues discussed earlier in the book.

The lack of care and consideration by much of the existing housing regime is evident through the amount of basic, as well as more significant, defects in many new dwellings. For example, recent research in Australia found that up to 85% of new dwellings in some jurisdictions contain defects such as cracks in floors or walls and issues with water proofing [11]. Financial and social defects do not only impact the homeowner [3]; defects also have significant financial impacts on those builders, developers and other key stakeholders responsible. For example, the cost of rework can amount to almost 5% of the overall project contract value [12–14], and can reduce company profits in some cases by approximately one third [15]. The impacts of poor quality and performing dwellings can escalate into systematic issues where governments are forced to step in and provide financial or other supports. The flammable cladding crisis (e.g., Australia, UK, Dubai) and the leaky homes/condo sagas (e.g., New Zealand and Canada) demonstrate some of the more extreme outcomes of systematic shortcomings across the housing sector [3].

In addition to issues surrounding quality of work, the wider housing sector typically builds only to minimum performance and sustainability standards. For example, in Australia, research into new housing construction found more than 80% of new dwellings only just met minimum regulatory requirements with less than 1.5% being designed and built to meet optimal cost and sustainability as outlined by researchers [16].

On the other hand, sustainable housing has been identified by both researchers and sustainable housing advocates as having a completely different set of guiding principles, which have continued to evolve over time as the sustainable housing sector grows [1, 2]. The drivers and motivations of sustainable housing stakeholders is not only centred on the housing consumers, but more largely on improved quality and reducing environmental impact—both in construction and during the life of the dwelling and household [17]. In effect, sustainable housing flips the thinking of the dwelling from being a place to sleep and eat to an opportunity to enhance the quality of life; it focuses on liveability and affordability for the household and shifts from short-term thinking to life cycle thinking. The aim is to ensure that the impacts and benefits of materials, technologies, and other elements of a dwelling are considered across the life of a dwelling, including during the dwelling's end of life [18, 19]. Within this set of guiding principles, the idea of financial profit is not a dominant consideration. Instead, financial considerations are linked to what can be achieved within the set budget and is thought about more from the perspective of the wider financial, social, and environmental value provided.

With a focus on improving the quality of a dwelling, sustainable housing aims to mitigate the number and range of defects [3]. This is done through more thoughtfully considering design and materials. This is also achieved through delivering a quality project the first time, which helps to reduce costs. Reducing costs can help to make housing more affordable from a capital perspective. If issues with quality did arise, a direct chain between the key stakeholders involved (e.g., builder) and homeowner allow for an open discussion on finding a resolution. Sustainable housing also goes significantly beyond what is set within minimum building code requirements by taking a more holistic view of the key sustainability elements. Typical building codes have had a narrow focus or definition of sustainability (e.g., focused on reducing energy for thermal comfort), but sustainable housing expands this to include considerations of water, transport, materials, and life cycle impacts with an increasing number of developments working to achieve outcomes within our current planetary means (e.g., one planet living and self-sufficiency living).

Guiding principles of sustainable housing have evolved in more recent years to consider a range of different elements such as ensuring affordability (across the life of the dwelling), transparency of decision making, community collaboration, occupant health and well-being, and ethical supply chains [2, 20]. This evolution is also about supporting the sharing of intellectual property (including what has worked but also any issues that emerge) across stakeholders to enable a wider collaborative approach to advancing the work and knowledge of others. This has elevated how we define sustainable housing—what it is and what it can deliver—not just for households, but for those in the housing industry engaged with providing, maintaining, and upgrading this type of housing.

6.2.1 Living Within Planetary Means

Living within our planetary means has become an increasing focus and a core starting point in terms of guiding principles for sustainable housing developments and retrofit projects. This focus on reducing the ecological impact from housing, and associated practices that occur within housing, is not only about addressing climate change but also about overconsumption of resources. We have one planet, and that planet has a finite number of resources and a limited capacity to replenish them [21]. Many examples have emerged over recent decades of individual dwellings and larger communities being designed, constructed, and used in ways that reduce the ecological footprint of the household and development down to near, or under, the resources required for living within our planetary means.

One example is the development of the rating framework 'One Planet Living',[1] which was developed by Bioregional in the early 2000s to help developments achieve this outcome. A notable example of a development following this framework is BedZED (UK) which was completed in 2002 and is still widely recognized as an early exemplar sustainable housing development that went beyond just providing a technical solution and reframed the idea of sustainable housing through the guiding principles of living within our planetary means [22]. Another approach has been the (re)emergence of self-sufficiency [23]. The idea of self-sufficiency is about living a lower environmental impact lifestyle and includes considerations for reducing finance and resource waste through frugality, growing your own food, producing and collecting sufficient energy and water onsite, reducing debt, living simply, and even using local materials for construction [24]. For example, Earthship homes not only repurpose large amounts of consumer waste within the construction process but also focus on outcomes to help the household live a simpler life [25]. Both BedZED and Earthship homes prioritize quality and needs over wants and trends, and they aim to enhance quality of life, affordability, and overall sufficiency and resiliency.

[1] http://bit.ly/3EVeLO0

6.3 Physical Attributes

Housing (noun) is defined as a dwelling or residence constructed for the purpose of shelter. This definition is centred on the physical attributes of housing. Appropriate or adequate housing is housing that meets minimum construction and maintenance standards as determined by local authorities, and includes elements such as structural integrity, heating and cooling, lighting, ventilation, sanitation, and occupation. For this book, we define the physical attributes of housing as the individual and combined physical elements of a dwelling. Examples of these elements include design decisions (e.g., passive orientation), use of materials (e.g., cross laminated timber), construction methods (e.g., prefabrication), and technology (e.g., solar PV).

The design and construction of housing continues to be largely influenced by the existing housing regime. While the design and construction of housing has slowly changed over time, it has done so within the confines of the existing way of providing housing [26]. This includes that standard or "off the shelf", "tried-and-tested" designs, materials, and construction techniques continue to be replicated with limited innovations beyond a small percentage of houses. In large part, this links back to the guiding principles, with a significant percentage of housing construction industry stakeholders focused on maximizing financial profits. Having standard designs, material supply chains, and construction processes means that the process, costs, and risks are (relatively) stable and well known. Whereas, pursuing higher quality and performance standards or using new or different materials, construction techniques, or technology is perceived as challenging, adds to the cost of housing, or increases risks for delivering the project.

In part, this has also been influenced by wider landscape-level factors, such as energy access and consumption. Decades of low cost centralized energy in many regions around the world has resulted in relatively low costs for operating housing. In fact, it has been cheaper and easier to put mechanical air conditioning systems into housing rather than improve the thermal performance, which results in an over-reliance on technology (and energy) at the expense of good design. With little demand for improved building quality and performance outcomes, and low energy bills, this approach has been allowed to continue. However, in the context of rising energy bills and the climate emergency, it is an approach that is no longer suited for housing.

The physical elements of new housing and renovations of existing housing tend to be similar to previous housing unless otherwise specified (and paid for) by a knowledgeable client, or if regulatory changes require it. Using similar practices for each construction project is perceived to offer financial and logistical advantages, such as buying materials in bulk, building trusted relationships with supply chain stakeholders, and knowledge of working with the technologies or materials leading to controlling some of the variables involved in the construction (or renovation) of a dwelling [1]. While there may be a perception that the dwelling owner has significant opportunity to engage in the design, material, and technological decisions, this is often limited by what the industry (or specific stakeholder) offers. Subtle variations to a dwelling design can often add significant costs (and time) for a dwelling owner and they are often structured this way to dissuade consumers from wanting things outside the normal provision of standard housing.

As Smith [1] and others found, the existing housing industry is not typically focused on how to improve design, quality, and performance (e.g., life cycle considerations). There is often little consideration for materials used in construction in terms of where they come from and what their inclusion means for the building or household. The focus is mostly around cost and ease of access. A just in time structure by many industry stakeholders to the ordering and delivering of materials also means that the construction industry needs certainty on product availability and costs, which has created familiar supply chain relationships that entrench practices. When sustainability elements are included, it is often the "bolt on" options (e.g., adding solar PV to a dwelling), rather than make deeper design and construction changes (e.g., improved insulation) to significantly improve the overall quality and performance of the dwelling.

Stakeholders involved in delivering sustainable housing think more holistically about the dwelling and centre on occupant needs. For the sustainable house (or renovation), designs typically begin from the ground up rather than trying to take standard designs and add sustainability elements to them [17]. In this way, sustainable housing providers can ensure they are maximizing key sustainable building technology and design principles such as orientation, passive solar, insulation, advanced window glazing, rainwater collection and storage, the use of local materials, and more. Incorporating these ideas from the start generally helps to reduce costs, both capital costs and through-life costs. To date, these sustainable housing stakeholders often have specialist sustainability design knowledge and/or have learnt by doing and experimenting with what works (or does not work). As the number of sustainable houses being constructed or retrofitted increases, key ideas around what design, material, and technology elements work means that future projects can build upon those that have come before without having to re-invent the design each time.

The scale of sustainable housing has changed in recent decades. Earlier sustainable housing examples were seen as unique, one-off small-scale designs that were so far removed from the typical housing market that they were not considered feasible for many housing consumers. The use of things like mud bricks, inclusion of off-grid renewable energy systems, or composting toilets were not seen as appropriate for the average housing consumer, nor were these approaches easy to scale up. As knowledge, understanding, and technologies have improved, there are increasing examples of sustainable housing that looks and feels like standard housing. In addition, with more evidence becoming available about the life cycle of various design decisions, materials, and technologies, there is a shift in focus from reducing occupancy impacts (e.g., heating and cooling) to reducing embodied energy impacts and considering what happens at end of life.

6.3.1 Cross Laminated Timber

An increasing area of physical attributes focus within the sustainable housing field has been on material innovations in order to make sustainable housing scalable, reduce costs, and improve quality and performance. Cross laminated timber (CLT) is an example of such innovation [27]. CLT is an engineered timber product composed of multiple layers of two-dimensional lumber glued together perpendicular to each other and compressed tight. As a naturally fire-resistant product, CLT was first used for walls, floors, and roofs in both residential and non-residential construction. The benefits of using CLT include a high degree of prefabrication and off-site assembly, and compared to light-weight timber construction, CLT has less air permeability and more capacity for humidity and thermal energy. CLT is also able to act as a load-carrying element, which makes it applicable as a stand-alone structural element, and it is being used as a substitute for reinforced concrete. This makes it an appropriate substitute for reinforced concrete, helping builders reduce their carbon footprint as CLT is much less carbon intensive than concrete and steel. More recently, CLT has been used to construct tall timber structures of up to 18 storeys. Examples include "Treet", a 49.9 metre-high apartment tower in Bergen (Norway) design by architectural office ARTEC [28]; "The Toronto Tree Tower",[2] a 62 metre-high residential tower in Toronto (Canada) designed by Penda (now Precht); and "Carbon12",[3] a 26 metre-high mixed-use building (residential and retail) in Portland, Oregon (USA) designed by Kaiser+Path. At the time of writing, there are proposed residential towers of 90 and 100 metres tall using CLT in Toronto and Switzerland, respectively. If built, these buildings would be the tallest mass timber structures in the world.

6.4 Knowledge

The housing industry approaches knowledge in a long-entrenched way. This involves standard knowledge development and reinforcing existing practices of providing housing. Knowledge across the mainstream housing regime has largely been developed by replicating tried-and-tested housing designs, use of materials and technologies, and construction methods. This has allowed housing construction industry stakeholders to refine their knowledge of what they do within the narrow parameters of standard practices. For this book, we define knowledge as the "doing,

[2] https://bit.ly/3AZFBUh

[3] https://bit.ly/3VYiH7R

thinking, and organizing" of housing. This includes the access, understanding, and use of information to design, build, and sell housing.

Knowledge is informed by guiding principles in that there is a significant focus on business practices and the financial bottom line. Knowledge around building quality and performance generally is about meeting minimum standards, regulations, or planning requirements with the least cost, effort, and change to practices. Without a better understanding of design, materials, construction, and technology, the current housing regime can be locked into inefficient ways of ways of meeting minimum requirements as they attempt to "bolt on" additional requirements rather than redesign from the ground up. In addition to design and technology dimensions, the housing regime is primarily focused on individual dwellings or buildings and rarely extends to the role housing plays within the wider urban context.

The housing construction industry is also generally protective of its knowledge and intellectual property. There is typically little sharing of knowledge, learnings, or lessons across the industry [29–31]. This stems from the focus on the financial bottom line and trying to eke out any market advantage possible. This approach also means that stakeholders rarely have the time or opportunity to return to completed projects to find out first-hand what has worked well, what could be improved, and what the key lessons are, or even share this information across the industry [30]. This means that the wider housing industry is repeating issues that could be easily addressed if proper consideration, reflection, and sharing on previous projects were conducted.

These knowledge sharing constraints not only exist within the industry but are also evident in how housing is marketed to consumers. Typically, marketing information relates to the price, location, number of bedrooms/bathrooms, and other perceived key amenities (e.g., garage, views), rather than providing information (or knowledge) about the implications of the design, materials, construction, and technology, which can significantly impact the quality and performance of a dwelling [32]. As noted earlier, this is reinforced by social norms about what a house should be, and the focus on wants over needs. There is also the lack of knowledge that housing consumers have about housing and their understanding around quality, performance, and sustainability. This is critical as wider housing industry stakeholders who push back against regulatory change often state that consumers have the knowledge of what they want and will use their purchasing power to drive sustainability change. However, research shows that housing consumers often lack knowledge about the impacts their decisions have on housing quality, performance, and design [33–36].

Sustainable housing stakeholders, on the other hand, are interested in information and knowledge as evidence to enhance their understanding and improve the design, construction, and retrofit of housing. By weaving this evidence in with housing consumer needs, a more considered and holistic sustainability approach is applied. While such knowledge was site specific in the early years of the sustainable housing movement, recent decades have seen the development of communal sustainable housing knowledge that is flexible enough to be adapted to different cultural norms, jurisdiction requirements, climate zones, and other local contexts (e.g., use of local materials). This knowledge is now integrated into many higher education courses related to the housing industry (e.g., architecture and construction management) to ensure those going into the wider industry have a higher level of knowledge and understanding to deliver sustainable housing. There has also been a focus on training for sustainable housing elements and delivering demonstration projects to reduce barriers of the unknown and to give actors experience with real-world outcomes [29–31].

Knowledge and evidence have expanded beyond just technical, material and design knowledge to include the role of the dwelling within the wider environment. For example, the focus on affordability through reduced utility bills, health and well-being through improved thermal comfort, and better productivity through improving natural light, and so on, are now as much a part of the sustainable housing language as the need to reduce the environmental footprint. Furthermore, improving housing performance based on what occurs around the dwelling is increasingly playing a role in the design, construction, and occupation of sustainable housing. This includes the strategic planting of vegetation to help regulate local micro-climates and reduce requirements for mechanical heating and cooling within a nearby dwelling.

The sustainable housing community is typically a community that is open to sharing and has engaged with ideas around open sourcing key information. This is evidenced by the range of publications on the topic (e.g., books, articles, videos, podcasts, blogs) where people are happy to share what they have done [1]. Importantly, the community is also happy to share lessons of what has not worked, and to revisit these reflections periodically to see if anything changes as the dwelling ages and households gain more understanding of how to maximize their performance. Increasingly, these niche sustainable housing stakeholders are engaging more and more with existing regime actors [1].

6.4.1 Vancouver House/Vienna House

In 2018, the City of Vienna and City of Vancouver signed a Memorandum of Cooperation to share knowledge and advance innovation in low carbon affordable housing across the two cities. Specifically, the agreement commits the cities to 'share insights on innovative new building approaches, effective market transformation programs, and research associated with different building approaches and standards' [37]. Vancouver House,[4] in Vienna, will consist of 107 rental units, a kindergarten, 12 units for assisted living, and 11 units for single parents in a hybrid wooden structure built to Passive House performance standards. Vienna House,[5] in Vancouver, will consist of 123 units of dedicated affordable rental housing in a high performance, low emissions building showcasing innovative materials and design processes. The knowledge exchange between the City of Vancouver and the City of Vienna has the potential to inform future sustainable and affordable housing projects. For this reason, knowledge transfer and dissemination will be a key part of the project's research and communications efforts.

Research on the buildings is publicly available through the project and government websites. In Vancouver, the University of British Columbia (UBC) is leading research through the UBC Sustainability Initiative, the

[4] https://bit.ly/3iuOP4b

[5] https://bit.ly/3GYDDXS

Department of Civil Engineering, and the UBC Collaborative Research Group. Researchers, students, and consultants will study the design, manufacturing, construction, and commissioning processes of the Vancouver project and document the challenges, solutions, and lessons learned. Potential areas of interest include energy performance, virtual design and construction (VDC), building information modelling (BIM), mass timber product performance, life cycle assessments, and prefabrication and construction productivity. The aim is for the project to be a showcase or demonstration project for the housing construction industry, as well as for policymakers facing similar challenges.

6.5 Geography

The current housing regime has paid limited attention to geography. Geography refers to places and the relationships between people and their environments. Geography of transitions is concerned with where something takes place, asking 'why do transitions occur in one place and not in another? How do transitions unfold across different geographical context? [And,] What is the importance and role of relations at different spatial scales for transitions process?' [38, p. 93]. For housing, scale includes the dwelling, neighbourhood, city, regional, national, and international scales. For this book, we define geography as the location (specific place) and scale of housing.

As already noted, the typical focus of the current housing regime is one of maximizing housing outcomes for the lowest cost. This means that dwelling quality and performance can be impacted by both where a house is built and how it is built. Often impacts on quality and performance are locked in during the initial master planning of new sites, either by developers or by local planning authorities, rather than design development that is based on maximizing the performance outcomes of dwellings and the social and financial benefits for occupants [39]. The initial planning stages lock in things like position of dwellings, road layout, and opportunities for active and public transport. With a focus on profit and only building to minimum planning and building code requirements, the current way housing is provided has had limited consideration of local context or larger urban or regional environments, such as the impact the dwelling might have on energy and transport networks.

Around the world, cities are experiencing increasing densification as populations grow and rural to urban migration increases. In response, there have been two main housing provision strategies. The first is increasing densification in areas close to amenities (e.g., public transport, shops, schools); the second is adding housing in urban growth zones and peri-urban regions. Both approaches have typically been delivered without significant consideration of place or the relationship between people and the environment. For example, there are numerous examples around the world of cities like Melbourne, Calgary, and Houston that have an ever-expanding growth boundary that is driven by the perception of providing "affordable" housing in areas where there are no existing constraints in the built environment (e.g., no existing roads or buildings which influence how new construction needs to be located). There is also the case that standard floor area of housing has increased in many regions over recent decades [40]. Combined with decreasing lot sizes, this constrains the ability to use the area around the dwelling to help improve performance (e.g., through tree planting to reduce the urban heat island impact).

Urban growth is often done at the expense of previous land use which, in some cases, has resulted in the loss of productive agricultural land and created wider societal issues around the provision of food. There are also examples of areas which have cleared significant native vegetation (e.g., forests, mangroves) to provide space for housing, which negatively impacts the local flora, fauna, and climate. Additionally, there are some locations which have been building on "reclaimed" land—land that might have been a swampland or waterway that has been filled in to build on. This can create many short- and long-term issues ranging from loss of nature to creating building performance and structural issues in dwellings. The case of the Miami apartment collapse in 2021 is, in part, thought to have been caused by shifting reclaimed land on which the apartment stood [3].

Place and scale have also been important for shaping, and constraining, building regulations. While building regulations have been widely recognized as being critical in lifting performance and sustainability in both new and existing housing, it has been challenging to overcome issues which emerge through place and scale. For example, in some countries, regulations are developed at the national level and then passed on for individual states or regions to implement. This approach hopes to create a more consistent and level playing field with regulations. However, as is the case in Australia and the USA (amongst others), this can also constrain outcomes when there is a need for agreement between regions on what is set at the national level. At times, this has resulted in a watering down of minimum performance requirements. Further, jurisdictions who want to push further ahead are either unable to or create their own requirements which can foster tensions across other regions or even with national regulators and the wider industry.

Sustainable housing has significant connection to place and community. Early examples of sustainable housing often used local materials (either onsite or from the nearby region) and demonstrated connection with, and to, the land where the building occurred. Ideas around having a "light touch" on the land or blending into the natural environment were often key objectives for sustainable housing. An increasing focus of more contemporary sustainable houses is on actively contributing to the local area wherever possible. The provision of sustainable housing often starts by considering the site, materials, and designs that are best matched to the local climatic conditions. This helps to deliver improved performance outcomes in the initial planning stages, such as through ensuring that optimal orientation and passive solar opportunities are leveraged. It also helps to limit the loss of productive land (e.g., nature, farming) and ensure that the location of housing is appropriate (e.g., not in flood zones or areas likely to be significantly impacted by future climate change).

Understanding the concept of place in transitions has become increasingly important. Explicitly acknowledging place provides important context to specific transitions processes, including historical, socio-political, economic, ecological, and other contextual considerations (considerations that are limited within the current provision of housing). In addition to the location of transitions, the scale is equally important. Transitions can occur at a national level, state or provincial level, regional level, urban or municipal level, or at a neighbourhood or site level. In some instances, transitions can also occur across scales or they may be situated within a multi-governance context. This is relevant for exploration the sustainable housing transition as the provision of housing involves regulation, influence, materials, technologies, and skills from across an increasingly globalized sector.

As sustainable houses move from one-off individual dwellings to the development of multiunit buildings and precinct scale developments, the benefits of the planning stage and understanding place and context is more significant for ensuring increased performance outcomes both within and across the development. At these early stages, local amenities are also considered and, in an increasing number of sustainable developments, are delivered either before or during the early stages of residential construction to ensure that the amenities are there when households start moving in and not years down the track. Sustainable housing stakeholders are also beginning to consider the role sustainable housing plays within the wider community and environment, and the implications it has for other sectors such as energy and transport where sustainability considerations can help make a positive impact beyond the individual dwelling or development site.

6.5.1 Zoning Reform

Single-family zoning, often referred to as R1 in planning documents, is a zoning policy that restricts development in an area to one dwelling per lot. This type of zoning is ubiquitous in the suburbs and other car-dominated landscapes. There are calls and movements to eliminate single-family zoning, normally through "upzoning" which refers to increasing density on a lot. The aim of up zoning is to increase housing in existing neighbourhoods. Jurisdictions across Canada and the USA are passing new zoning ordinances to allow more units on traditional single-family lots or to eliminate single-family zoning altogether. These jurisdictions are doing this to use land more efficiently and environmentally, and to respond to housing affordability challenges. One of the most well-known examples of "upzoning" is the State of Oregon's House Bill 2001[6] which

[6] https://bit.ly/3GVBJHz

was passed in 2019. The bill essentially eliminated single-family zoning across the state. For cities with populations greater than 25,000, the bill allows duplexes, triplexes, fourplexes, and “cottage clusters” to be built on parcels that are currently reserved for single-family houses. In cities with populations of at least 10,000, duplexes are allowed in single-family zones. This topic is receiving a lot of attention from planners, particularly in places like the USA. In 2020, the Journal of the American Planning Association published an entire special issue on the idea of ending single-family zoning [41]. Manville et al. [41, p. 106] argue that ‘R1 is inequitable, inefficient, and environmentally unsustainable’. Meanwhile, Kendig [42] thinks eliminating existing single-family zoning is a mistake, and Chakraborty [43] believes this topic deserves more scrutiny.

6.6 Industrial Structures and Organizations

Industry actors such as firms and organizations play critical roles in sustainability transitions; they can be innovators and develop new ways of doing things, or they can restrict change and prevent the formation of new products, technologies, business models, and even new industries. These actors also engage in institutional work, where they participate in shaping cultural norms, regulations, and legitimize or shape new discourses. For this book, we define industrial structures and organizations as the multiple actors and stakeholders across the traditional housing industry, including developers, builders, and manufactures. We are particularly interested in how the sector operates and how they organize themselves.

Actors in the existing housing regime have operated as a larger whole, with similar industrial structures, organizations, and industries dominating and protecting the sector against challenges (i.e., sustainable housing) and locking in entrenched practices of operation and organization. The housing industry has been described as ‘an institution [where] understanding the housing system requires recognizing its “rules of the game”’ [44, p. 9]. These “rules” and the entrenched operating practices have shaped the way housing is provided. For example, to achieve cost efficiencies, developers and volume builders are prevalent in many markets (e.g., Australia) and represent most of the new residential construction. The preference of developers and volume builders is to develop larger detached housing estates rather than one-off dwellings. This provides opportunities for standardizing designs, materials, and construction processes and allows for controlling costs and maximizing profits, with the focus largely around financial outcomes. This also leads to developers and volume builders having established relationships with other industry stakeholders, which often carry over from one project to the next. The operation, practices, norms, and discourse across similar actors in the industry are also established and enacted through peak industry and professional associations [44]. Again, there are financial and other efficiencies for maintaining these relationships, but it leads to doing things the way they have been done previously.

In many regions of the world, the wider construction industry is one which is heavily based on subcontracting labour. This has a range of implications including that it creates, to some degree, a transient workforce that follows the money or work with little connection to the employer (other than to ensure they get future work), the end product (with accountability passed back up the management chain), or the community (no knowledge of the local environment). This has created mixed outcomes with research showing that the length of time to build a house in places like Australia is increasing, and that part of this additional time is due to different trades and subcontractors having challenges sequencing their components of work [45]. This structure of employment also means that there is limited incentive for subcontracted workers to report issues or learnings to those in decision making roles. As such, the cycle of continuing to produce the same type of housing continues.

While some smaller builders or developers may just work on a single project at a time, many medium-to-larger building companies or developers often have multiple projects underway at any one time. Part of this relates to market structures and helping to diversify risk and costs by spreading the risks and resources across multiple projects. It can also help with organizing the workforce. For example, if different trades can be sequenced across multiple projects, it can be more productive and financially beneficial for both the builder or developer, and the labourer. It also means that trades can be moved to different sites should the need arise to do certain work or meet deadlines. However, this also means that the current housing sector is highly reliant on a small number of organizations and, as increasing research finds, this is challenging to do and results in delays and other outcomes.

The current provision of housing is also heavily reliant on a select number of key industries and supply chains. Increasingly, the housing sector is becoming more globalized and a key result of this is a reliance on international supply chains for materials and technologies in many jurisdictions. This has largely been driven by the pursuit of finding cost efficiencies, but is in part driven by a decline in manufacturing in many regions which has forced housing industry stakeholders to look elsewhere for the materials and technologies required for housing construction. While this has helped to improve the bottom line of some stakeholders, global supply chain issues during 2020–2022 have highlighted the overreliance on this structure with material and technology shortages and skyrocketing costs. This has contributed to developers and builders going bankrupt when they have been unable to deliver on fixed cost contracts for construction [46].

For a long time, sustainable housing has been seen as bespoke one-offs or small groups of housing delivered by specialist designers and builders [1]. It has historically been a process where early adopters (both industry and households) have learnt by doing and attempted to fix any issues that arise along the way. As the previous dimension explored, this process has also involved sharing knowledge and learnings with the wider sustainable housing community [1]. While sustainable housing has typically been attempted with the constraints of budget in mind, there have been cost premiums for some sustainability elements and inclusions for early adopters, such as with the higher cost of solar PV and battery storage. This cost premium has been used by the existing regime as a key reason why sustainable housing should not be more widely pursued.

However, sustainable housing has shifted over the past decade or so, from high levels of experimentation in one-off projects to replication of prior learning and upscaling [29]. This has not only had an impact on the scale of sustainable housing, but has also helped pushed the performance benchmark of housing forward. In part, this is driven by increasing knowledge and cost reductions for materials, construction methods, and technologies. Sustainability is no longer seen as a premium feature; when sustainability is designed in from the start, it can be achieved with significant design and cost efficiencies. The cost of key sustainability technology has continued to fall, making it even more affordable to include elements such as solar PV on homes. This decrease in costs along with a change in housing culture has encouraged some sustainable housing actors to cap profits to ensure that decisions are ethically driven and they benefit the homeowner and the environment. This change in approach has also pushed actors to work with the financial industry to find innovations to fund sustainable housing construction.

Within transitions research, there is an increasing focus around the industrial structures and organizations involved in transitions. This is relevant for our focus on the sustainable housing transition and has been explored from a range of perspectives, including understanding business practices (e.g., how to develop, protect, and/or elevate key or new structures), organizations, and industries to help challenge incumbent regimes [47–50]. Given our discussion across earlier chapters, the provision of sustainable housing will likely require housing industry actors and stakeholders to adapt or evolve. However, Sovacool [51] and others are increasingly concerned with the slow pace of transitions. For example, if the pace of transition is too slow, the incumbent regime is more able to resist change or make minor changes to continue provision of houses without including wider sustainability considerations. Speed is a pertinent issue for sustainable housing given that housing is a long-life infrastructure likely to last 40 or more years once built.

An important element already emerging in the sustainable housing transition has been around challenging traditional notions of finance and affordability. Within the wider transitions literature, there is an increasing focus on the role that finance capital plays to enable or constrain transitions [52, 53]. Given that existing housing regime practices have largely been enabled by the wider market, it stands to reason that the market, and specifically the financial structure and organization of the market, must change. This has been noted by the UNEP [54] in relation to sustainable development. Wider research has also stated that the financial recovery from COVID-19 will be greater with a shift towards delivering improved sustainability across a range of sectors [55, 56]. Within the housing sector, there is a need to shift the way housing is viewed in terms of cost, value, and affordability. Furthermore, transitions researchers have highlighted the importance of new ways of doing, thinking, and organizing and the role that innovation (such as digitalization) will have in restructuring various industries and sectors [57–59]. The emergence of several innovations in recent decades, such as prefabrication, has highlighted how this might play out within the sustainable housing transition and associated sectors such as considerations of energy as a service.

6.6.1 Prefabrication

Prefabrication, or prefab as it is commonly referred to (or in some locations, off-site manufacturing), is construction undertaken away from the final building site in a factory-like setting. Once constructed in the factory, various prefab elements are taken to the building site where they are assembled. There are different types of prefab including modular (large modules of rooms or sections of a home including the structure and finishes of roofs, walls, and floors and any built in elements such as kitchens, bathrooms, storage, and all electrical and plumbing) and panelized (where smaller sections of the home are built before being assembled into the larger structure onsite). Benefits of prefab include that it can deliver improved quality, reduce material and labour waste during construction, improve construction safety, shorten construction times onsite, reduce construction costs, create less disruption to neighbours, and reduce project risks [60–62]. Prefab offers innovation and new ways of providing housing which challenges the established cultural practices, norms, regulations, and discourse around housing design and construction. It also presents a different way for how the sector can operate and how they organize themselves. For example, constructing in a factory means that work is not impacted by weather, and improving sequencing of trades can improve overall efficiency by reducing construction time and costs [62]. In this way, prefab changes business practices and challenges incumbent regime actors.

Some countries have embraced the use of prefab over recent decades, while others have only more recently engaged with this different construction approach. For example, Sweden is considered a leader in the prefab construction of housing, having been constructing housing in factory-like settings since the 1940s with prefab now representing over 80% of the housing market [61].

6.7 Markets, Users, and Power

In many regions of the world, the politics around the provision and maintenance of housing has been focusing on three key deliverables: the provision of more housing, affordability (capital costs), and getting a higher percentage of people into home ownership. This means that decision makers must often consider trade-offs from any new regulatory changes against the impacts on these three deliverables. Requirements for improving the performance, sustainability, and quality of housing have typically been portrayed by the incumbent housing regime as negatively impact these key deliverables. This narrative has been playing out across different housing markets and with different users tied to different housing situations. This creates a complex landscape for decision makers to navigate. For this book, we define markets, users, and power as where and how housing is sold or exchanged (markets), the consumers or occupiers of housing (users), and the politics and regimes, including government and industry players, that dominate the housing sector (power). Markets, users, and power are also about the complexity of relationships and the interactions across these entities as well.

The current housing regime has power and agency over the first policy levers pulled when the economy starts to decline. However, the housing construction industry can often leverage the politics around construction to suit its position. Governments regularly collaborate with the housing construction industry on new policy initiatives, often through a process of negotiation where there is significant power on the side of the construction industry. An example of this is when the Victorian Government (Australia) announced plans to put a small financial levy on residential developments over a certain size (3+ dwellings) to help create a social housing fund to build more affordable housing for those most in need. Days after the Victorian premier announced this plan, he was forced to withdraw the proposed policy changes after he claimed the construction industry withdrew its support for the plan despite it having significant benefit for them [63].

The housing construction industry also has significant power and agency over housing consumers and is notorious for saying it strongly engages with the housing market and users and aims to deliver what users demand. Time and time again, studies find this is not the case and that housing consumers have limited agency. The notion of the "free market" is often put forward with the housing sector arguing that, if consumers wanted higher quality or more sustainable housing, they would ask for it and be happy to pay for it. However, research has found that consumers do not have a clear understanding of what sustainable housing is, what benefits it can provide, what opportunities are available to them, and how to go about asking for something that is portrayed as "different".

Because misinformation proliferates sustainable housing discourse (e.g., added cost), consumers do not have clear and unbiased information about sustainable housing. Social norms around housing are also reinforced by key actors beyond the housing sector, such as building or renovation shows where the focus is on the flashy, nice to have elements, with little consideration for quality and performance. This helps reinforce ideas around what housing should or could be. Therefore, the idea of the "free market" is not really working in this context. In regions where volume builders dominate, the housing consumer often has limited opportunity to be engaged in the process beyond selecting a template design from a limited range and some "custom" additions that are available.

Sustainable housing differs from the current regime as it has a longstanding practice of collaborating with housing consumers and key stakeholders of the design and housing construction industry. A collaborative approach like this means consumers are aware of all key decisions and their implications. This practice ensures that the needs of the household are met and environmental impacts are reduced. In the earlier days of sustainable housing, there was a high level of user involvement as many sustainable houses were self-built or custom projects. This has evolved to some degree (from one-off projects to larger scale, industry-built developments), but there is still a strong tradition in self-built sustainable housing in the growing community of tiny houses and off-grid projects.

For industry-built sustainable housing developments, there often remains some user involvement throughout the design and construction process, as well as in the management and maintenance phase, to maximize performance outcomes. In some cases, collaborative engagement also helps to educate future residents about differences between sustainable housing and traditional industry-built dwellings.

The sustainable housing construction industry has had limited power over policy makers. At the moment, sustainable housing is still fighting to have their voice heard. This is despite providing an increasing number of successful examples of developments that provide a range of benefits. While sustainable housing may not have political power, we have recently seen a upscaling of sustainable housing development within the existing constraints of regulation, financing, and the wider housing regime (see Chap. 7). The sustainable housing industry's ability to influence and deliver change will grow alongside the sustainable housing movement grows. As more housing consumers start to understand the impacts of housing decisions on longer term liveability and affordability, users are helping to shift power dynamics for sustainable housing. This shift is also starting to occur with other housing provision stakeholders, such as financial institutions working with niche developers or funding sustainability retrofits.

Sustainable housing actors and the current housing regime have often been likened to David and Goliath, with the current regime holding the power. This dynamic plays out within sustainability transitions theory, where the regime is the dominant social order and niches are small-scale interventions, radical innovations, or experiments that push for bottom-up change. Regime actors often use their power to actively resist transitions in various ways [64], whereas niche actors try to change the regime [65–67]. As part of housing transitions research, scholars have examined different elements relating to specific sustainable housing niches [68], as well as the relationship between sustainable housing as a niche and the existing regime. However, as sustainable housing continues to evolve and become more embedded within housing practices, the power dynamics between sustainable housing and the current regime will have to be refined and possibly redefined.

6.7.1 Rating Tools

In many locations, minimum performance requirements (including rating tools) have been used to lift the bottom of the market. However, typical rating tools often focus on reducing energy or carbon metrics through purely "technical" elements, rather than design, material, and social considerations. In response to these limitations, an increasing number of voluntary rating tools have emerged in recent years, working to reframe ratings and measurements to be about improving outcomes for occupants and the wider environment as a whole [69]. For example, the WELL Building Standard,[7] which was launched in 2014 and has now been applied to more than 21,000 buildings in over 120 countries, has developed a rating tool which uses medical research as a starting point to improve occupant health and well-being outcomes. Certified spaces are designed to address Seven Concepts of the WELL Building Standards: Air, water, nourishment, light, fitness, comfort, and mind. In doing so, outcomes improve the nutrition, fitness, mood, sleep patterns, productivity, and performance of the people working, living, shopping, or playing inside these spaces. Building the tool from medical evidence has resulted in a more user focused outcome and, to some degree, takes away the input from the "free market" as it is based upon the best available evidence rather than influenced by consumer trends.

Another more innovative rating system challenging markets is the Living Building Challenge,[8] launched in 2006. This tool attempts to radically change the way we consider, design, build, and use buildings and has been described as the world's most rigorous building performance standard.

Where other tools try to reduce environmental harm, this tool aims to make a positive contribution to the environment by being regenerative (i.e., fixing the damage). For example, it sets targets beyond what is needed to support just the building, such as 105% renewable energy generation. Like the WELL tool, the areas of focus are different to those of

[7] https://bit.ly/3FgcTAL
[8] https://bit.ly/3Fj6qW4

traditional tools and include place, water, energy, health and happiness, materials, equity, and beauty.

6.8 Policy, Regulations, and Governance

Within the sustainable housing space, housing and built environment researchers have been paying a growing amount of attention to the role of policy, regulation, and governance in maintaining status quo within existing housing (or built environment) regimes [70–73]. These researchers have also begun to explore how different policy, regulation, or governance approaches have, or could, help facilitate sustainability transitions. This has included evaluating different policy, regulation, and governances approaches and identifying key mechanism to help with upscaling the provision of sustainable housing. For this book, we define policy, regulations, and governing as the rules of engagement for the housing industry that are set by the government. Whereby, the government governs the housing industry using mandatory and voluntary interventions or directives.

The existing housing regime is characterized as an industry that broadly wants less policy and regulatory interference from governments. The perspective is that any development or increase in policy or regulation would negatively impact the industry being able to deliver what the market wants. While regulations for minimum housing quality and performance are not new (see Chap. 2), the past 20 years have seen an increasing focus on policy to lift minimum requirements for new housing and retrofits. This challenges the status quo of the current regime which is forced to reorganize the way it provides housing. For the most part, policy changes have been made in incremental steps (in comparison to what is required for a low carbon future), and the wider housing industry has largely been able to adapt to changes by adding on sustainability elements rather than requiring deeper, structural changes. However, as housing quality and performance requirements head closer towards a zero carbon requirement, it is harder and harder for the housing industry to meet higher standards without having to make those deeper changes.

While most in the housing industry largely adhere to minimum land use and building regulations, there is often a lot of push back against increased sustainability requirements. This rejection of additional requirements is often under the guise of not wanting to inhibit innovation or drive up the cost of housing [74]. Critiques to proposed policy changes are important and should occur, but much of industry push back is based on dubious evidence and misinformation. This has resulted in slow progress towards lifting minimum performance requirements (or, in the case of the UK's Code for Sustainable Homes, removing it all together) and other policy changes. What is left is a largely self-regulated industry with few checks and balances. In countries like Australia, there has been a long history of self-regulation which has arguably contributed to significant building quality and performance issues such as the flammable cladding crisis and dwellings not even meeting minimum sustainability requirements [3].

Sustainable housing has both benefited and been constrained by the development of planning regulations and building code requirements. While both planning and building codes have evolved over time, early examples of sustainable housing often had to demonstrate how they met and exceeded minimum building requirements. This created additional challenges for early sustainable housing projects as many sustainable housing elements fell outside the typical ways of doing housing. Current performance standards have increased, and many jurisdictions use energy rating tools, but sustainable housing providers are still facing challenges as they keep innovating and pushing the boundary of sustainable housing. This is primarily due to problems of demonstrating improved performance when the regulatory systems have not kept up with new developments in terms design, materials, construction, and technologies. Unlike the current housing regime, sustainable housing advocates typically want to see more changes in policies and regulations.

However, there is increasing research, policy, and industry recognition that the provision of more sustainable housing cannot be solely driven by a top-down governance approach and that a range of actors and other approaches (including policy and regulation) will be required as part of the transition. Part of this rationale is from the uncertainty around how to upscale sustainable housing, with the possibility that other actors, designs, materials, technologies, and construction approaches may be needed to deliver this transition at scale. In response, there have been various experiments and urban living labs developed in recent years [31, 75–77]. Essentially, these are places and spaces where additional protection is provided (often by government) to allow sustainable housing innovations to attempt to establish themselves [76, 78]. This is important for creating and establishing new rules around "doing" housing and urban development and exploring what works, or does not work, without typical pressures or restrictions. Urban living labs are not just about testing feasibility; these experiments show the wider industry what can be done and help to establish the supply chains and other changes required to deliver such an outcome. The role of demonstration through exemplar projects has been critical in recent years to help shape and reshape policy and regulations.

Transitions seek to change governing arrangements, markets, culture, meanings, language, infrastructure, technologies, practices, and networks. The challenge is how do these changes occur? In the housing sector, this is often done by developing policies and establishing new regulations [79], by creating "protected spaces" for innovations to occur [80], or through demonstration or pilot projects [30]. These actions and initiatives are established by governments with the aim to either enhance the top end of the market or bring the bottom of the market up. Sustainable housing primarily sits within the top end of the market, while many in the existing housing industry are at the bottom end. A major challenge is finding a balance that pushes the existing regime to deliver better outcomes without constraining sustainable housing [1]. A second major challenge is related to governance; while most of the policies and regulations are introduced by governments, the private sector has a lot of influence, particularly in some jurisdictions.

Over recent years, the sustainable housing movement has evolved beyond just advocating for improved policy and regulations. Sustainable housing advocates are now challenging the existing governance and industry regimes on multiple fronts. This includes locating the need for sustainable housing within the climate emergency, energy resiliency challenge, and addressing wider social outcomes like fuel poverty and health and well-being outcomes [81–84]. In this way, sustainable housing has shifted within the policy, regulation, and governance discourse from a technical challenge to a more holistic focus on social and environmental outcomes. Part of this shift has been calling for greater compliance checks across the industry to ensure that quality and sustainability issues are not only met, but that there is increased well-being and a level of protection for housing consumers [3].

6.8.1 Banning Fossil Fuel-Based Heating

With the goal to cut greenhouse gas and methane emissions by transitioning to electric heating, jurisdictions around the world are banning certain kinds of fossil fuel-based heating systems in new home construction. These bans are a response to the Paris Agreement's 2050 targets and the UN's Sustainable Development Goals which include the move away from polluting fuels. Bans are taking place at the national level across the European Union,[9] at the provincial level in Quebec,[10] and at the local level in places like Dublin,[11] New York City,[12] and Vancouver.[13] Denmark was an early leader in introducing such bans, with the installation of oil-fired boilers and natural gas heating banned in new buildings in 2013 and all buildings in 2016.[14] In Quebec, oil-powered heating for new construction projects was banned at the end of 2021 and, in 2024, it will be illegal to replace existing furnaces with fossil fuel powered heating systems. The province is trying to reduce emissions related to heating building by 50% by 2030, and with 60% of household emissions coming from heating, transitioning to electric heating options makes sense. In Vancouver, starting in 2022, equipment for space and water heating in new low-rise residential buildings must be zero emissions, and by 2025, all new and replacement heating and hot water systems must be net zero. Currently, burning fossil fuels in buildings represents 57% of Vancouver's

[9] https://bit.ly/3B25iDv
[10] https://bit.ly/3Vxmp86
[11] https://bit.ly/3H1tPfY
[12] https://bit.ly/3XQ0vi8
[13] https://bit.ly/3gMY4fU
[14] https://bit.ly/3GW4aoN

carbon pollution, so drastic policy changes are needed to help the City reduce its emissions.

6.9 Everyday Life and Practices

The dimension of everyday life and practice draws on social practice theories that focus on practices as a unit of analysis where change is understood in terms of transitions in practice [85]. Much practice theory research tends to focus on the performance of practices—the "doing" of everyday life, the elements of which it is comprised, and the ways practices are socially constructed [86]. Practices are performed by people; here, we focus on housing users. Users are active players in transitions processes; contribute to new innovations in technologies, products, and practices [87]; and champion change [88]. In addition to consumers, users can also be voters within democratic institutions and participants in political and social movements [89]. For this book, we define everyday life and practices as the activities that are typically and habitually performed in everyday life by individuals, including cooking, showering, and going to work. For housing, we are interested in how dwellings are used and how we might change those practices.

The current housing regime has had limited consideration for current or future households or users, including how these users use and manage their dwellings both in the short term and across the life of the dwelling. As noted in Sect. 6.6, users have often been seen as passive or silent actors in the provision of housing. When users are considered, it is often around elements of the dwelling, such as materials and technology, that are perceived to attract more housing consumers. These include the size and finishes of kitchens, and number of bathrooms. These elements are marketed as elevated elements and work to change social norms about what to expect from dwellings. It was not long ago that many houses would have had a single bathroom, but now an absence of multiple bathrooms is seen as a negative [26].

While there have been a variety of changes to housing design and technology, the current housing regime has primarily focused on the role of technology in delivering improved outcomes: for example, the focus on delivering improved thermal comfort by using more technologies (e.g., a mechanical heating and cooling systems) rather than through materials, passive design elements, building orientation, or landscaping. For many regions, this has created unsustainable practices for occupants. These unsustainable practices are often supported with policies and design, and performance-rating tools where assumptions are made around an "average" user. However, averages range geographically and demographically. These assumptions range from the hours people are at home, the temperature set for heating and cooling systems, and the location of housing. Assumptions like these remove agency from users and impact current and future outcomes.

Sustainable housing starts with the (initial) users at the centre of its thinking. Sustainable housing users have been critical for the development of a wider sustainable housing community and helped shape, or reshape, policy and social norms. Questions around how the dwelling can improve a range of household outcomes (e.g., liveability, affordability, and health and well-being) are often just as important as the environmental impact. Increasingly, these questions are not just about the individual household, but also about how a dwelling can influence and facilitate changes in everyday life and practices. For some sustainable housing providers, this has meant moving away from a technology-focused approach to providing more agency to users through the day-to-day management of their dwelling (e.g., needing to open and close windows or lowering and raising blinds to help regulate thermal comfort and performance) [90]. In addition to increased agency, this also makes the dwelling more resilient to technology failures. However, this is not an argument against technologies; they still have a role to play in improving performance outcomes. For example, the electrification of housing and mobility, through smart home technologies, solar PV, electric vehicles, and two-way battery charging, have created benefits related to improving efficiencies within dwellings and lowering environmental impacts. These improvements have also enabled easier (or more comfortable) off-grid living.

Despite attention paid on the ground, wider transitions research has had limited interest in user practices, consumption, and the everyday life. Where it has been included has largely been in the more technology focused studies [59, 91–94], including within the housing and built environment and wider energy space where a number of papers have emerged in recent years. Early adopters of different design approaches, material selection, and technologies were guinea pigs testing out how things worked, and they often paid higher capital costs for the privilege [95–97]. The experiences of sustainable housing advocates and users, demonstrates the role they can play in helping to guide and accelerate transitions through different (re)configurations of structures, networks, and rules of the game to challenge the existing regime.

6.9.1 Electrification of Homes

The move towards the all-electric home has become an increasing focus amongst some stakeholders in the sustainable housing space [98]. While the use of natural gas (and other resources such as wood) was initially seen as a more sustainable energy option as compared to fossil fuel electricity, this view has been revised in recent years due to the increase in renewable energy generation and the emerging evidence for the wide negative impacts of gas and other fuel types (e.g., on health and well-being). Electrification of homes has been identified as an important step towards not only delivering a more environmentally sustainable home, but also delivering a home that is more affordable to operate (due to paying for only one energy type, which avoids connection fees) and is healthier for users. The move towards electrification has been identified by researchers and policy makers in different regions as being feasible and important for achieving wider decarbonization goals. Research has also identified how an existing dwelling can transition to an all-electric home by replacing various gas (or other) appliances as they are due for replacement.

While evidence for the benefits of the all-electric home has emerged, it has been housing users, rather than policy makers, who have been actively driving the translation from research to practice. Sustainable housing users have been repositioning themselves from passive or silent actors to actors that actively shape and reshape housing, social norms, and even policies. This was not simply a matter of changing appliances or the energy type but has also required associated changes to practices (e.g., using appliances when sufficient solar energy is being generated, or adapting to different ways of heating and the different feelings of warmth those approaches delivered). In places like Australia, the ground up support for the all-electric home has grown significantly in recent years (as exemplified by the My Electric Home Facebook group[15] which now has over 70,000 members) and this ground up support has pushed back on government requirements to have gas connected to new housing, resulting in households removing gas connection from existing housing at record numbers. In 2022, this resulted in the Victorian government announcing that it would change requirements to allow for new housing developments to proceed without connection to gas infrastructure.[16] However, despite increasing support for all-electric homes, sustainability benefits may fall short if electrical grids rely on fossil fuel energy. A wider energy transition away from fossil fuel infrastructure is also needed.

6.10 Culture, Civil Society, and Social Movements

The shift towards more sustainable housing represents a change in culture. For the existing housing industry, the culture around housing is represented by markets and regulations. In contrast, early iterations of sustainable housing were about delivering more sustainable homes, where sustainability was both the outcome and the culture. More recently, we are seeing sustainable housing advocates and providers delivering models that are challenging traditional cultural norms around different elements of housing, including financial, social, and community elements. For this book, we define culture, civil society, and social movements as individuals and organizations challenging and changing the status quo. Change can come from anywhere, inside or outside the regime. We are particularly interested in changes that go beyond individual dwellings and work towards a reconceptualization of housing.

[15] https://bit.ly/3XNUO4A
[16] https://bit.ly/3gQjLLT

In many regions of the world, housing has been delivered via the use of a "less is more" regulation approach and a reliance on the wider consumer market to demand improvements or changes. This has resulted in the replication of tried-and-tested housing typologies, design, materials, and technologies with a business model focused on improving the financial bottom line rather than quality and performance outcomes for housing consumers. Key housing regime actors, such as peak industry bodies, continue to push back against calls for increasing minimum regulatory requirements for quality and performance of new and existing housing. Regime actors are not seriously engaging with the wider structural housing issues created and propagated over recent decades, rather they are protecting the status quo. This creates a range of challenges to shifting the housing industry, and housing consumers, towards a low carbon future.

Sustainable housing has emerged as a new culture within the larger housing industry. This culture is tied to ideas and actions around how housing can be more sustainable. Sustainable housing has been exploring different ways to deliver housing and, in doing so, has established new customs, values, and norms across industry stakeholders and consumers. In the earlier years of the sustainable housing movement, sustainable housing was not primarily about replacing unsustainable materials and technologies with sustainable ones; it emerged more as a bottom-up rethinking of housing across all elements of design, construction, and use. For example, it acknowledged that bigger was not better and that improved design functionality could improve small-space living, and argued that materials should be considered for their durability and ability to improve thermal comfort (not solely aesthetics) as well as for considering the end of life for materials and whole dwellings [7, 99]. These examples represent a shift towards sustainability in the culture of building and designing housing.

Social movements around sustainable housing, at local and international scales, have been instrumental for challenging the housing status quo. Such social movements were developed off the back of wider movements engaging with ideas of sustainability, as well as from the desire to share and learn across sustainable housing projects [100]. Earlier on, these movements were grassroots, both in terms of scale (one-off projects) and actors (non-regime or traditional housing industry). Sustainable housing communities were created through initiatives such as eco-villages and co-housing developments, which allowed like-minded people to come together and elevate the benefits of sustainable housing. These communities also served as a place of learning where ideas could be replicated in neighbouring building, or where communities could serve as inspiration for new developments. Finally, sustainable housing communities are encouraged thinking across buildings to consider benefits at a larger scale [101]. This helped to shift the sustainable housing culture from focusing on individual dwellings to considering the role of these dwellings within the larger urban environment and wider community.

Within the wider transitions literature, there has been an increasing interest in the importance of culture, civil society, and social movements and how these play critical roles within sustainability transitions [102–104]. These elements challenge the current ways and rationale of doing things and can create wider culture change through changing social norms, values, and everyday practices [102]. In doing this, they help create protective spaces for innovation and shape the support and effectiveness of transitions policies. There has been some focus on these points within a framing of sustainable housing transitions. Our own work, for example, highlights that wider culture, civil society, and social movements are evolving not just within the sphere of direct stakeholders designing, building, and occupying sustainable houses, but within a much wider reach of stakeholders who intersect with the transitions process such as financial institutions who fund housing development [2, 65].

6.10.1 Renew—Organization and Sustainability Magazines

Renew[17] (formally the Alternative Technology Association) is an Australian not-for-profit organization that was established in 1980 to provide inspiration, information, independent advice, and advocacy to help people live more sustainably in their homes and communities. The organization is involved in a wide range of activities including

[17] https://bit.ly/3ERjCji

undertaking sustainability consultations, providing free advice to members, organizing and hosting webinars and events (including a Speed Date a Sustainability Expert and annual Sustainable House Day event), and publishing two quarterly sustainability magazines: *Renew—technology for a sustainable future* (with over 160 issues) and *Sanctuary—Modern green homes* (with over 60 issues). The organization and publications engage with more than 250,000 people each year and have an active membership of 11,000 people (2020–21). Renew has played a key advocacy role in driving recent regulatory changes in Australia through disseminating research and continued supporting dialogue with key stakeholders (including households). Beyond just a focus on the physical home or technologies, Renew is increasingly evolving to include spaces around houses and communities (such as gardening and urban greening), new considerations of housing such as the role of electric vehicles, and addressing future climatic and resiliency challenges as a community. For example, issue 60 of Sanctuary magazine was a flood resilience special. Through these various activities, Renew has helped reconceptualize housing and sustainable housing for Australian households through a largely bottom-up community approach and, in the process, has managed to help establish new customs, values, and norms.

6.11 Ethical Aspects

For decades, ethical considerations for the design, construction, and maintenance of new and existing housing have been at the centre of research and advocacy work. However, these issues have received less attention within sustainability transitions scholarship. This dimension draws upon many of the previous dimensions in relation to the way the current housing regime operates, focusing on how these operations impact ethical aspects of transitions. For this book, we define ethical aspects as good governance practices and considerations of poverty, justice, and inclusivity. In addition, we emphasize equity, rather than equality, to ensure that everyone has an opportunity to participate in a way that is appropriate for them.

The housing sector is largely driven by guiding principles and business practices that prioritize maximizing financial profit over quality, performance, and occupant outcomes. However, this financial lens on housing has meant dwellings are too often distilled into financial outcomes, rather than considering the wider social, environmental, and through-life benefits of improved quality and performance. As we explored in the earlier chapters of this book, this framing around the capitalization of housing has impacted wider social outcomes including poverty, justice, and inclusivity [81, 84, 105–107].

This financial framing, along with consistent push back against increasing regulations or compliance requirements, has led to a housing industry that does not prioritize ethical considerations or consider the wider climate emergency context. While individual stakeholders are not likely setting out to be unethical, the industry's engrained practices and the short cuts or lack of checks and balances can add up to negative outcomes. This is evident in the rise of minor and major building defects in new dwellings, and the significant challenges that housing consumers face trying to get these issues addressed. Notable examples include the use of asbestos, leaky homes, and the flammable cladding crisis [3]. The shift of the construction industry from being a more local industry to one that is part of the globalized network is another example of unethical practices. As supply chains have become more globalized, there has been limited oversight which has led to major environmental impacts from some materials and technologies, and has supported modern slavery practices.

Sustainable housing attempts to address a number of these ethical issues that have emerged through the current housing regime. This includes addressing things like the ethical considerations in supply chains and modern slavery (e.g., doing checks on where materials come from and how they are manufactured and ensuring everyone is paid a fair wage) [108, 109]. It is not just about ensuring ethical practices at the global level, but also shifting back towards using local material and labour where possible to help local economies. There is also an increasing focus of sustainable housing stakeholders on how quality housing can be provided not just for those who have wealth and resources, but also for vulnerable and marginalized households who are often left behind in the move towards a more sustainable future. This includes being able to provide such housing for low income households, renters, the unhoused, and so on. This is partially in recognition that the benefits of sustainable housing are likely to have even greater benefits for health, well-being, finance, and social outcomes for these vulnerable housing cohorts. In this regard, sustainable housing has been discussed as being able to help wider ethical and justice considerations such as addressing the increasing rates of fuel poverty around the world.

It will not be possible to knock down and rebuild all existing housing to a higher quality and performance level, so the attention in recent years has shifted to the necessary role of deep retrofits on existing housing. There are ethical considerations wrapped up within this focus, with the idea that we leave as many raw resources "in the ground" as we can for future generations. This symbolizes a growing movement within sustainable housing consumers that housing must be seen as long-life infrastructure. It is no longer just about the first or current user, but about what happens across the life of the dwelling. Increasingly, this is being considered within the context of a changing climate, and responding to the climate emergency requires us to consider ethical aspects of how we will scale up sustainable housing.

Ethical aspects of transitions within the housing domain have not received much attention, but there are opportunities for sustainable housing research to incorporate good governance practices and considerations of poverty, justice, and inclusivity. This includes exploring the ongoing question within transitions research around 'who wins, who loses, how and why' [110, 111]. In the race towards a more sustainable future, we need to ensure that social aspects of socio-technical dimensions are not forgotten. This means that a more sustainable future must also be just [112]. For our definition of ethical aspects, we drew on the work by Barrett et al. [113] work on ethical cities which argues we need to integrate climate action, good governance, and action on inequality to achieve ethical outcomes. From this perspective, ethics shape both process and outcomes related to sustainable housing.

6.11.1 Half a House

In 2016, Chilean architect Alejandro Aravena won the Pritzker prize for his affordable housing concept of providing people with half a house.[18] Aravena's practice, Elemental, was commissioned to design 100 houses with a budget of US$7500 per house (including land, materials, and construction). This amount would normally finance houses that are ~30 square metres, whereas the average middle class family in Chile lives with 80 square metres. Rather than build small single-storey houses, Aravena proposed building 'half a house' of two to three storeys. The idea was to build good structures with basics such as plumbing for a kitchen and bathroom and core shelter, while leaving the other half of the house incomplete for the households to finish as their individual resources and circumstances allowed. These half houses are also robust and built to withstand earthquakes and other disasters. Rather than just being a house, the half a house is a tool to escape poverty for the households. Once families moved into their houses the unfinished concrete cubes quickly transformed into different spaces that reflected the needs and skills of the household. As we have stated earlier in the book, shelter is a basic need, and good quality housing provides many benefits including increased health and well-being for the inhabitants. Aravena's approach to affordable housing centres ethics and equity, as well as the environment, with the overall aim of increasing the capacity of the households.

6.12 Conclusion

In this chapter, we explored ten important socio-technical dimensions that we feel will play an important role in delivering the required sustainable housing future. These dimensions build upon earlier sustainable housing transitions research undertaken by scholars around the world over the past two decades. However, we have expanded on these to account for current context and recent/future changes across the housing and sustainability markets. We have defined each dimension and

[18] https://bit.ly/3H0Vg9v

discussed how it was viewed within the wider transitions literature; we have explored how the current regime is operating related to that dimension and highlighted the opportunities that sustainable housing offers in engaging with the dimension. For each dimension, we have provided a short example to demonstrate how these dimensions are playing out in innovative ways. We explore these socio-technical dimensions in more detail across in-depth case studies in Chap. 7.

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7

Sustainable Housing in Practice

7.1 Introduction

Across the opening chapters of this book, we discussed the importance of needing an urgent transition to a sustainable housing future from environmental, social, and financial perspectives. We also explored the current provision of housing and the disconnect between that and where we are required to be for a low carbon and equitable future. Despite the mounting evidence around the benefits of sustainable housing, we still face several challenges in trying to change the system of housing provision. In Chap. 5, we discussed the potential for a sustainability transitions framing to help address some of these ongoing challenges and to help scale up and accelerate the provision of sustainable housing. We identified ten core socio-technical dimensions from previous research and our own reflections, which were presented in Chap. 6 along with short examples of these dimensions playing out in the sustainable housing space.

In this chapter, we explore these socio-technical dimensions in more detail through key themes we have introduced throughout this book: high performing housing, small housing, shared housing, neighbourhood-scale housing, circular housing, and innovative financing for housing. Through these themes, we address sustainable housing at different scales

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as per our discussion in Chap. 3: the dwelling scale, neighbourhood and city scale, and the state, national and international scale. In this way we hope to demonstrate different elements and approaches to providing sustainable housing, and indeed, sustainable communities more broadly.

For each theme, we present an overview of and examples of how the theme addresses the different socio-technical dimensions. We then present real-life case studies of where the theme is being demonstrated in practice, again referring to the socio-technical dimensions. We have selected these cases based on our own understandings and knowledge, but there are many other equally promising cases we could have included and many of the case studies we selected could have fit within various themes. Our intent is to show how key ideas from the book are translating into the current provision of sustainable housing and demonstrating elements already being provided for what could be the basis of a sustainable housing transition. In each section, we use the key terminology of the socio-technical dimensions as presented in the summary table (Table 7.1).

7.2 High Performing Housing

The type of sustainable housing we have described in this book provides significantly improved performance outcomes compared to the current provision of the majority of new and existing dwellings across a number of dimensions. Importantly, the *physical attributes, knowledge,*[1] and *everyday life and practice* considerations go beyond the current and previous focus on improving energy performance for heating and cooling loads and takes a more holistic view of the dwelling's impact across the whole of its design, construction, use, and end of life phases. In this way, consideration is given to all *physical attributes* (elements) within a dwelling, such as the impact of material choices, and the way the dwelling can enhance liveability outcomes. It is clear from the wider evidence

[1] In this chapter we highlight where socio-technical dimensions are being addressed using the terminology from Table 7.1 and italicizing the terms to make it clear where each dimension is being discussed.

Table 7.1 Summary of the socio-technical dimensions the themes engage with

Socio-technical dimension	Definition	Theme: High performing housing	Small housing	Shared housing	Neighbourhood scale housing	Circular housing	Innovative financing for housing
Guiding principles	The embedded moral values that establish a framework for expected behaviour, practices, and decision making.	■	■	■	■	■	
Physical attributes	The individual and combined physical elements of a dwelling.	■	■	■	■	■	■
Knowledge	The 'doing, thinking, and organising' of housing.	■	■	■	■	■	■
Geography	The location (specific place) and scale of housing.	■	■	■	■	■	
Industrial structures and organization	The multiple actors and stakeholders across the traditional housing industry, including developers, builders, manufactures, amongst others.	■		■	■	■	■
Policy, regulation, and governance	Where and how housing is sold or exchanged (markets), the consumers or occupiers of housing (users), and the politics and regimes, including government and industry players, that dominate the housing sector (power).		■	■	■	■	■
Markets, users, and power	The rules of engagement for the housing industry set by the government.	■	■		■	■	■
Everyday life and practices	The activities that are typically and habitually performed in everyday life by individuals; these include cooking, showering, and going to work. For housing, we are interested in how dwellings are used, and how we might change those practices.	■	■	■	■	■	
Culture, civil society, and social movements	Individuals and organizations challenging and changing the status quo.	■	■	■	■		■
Ethical aspects	Good governance practices and considerations of poverty, justice, and inclusivity.	■		■	■	■	■

Shaded box indicates the theme demonstrates that socio-technical dimension

(knowledge) from different locations around the world that sustainable housing can be zero energy and carbon across its design, construction, and use, and also provide housing which has zero operational costs to run and which can significantly improve health and well-being outcomes that impact *everyday life and practices* as well as *ethics* of housing [1–4]. Others will no doubt have different definitions of what a sustainable house is, and it almost does not matter how a sustainable house is technically defined if it is centred around the core ideas discussed in this book. We also know that the way we define sustainable housing (and communities more widely) will continue to shift as we provide more high performance housing and new knowledge, materials, construction practices, and technology innovation shapes and reshapes what sustainable housing is or could be.

There are important benefits of moving from incremental performance improvements to significant performance improvements. Chief amongst those is that to achieve zero carbon emissions goals by 2050, the residential sector will need to reduce carbon emissions by 90–100% by that time, if not sooner. This means changing both the *guiding principles* and *physical attributes* of housing. Therefore, all new housing that is not built to that future standard will need to undergo retrofits at some point in the future which will add further housing costs and require more resources. Furthermore, while there can be some small performance improvements through one-off retrofit activities, deep retrofit is required to provide significant emissions reductions, and also to provide a greater range of benefits for the household such as reducing operating costs and improve health and well-being outcomes [4–8]. There are also a number of wider benefits beyond housing that could be achieved through significant improvements to the performance of housing, including reducing energy generation requirements at a network scale (*geography*).

We are not going to attempt to list all the *physical attributes* and *knowledge* considerations for providing a high performance house; such considerations will depend on a range of factors including local climatic conditions, local materials, the make-up of the wider energy grid (if there is one), whether the dwelling is new or retrofitting an existing dwelling, and the scale (e.g., individual dwelling or neighbourhood/city) [3, 9]. Experts in different jurisdictions will be able to guide the specifics for the best options in each context, but there are some broad rules of thumb that are largely relevant across the world. For new homes, *physical attributes* and *knowledge* include:

- The size is only as large as required for the needs of the occupants
- Optimal orientation
- Use of passive design principles
- Improved thermal performance through increased insulation and window glazing
- Use of local and robust materials
- Maximizing energy and water efficiency (e.g., appliances)
- All-electric energy provision
- Inclusion of rainwater tanks plumbed into key internal uses where safe to do so

- Inclusion of renewable energy generation, battery storage, smart appliances, and electric vehicles

For existing homes, *physical attributes* and *knowledge* include:

- Sealing up gaps and cracks
- Improving or adding ceiling, wall, and underfloor insulation
- Ensuring good quality blinds/curtains, and adding seasonal external shading options where possible
- Replacing inefficient appliances with modern smart energy and water efficient appliances like heat pumps (heating, cooling, and water heating)
- Adding secondary glazing or window films, or undertaking full double-glazed window replacement

As discussed earlier in the book, there are a number of formal and informal ways to provide significantly improved performance outcomes in housing. One of these approaches is the Passive House (or Passivhaus in German) standard that has emerged in recent decades as one of the most rigorous dwelling standards. Passive House demonstrates different *guiding principles, physical attributes, knowledge, industrial structures and organizations, everyday life and practices, culture, civil society, and social movements, and ethical aspects*. Below, we introduce and discuss the standard and present two cases demonstrating where this has been applied and what benefits were achieved.

Passive House is a voluntary low energy building standard that was developed in Germany in the late 1980s [10]. Since this time, over 25,000 dwellings have been certified to the standard, with more than 100,000 additional non-certified dwellings estimated to have been constructed following these principles. The increasing numbers of Passive Houses highlights how they are setting new *guiding principles* and requirements for *physical attributes,* and starting a *social movement* [10]. The majority of these buildings are in Central Europe; however, there are increasing numbers of buildings around the world which meet the Passive House standard, including in the USA, Canada, and Australia which demonstrates change in *geography*. The aim (*guiding principles* and *knowledge*) of Passive

Table 7.2 Performance targets for a European climate for Passive House performance for new dwellings and retrofit [adapted from 10]

	Passive House (new dwellings)	EnerPHit (retrofit of existing dwellings)
Primary energy demand	≤135 kWh/m^2. yr	≤135 kWh/m^2. yr + heat load factor
Primary Energy Renewable (PER)/ Energy use intensity	≤60 kWh/m^2. yr	PER: ≤71 kWh/m^2. yr (Cool Temperate) PER: ≤65.5 kWh/m^2. yr (Warm Temperate)
Space heating demand	≤15 kWh/m^2. yr	≤20, 25 or 30 kWh/m^2. yr
Space cooling demand	≤15 kWh/m^2. yr	≤25 kWh/m^2. yr
Airtightness	≤ 0.6 air changes/hr @ n50	≤1.0 air changes/hr @ n50
Summer overheating	Max 10% >25 °C	Max 10% >25 °C

House is to achieve an energy efficient, thermally comfortable, and affordable house. To be certified to the Passive House standard, a building must meet the following *physical attribute* criteria (Table 7.2), adjusted based on the country and climate zone.

7.2.1 Erneley Close—United Kingdom

Erneley Close is a social housing development in Manchester (UK) that underwent a retrofit to EnerPHit Standard in 2015. The project involved the owner (One Manchester) (*markets, users, and power*) undertaking a retrofit of 32 two-bedroom walk-up flats for a cost of £3.1 m. The *guiding principles* for the project were to reduce living costs, and improve health and well-being outcomes for the occupants, as well as initiate wider regeneration of the area [11]. As David Power (Chief Executive, One Manchester) said "…the reason why we've done this scheme is about creating long-term value for the neighbourhood and setting a standard for an area which needs wider regeneration" [12].

In terms of technical performance and *physical attributes*, there was a significant improvement in overall performance. Research that monitored the performance of the refurbished dwellings found that they performed significantly better than typical dwellings, with more stable indoor air temperatures and a reduction in the use of heating and cooling technologies [11]. For example, space heating demand reduced from 300 + kWh/m^2/yr to 23 kWh/m^2/yr and air tightness reduced from more than 10 air changes per hour (at 50 Pascals) to 0.8 [13]. This contributed to a reduction in energy costs for households, with tenants reporting savings of up to £100 a month. As one tenant reflected:

> Before all these works my flat was freezing. I was spending about £15 per week on heating the flat and even using fan heaters to get the temperature up. Since moving back in December, I've only used the heating once. It's really taken the pressure off, knowing we won't be spending an arm and a leg on keeping the house warm, day in, day out. More than that though, everyone here is just so proud of what's come out of this project—it's really put Erneley Close and Longsight on the map. There's a real community spirit here now … My little grandson calls the building 'Nanny's castle' because he says it's magical. [14]

The *ethical aspects* of the Erneley Close high performance housing were not only related to lower energy costs and a reduction in energy for heating and cooling. There was a significant uplift in community value and pride in the area—benefits that went beyond the individual dwelling [11]. Additionally, tenants reported that their health and well-being improved. For example, several tenants spoke about having lower stress due to reduced energy bills and one tenant reported reduced asthma symptoms. Another tenant stated their child was sleeping significantly better due to the quietness in the dwelling from the improved building envelop. This quietness also helped the child with their concentration while studying, potentially leading to better academic outcomes.

7.2.2 Whistler Housing Authority Employee Housing—Canada

The Whistler Housing Authority (WHA) is a municipal owned corporation in British Columbia (Canada). WHA oversees the development administration and management of resident restricted housing in

Whistler. Its aim is for at least 75% of employees to be housed locally through both rental and ownership opportunities that are affordable for local income earners and retirees in perpetuity. As a resort municipality, Whistler struggles more than most with housing affordability. In 2022, the municipality completed the Whistler Housing Needs Report (mandated by the provincial government) and one of the more significant findings was that close to 90% of Whistler's workforce could not afford market housing rates within the municipality [15].

Completed in 2018, the WHA Passive House Employee Apartments is a 24 rental unit, multi-unit residential building [16]. The project is a collaboration between Integra Architecture, BC Passive House, and WHA, representing stakeholders within both the *industrial structures and organizations* and *markets, users, and power* dimensions of housing. The building meets Passive House standards and it was designed and constructed using a prefabrication system. The *physical attributes* of the building included the use of offsite modular construction, a panelling system, and simple massing. These helped to reduce costs and increase productivity, as well as increase energy efficiency. In addition, the building was designed with an entry canopy and exterior shading devices, elements that are critical to the building's performance by providing solar shading to avoid unnecessary heat gains and improve occupant comfort. As the building has an extremely low life cycle cost for heating, cooling, and overall electricity, the WHA can maintain it at a lower cost which translates to lower rents for local employees. This benefit is particularly important for organizations like WHA that both develop and manage residential buildings. Finally, a unique "Whistler" element to the building is that it was designed with bicycle circulation in mind to support the residents' *everyday life and practices*—bicycles can enter, exit, and be stored easily within the building.

7.3 Small Housing

The size of a dwelling is related to various factors, including location, culture, and costs [17]. How much space one person, or a family, occupies varies across the world [18]. In Australia and the USA, the average size of a house is around 2500 sq. ft. (240 sq. mt.) [19, 20], which is the largest global average size. However, the size of houses in these countries was not always this big [18]. In the 1950s in Australia, the average house was approximately 1075 sq. ft. (100 sq. mt.), meaning sizes have more than doubled. At the same time, the average number of people living in each house has declined [21]. Larger houses consume more resources and require more energy for heating and cooling. In terms of *physical attributes*, they need more materials for building and maintenance, and need more energy to manufacture and replace any materials or technologies. Larger houses also require more land; while this may be obvious, it is significant because larger houses and lots translate to lower densities. Density is an important consideration from a *geography* perspective, including access to transit, jobs, services, and other amenities. Many low-density neighbourhoods are car dependent which further increases the environmental impact of larger houses. Finally, low density developments contribute to non-communicable disease risk factors such as physical inactivity, social isolation, unhealthy diets, and poor air quality [22]. And yet, large single-family houses in low density neighbourhoods are embedded within the culture of certain jurisdictions (e.g., Australia), as well as institutional and legal structures [23].

While "the Anglophone ex-colonies of the United Kingdom, such as Australia, the United States and Canada, are characterized by suburban sprawl, mostly large detached houses with a big backyard" [24, p. 299], small dwellings are the norm in most parts of the world, including Asia, Africa, and Europe. Perhaps surprisingly (or not), the regions with the largest houses are where we also find a growing tiny house movement although, the movement has taken hold in some European countries including France, Germany, and the Netherlands [25]. This movement refers to all housing typologies with a smaller footprint and is often connected to the *guiding principles* and *everyday life and practices* of minimalism and living with less. Many credit the movement's roots to Henry David Thoreau, nineteenth-Century US naturalist and essayist, and his call for simple living in natural settings and divestment from material dependence. As an example of *culture, civil society, and social movements*, the tiny house movement has amassed a large internet following through social media accounts, blogs/websites, and YouTube channels, as well as a growing number of documentaries and TV series.

Small housing is frequently claimed to be more environmentally sustainable than conventional sized dwellings [17, 24, 25]. This is primarily due to the scale and *physical attributes* as they use fewer resources. Others argue that living in small housing fosters more sustainable behaviours. In fact, *guiding principles* of environmental sustainability is identified as a strong motivator for many who choose to live small [26]. Some research has found that residents of small housing are more likely to use public transport if they are in urban areas, and for residents in more rural areas, there is an increase in renewable energy use and rainwater harvesting [25]. Less material resources translates to financial savings for small housing homeowners. Based on Rawlinsons Australian Construction handbook, in 2016 each additional square metre of brick-veneer house in the state of Victoria cost an average of AU$1245 extra for construction. Stephan and Crawford [27] calculated that, when combined with heating, cooling, and lighting energy bills over 50 years, the total cost per square metre is higher at around AU$2000.

Another element of small housing is the potential for density, which is a *geography* dimension. As the world's urban population continues to grow, many cities are looking for ways to incorporate more households within existing built-up areas. Densification or urban consolidation involves increasing or maintaining the density of housing in established residential areas. There are numerous ways to achieve this goal with more common ones including height and infill. Height primarily refers to apartment buildings built to medium (gross of ~20–40 dwellings per hectare) or higher densities (gross of more than 40 dwellings per hectare). Height allows for dwellings to be stacked, meaning they use less land than single-detached housing. And, while not always the case, apartments are often smaller than single-detached housing. Infill housing generally "fits within" an existing neighbourhood without significantly altering its character or appearance. Examples of infill housing include accessory dwelling units (ADU), secondary suites, and missing middle typologies such as duplexes, triplexes, fourplexes, multiplexes, townhouses, row housing, cottage clusters, and courtyard apartments. *Policy, regulation, and governance* and *markets, users, and power* are the primary dimensions related to this type of development and will determine whether developments are permitted (by the government) and accepted by local residents.

7.3.1 Tiny Houses—Globally

Tiny houses are self-contained dwellings of 400 sq. ft. (37 sq. mt.) or less that can be built on a trailer base and towed by a standard vehicle/truck [24]. The mobility of tiny houses is mostly due to the *policy, regulation, and governance* surrounding the units. Non-permanent or mobile houses are not recognized or regulated by governments, making it easier to find a "parking spot". This means that these houses can be located on lots with single family (R1) zoning or on rural properties. The mobility of tiny houses also makes it necessary (or an opportunity) to have the houses operate off-grid. Many tiny houses have *physical attributes* such as composting or incinerator toilets, exterior water tanks, PV systems with battery storage, and propane/gas tanks (usually for cooking). Besides the gas for cooking, the off-grid elements increase the sustainability of these houses, as does the size of the house itself. The tiny house movement also has connections to *guiding principles* of the de-growth movement and those seeking to living within planetary means (see Chap. 6). For many, the affordability of tiny houses is the strongest motivation for building or acquiring this type of housing as they are seen as a pathway to home ownership for those unable to get into the traditional market [24]. There is a strong do-it-yourself culture associated within the *everyday life and practices* of residents which relates both to environmental and affordability concerns. However, as the popularity of the typology has grown, there are now dedicated tiny house builders for designing and constructing tiny houses. This shift is similar to what we find within the sustainable housing movement more broadly.

7.3.2 Laneway Houses—Canada

Laneway houses are a form of detached secondary suites (self-contained dwelling) or ADU built on pre-existing lots.[2] These units are usually in a backyard with an opening to a lane or street, sometimes replacing a detached car garage. Laneway houses are being used across cities in

[2] https://bit.ly/3B3kiRo

Canada, particularly in Vancouver and Toronto, to create opportunities to increase the number and diversity of rental (and in some cases ownership) units in lower density neighbourhoods. Laneway houses can accommodate a variety of occupants, including multigenerational or multi-family living and more common renter occupants. Placing housing in existing neighbourhoods increases opportunities through *geography* for people to access amenities such as transit, jobs, and services. The locations and size of laneway houses is dependent on the local *policy, regulation, and governance* such as zoning and bylaws. The location is related to zoning, where lots need to be zoned R2 or higher (meaning more than one dwelling on the lots). Bylaws will determine some of the *physical attributes*, including the footprint and setback of the unit in relation to the size of the lot and distance between other structures, the height, number of storeys, minimum floor area, minimum room sizes, the orientation, and exterior components such as deck or balcony.

7.3.3 Never Too Small—Globally

Never Too Small (NTS) is a media company that features small footprint design and living.[3] NTS is based in Melbourne, Australia, but showcases small footprint living from around the world. Most of the projects shared are less than 600 sq. ft. (55 sq. mt.), with most being much smaller. Through their YouTube Channel, Instagram and Facebook accounts, hardcover book, and website, they feature designers and their award-winning tiny/micro apartments, studio, and self-contained projects. In their book *Never Too Small: Reimagining Small Space Living*, they include the layouts of each of the projects to share *knowledge* and encourage more people to live small. NTS's *guiding principle* is that, through design and creative use of space, we can transform the way we live in cities. Many of the designers from the projects showcased are passionate about supporting more sustainable housing outcomes by being more intentional about the size and location of dwellings and the *physical attributes* used as part of the design and construction.

[3] https://bit.ly/3VIoT3x

7.3.4 600sqftandababy—Canada

600sqftandababy (600) is a blog and Instagram account chronicling the experience of a family of three, then four (two adults and two children), living in a 600 sq.ft. one-bedroom apartment in Vancouver, BC.[4] 600 also includes *knowledge* sharing through "Small Home Tours" of other families intentionally living in spaces of ~1000 sq. ft. (93 sq. mt.) or less. By sharing images and stories, the author shares their family's *guiding* principles around doing their best to live small, thoughtfully, and sustainably in an urban context. There is a strong focus on living with less not only in terms of square footage, but also when it comes to the "stuff" we put in our homes. While not always explicit in the material, affordability also plays a big role in the choice to live small. As the popularity of the blog (and the concept) grew, the author also began offering small space design consults. The aim of 600 is to demonstrate through *everyday life and practices* how a family lives small with the hopes of encouraging others to consider doing the same, as well as offers a sense of community and confidence to those that already do.

7.4 Shared Housing

For most of human history, people have lived communally. People lived in communities, camps, settlements, villages, or in multigenerational family arrangements where resources and labour were shared or traded. This began to change at the onset of the industrial revolution (beginning in the late 1700s), which represents the process of change from an agrarian and handicraft economy to one dominated by industry and machine manufacturing. As industry changed, so did social and political conditions. Famers and artisans moved to cities to become industrial workers in factories and populations began to increase (particularly in cities). By 1800, London was the largest city ever known with nearly 3 million inhabitants. Tenement buildings were built to house the growing populations of workers and their families. While many people lived in the same

[4] https://bit.ly/3ixYKWI

buildings, families lived in individual units and spaces were not shared. These buildings were overcrowded and referred to as slums. Those who could afford better living conditions and larger spaces moved to areas outside of the cities, what we now call the suburbs. Early suburban developments solidified our understanding of housing nuclear family units within self-contained houses and yards. What began in the UK has shaped the way many people have lived (and continued to live—*everyday life and practices*) in the USA, Canada, Australia, New Zealand, and many parts of Europe. These living arrangements were further entrenched in 1900s through the use of *policy, regulations, and governance* mechanisms to enforce separation of land use types, distance between buildings, and minimum sizes of rooms and dwellings.

The post-war era (1950s) is often referred to as the era of the suburban. While the suburbs were full of promises—peace and prosperity—they also revealed problems within society. The dispersed nature of suburban developments meant there was an over-separation of uses, lack of activity, privatization of public spaces, reliance on private vehicles, neglect of the inner city, and many were left out (e.g., racialized and queer populations). The 1960s and 70s saw a backlash in the post-war suburban societies in places like the UK, Europe, and the USA. Communal movements began to take shape where people created communes and cooperatives, squatted in empty or under-utilized buildings, and practised alternatives to economic capitalism. Motivations (*guiding principles*) differed from environmental to spiritual to anti-government, among other ideologies. But, each communal approach represented a radical departure from the nuclear family model. The communal movement has been experiencing a revival since 2010's. Some of the external factors for this include the impacts of COVID-19 lockdowns, loneliness, the desire for low carbon living, and housing affordability.

Cities, and suburbs, can be isolating places, particularly for those living alone. A 2017 Vancouver Foundation survey found that almost a third of 18–24-year-olds in the region experienced loneliness "almost always" or "often" compared to just 14% of the rest of the population [28]. Housing affordability was identified as one of the main culprits for making people lonely. In Canada, the 2021 census data revealed that couples with children accounted for 26% of the total population while one-person households represented 30% of the population [29]. For the most part, the *physical attributes* of housing have not necessarily changed at the same pace as the changes in demographics. As mentioned in Sect. 7.2 in the small housing theme, the average house size in places like Canada (as well as locations like Australia and the USA) has increased (as has the price tag). We are seeing more apartments, particularly one-bedroom dwellings, but we are missing middle and alternative housing options, such as shared housing.

Buildings, including housing, and neighbourhoods can offer spaces and opportunities to interact and form communities. One of the *guiding principles* of shared housing is to explicitly create opportunities for encounters and conviviality between residents, as well as promote people to linger through *physical attributes*. Danish urban designer Jan Gehl emphasizes the importance of “life between buildings” as it promotes trust and intercultural and intergenerational tolerance, and it enables people to get to know their neighbours [30]. In shared housing, design is used to provide the conditions for community, but it is through people’s *everyday life and practices* that connections are created and held. This can be done in intentionally communal spaces such as lobbies and circulation, as well as shared laundry facilities, gardens, rooftop terraces, and other amenities. These spaces can also be designed to invite people to linger or incorporate elements such as furniture, information boards, or art displays. In addition to physical interventions, some shared housing has a strong emphasis on selection or self-selection of residents. In some cases, people self-organize to develop shared housing, like Baugruppen in Germany (see Sect. 7.3 for more on this approach). For existing shared housing development, this may be done through application or vetting processes or by limiting residents to owner-occupiers.

There are many arguments and claims of greater sustainability and reduced environmental impact for shred housing, when compared to mainstream housing [31]. This is often attributed to the *guiding principles* of the developments or residents. Many are drawn to shared housing for environmental reasons, and social interaction with others engaging in pro-environmental *everyday life and practice* can contribute to higher participation across the development or community [32]. In terms of *physical attributes* and *geography*, shared housing can support sustainable housing outcomes. Sharing spaces or facilities (such as laundries) can reduce the size of individual dwellings and minimize the environmental footprint of the development and improve resource efficiency [33]. Shared housing offers opportunities for more efficient use of land through use of space and density. The scale and communal nature of shared housing can support effective use of resources and waste management practices. These include more elaborate composting and recycling programmes; grey water filtration systems; rainwater collection; community scale energy projects; and sharing resources and bulk purchasing [32].

7.4.1 Co-Housing—Globally

The concept of co-housing (bofællesskab in Danish) originated in Denmark in the late 1960s, but it is now a global movement (*geography*) [34]. Co-housing developments are self-managed housing clusters that include self-contained dwellings with all the amenities of a typical dwelling (including a kitchen, bathroom, etc.), as well as shared spaces and facilities (*physical attributes*). There are no strict rules when it comes to the size or form of the developments. Co-housing developments can include new and existing buildings, attached and detached housing types, different types of tenures (owner-occupier, rental, co-operative), different numbers of occupants or residents, different demographics, and different locations (urban, suburban, rural). What is shared across the communities is the belief in creating intentional communities by living with your neighbours, not beside them (*guiding principles*) [35]. In a study of 18 collaborative housing communities in England and Wales conducted in 2020 during the first wave of COVID-19 lockdowns, researchers found that co-housing dwellers experienced a higher level of support and care than typical households (*ethical aspects and everyday life and practices*) [36]. Co-housing developments are primarily bottom-up initiatives with future residents taking the lead, or at least participating in the design and management of the community (*knowledge*).

Co-housing has been proposed as a response to both the housing affordability and climate crises [37]. As an alternative housing model, it aims to combine “the three pillars of sustainable lifestyles: technical (energy), social (community), and economic (affordability)” [37, p. 66] (*guiding *principles*). Measuring the sustainability of co-housing is challenging because there is high variability across developments [38]. However, as residents tend to live in smaller units and share spaces and facilities, they often have a lower footprint. In addition, the value of cultivating an intentional community attracts a lot of people interested in living more sustainable lifestyles (*everyday life and practices*). The co-housing concept, therefore, has potential to support sustainable housing outcomes.

7.4.2 Nightingale Housing—Australia

Nightingale Housing, a model that prioritizes shared and sustainable housing, emerged in Melbourne (Australia) in the late 2000s [39, 40]. This model was pioneered by architect Jeremy McLeod of Breathe Architecture, in conjunction with a collection of local architects working with the current *industrial structures and organization* of housing who shared a similar goal: to provide higher density housing that properly, and equally, addresses the triple bottom line of sustainability and affordability outcomes. The *guiding principles* of Nightingale Housing have since evolved and now include sustainability, reductionism, energy efficiency, affordability, community, alternative transport, healthy homes, engagement, housing security, resales, Teilhauses (German for "part of house", also known as micro units), community contribution, and reconciliation [41]. While the model started in Melbourne, it has moved to other regions of Australia (*geography*). Through *knowledge sharing*, there are now 15 completed developments with seven more under construction and another ten upcoming [42]. While the developments go significantly beyond minimum construction code performance requirements (e.g., providing a minimum thermal energy load of 68 MJ/m^2/year which is 40% lower than regulated minimum for new housing of 114 MJ/m^2/year in 2022 for the Melbourne climate zone), it is the provision of shared and community spaces that is challenging business-as-usual design in Australia.

The *physical attributes* of Nightingale Housing follow a reductionist design approach to remove some of the key private elements from individual apartments that are be typical in standard apartment developments in Australia. In particular, a key difference is the removal of individual laundries in favour of a shared laundry located on the roof of developments. The aim of this approach was to not only save internal space in the apartments, along with associated costs and resources, but to also include a deliberate plan to help foster *culture* and community by providing a place for residents to engage with each other. As McLeod has stated, "when you are doing your washing on the rooftop you quickly meet all your neighbours. Meeting people over washing laundry is a good way to break down barriers pretty fast. After that happens a few times, there are no awkward silences!" [43]. The rooftops typically include a rooftop garden with space to relax, entertain, and even host events. Again, this reduces the need for private space and opens up opportunities for sharing and community engagement. Other opportunities for sharing within the model include the provision of access to shared cars, although the developments are designed to reduce dependence on cars (e.g., through reduced or eliminating car parking on site). The ground floor of these developments also typically includes a combination of office space and retail/services to activate the street frontage and, again, create vibrant opportunities for engagement for building occupants and the local community. In several cases, the cafes that have been included have *ethical aspects,* as they are social enterprizes, giving an opportunity for work to people who might not have typically had that type of opportunity otherwise.

7.4.3 Three Generation House—Netherlands

While common before the Second World War, most families in the Netherlands now live in nuclear family homes separated geographically from other generations and family members. The Three Generation House, is a single multi-storey building located in *Amsterdam Noord* and designed by BETA Office for Architecture and the City, sought to change this paradigm and reconsider multi-generational living (*guiding principles*) [44]. As the name suggests, the house is home to three generations: grandparents, parents, and two children (six people). The house was completed in 2018, with the younger couple and children living in the city prior to completion and the grandparents living separately in a suburban environment. The aim of the project was to create a house that offered all the benefits of shared spaces and living together without sacrificing privacy. The *physical attributes* of the house were designed as two separate apartments stacked on top of each other with a shared communal entrance. Circulation throughout the house is possible by having both an elevator and central staircases. The house is reductionist in terms of aesthetics and, from a sustainability perspective, includes high-grade thermal insulation and triple-glazed windows.

In addition to being designed to accommodate three generations, the house is designed to accommodate changes in *everyday life and practices* and for residents to age in place. The central circulation allows for future adaptability of floorplates so that studio apartments can be carved out of existing spaces or floor space from one unit can be added to the other. So, as the children age and want their own space, the house can evolve with the family. While the elevator is an obvious inclusion for ageing in place, the grandparents' unit has level floors and wider door openings to accommodate wheelchairs if needed. In the Apple TV show "Home", one of the architects and the father in the family states that he intends to die in the house, emphasizing his belief in both multi-generational living as well as adaptable and universal design principles.

7.5 Neighbourhood-Scale Housing

When people talk about sustainable housing, the focus is usually on the *physical attributes*. People tend to look to architects, engineers, and builders, but planners, urban designers, and landscape architects, among other professionals, are also involved in housing. As we have made clear throughout the book, there are so many other dimensions that contribute to, and impact, sustainable housing provision and outcomes. When housing is planned and developed at the neighbourhood-scale, there is a lot of government oversight through *policy, regulations, and governance* mechanisms that influences the result. As discussed in Chap. 2, buildings must be built to the minimum specifications outlined in building codes, where planning is responsible for approving developments which includes location, type, size, and mix, among other considerations.

There is no prescribed definition of the neighbourhood-scale. The size or attributes are context specific. Neighbourhoods can be understood as spatial units that people can relate to; they are places where you can work, live, and have access to shops and services [45]. Neighbourhoods are smaller than cities or towns and are comprized of multiple buildings.[5] The scale is appropriate for both experimentation and impact. From a sustainability perspective, neighbourhoods are often better places to respond to environmental, social, and economic considerations. Working at the neighbourhood-scale, compared to one-off buildings, offers opportunities to combine resources and coordinate efforts, and to interact with other *institutional structures and organizations* [46]. Examples include district heating and cooling,[6] community renewable energy generation and use (*physical attributes*), and shared amenities such as car co-ops and shared outdoor spaces (*everyday life and practices*). Neighbourhood-scale developments also have the ability to incorporate *ethical aspects* by considering housing mix, diversity, and affordability.

Neighbourhood-scale housing is closely tied to urban form and site type (*geography*). Urban form refers to a neighbourhood or city's physical characteristics. It is commonly represented by density, land use types, mix or diversity of land use types, spatial configuration, transport networks, infrastructure networks, and environmental conditions. Site types refers to the status of the land and its surroundings. There are generally three common approaches: greenfield (development land or change of land use), brownfield (previously developed land), and infill (un(der)development land boarded by developed land). Greenfield sites are most often found in dispersed (sub)urban forms while brownfield and infill can be found in a variety of compact urban forms. These include smart growth, new urbanism, and the 15-minute city. Smart growth is an approach to development that encourages a mix of building types and uses, diverse housing and transportation options, development within existing

[5] Whittier, Alaska being the exception; most of the town's population lives in one building that includes a school, post office, health clinic, store, and other amenities and services.

[6] District heating and cooling is the centralized generation and distribution of heating and cooling. For example, a district heating network allows many individual consumers to access heat that has been produced from multiple sources, such as combined heat and power, large scale heat pumps, municipal waste incineration, biomass boilers, or industrial waste heat recovery.

neighbourhoods, and community engagement. New urbanism is based on principles of "traditional" cities and towns where housing is located within walkable communities, near shopping and public spaces. The 15-minute city is more of an idea or goal where everyone can meet their essential needs within a 15-minute walk or bicycle ride [47]. At the core of these forums is the connection between density and diversity. Density refers to the number of dwellings in a particular area while diversity refers to the mix of housing typologies as we add other building types and land uses.

The compact urban forms mentioned above represent different approaches that can be adapted to different locations and contexts. There are also rating tools that have been developed to "certify" developments that focus on specific outcomes and use formalized rating schemes. In 2007, the U.S. Green Building Council (USGBC) worked with the Congress for New Urbanism and Natural Resources Defense Council to develop LEED for Neighborhood Development (ND) [48]. This collaboration brought together key stakeholders from the *market, users, and power* dimension. The impetus for the new LEED classification was the recognition of the importance of cities and neighbourhood-scale responses to climate change. Individual building and dwellings cannot be separated from their surroundings. The aim of LEED ND was to encourage community planning processes to support "green" innovation and transformation [49]. The LEED ND rating system comprizes two adaptations: LEED ND: Plan and LEED ND: Built Project, which have certification options unique to this rating system. Like all LEED programmes, neighbourhoods can achieve one of four levels of certification: certified, silver, gold, or platinum. There are five categories for LEED ND: smart location and linkage, neighbourhood pattern and design, green infrastructure and buildings, innovation, and regional priority. Each category has several prerequisites and credit components. The credits are then calculated to determine the level of certification. For example, for smart location and linkage, agricultural land conservation and floodplain avoidance are prerequisites while access to quality transit and steep slope protection are credit options.

7.5.1 Dockside Green—Canada

Dockside Green (DSG) is a residential neighbourhood spanning 15 acres along the harbour near downtown Victoria, BC.[7] DSG is a brownfield redevelopment (*geography*) that incorporates Smart Growth principles, LEED ND Platinum certification, building reuse, economic development, and environmental regeneration. Prior to redevelopment, the land was used for shipping and shipbuilding, timber processes, an oil refinery, and an asphalt plant. All of this left a heavily contaminated shoreline with vacant buildings. The parcels of land that now make up DSG were purchased by the City of Victoria for $1 in 1989 and in 2002, an environmental assessment commissioned by the City concluded the land could be developed. A detailed development concept was completed in 2004 after extensive public consultation which established the *policies, regulations, and governance* approaches for the development. Later that year, the City issued a request for proposals to remediate and redevelop a large portion of the site. Windmill Developments won the bid and selected Busby Pekins+Will as the architects due to their *knowledge* with LEED buildings. A large portion of the financing came from VanCity, one of Canada's largest credit unions, who also became a co-developer of the project. DSG also received funds from the federal and provincial governments.

Inspired by BedZED in the UK (see Chap. 6), the *guiding principles* for DSG were to imbed a triple bottom line approach to sustainability by building one of North America's most innovative neighbourhoods and be a model for sustainable development. The *physical attributes* of the development itself are comprized of LEED Platinum buildings, a wastewater treatment plant, a biomass plant, electricity metres, efficient appliances, reclaimed materials, car co-op memberships, and other amenities. The master plan includes 26 buildings (75% residential) with the development divided into 12 phases. Construction began in 2006 with Phase 1 of the project being completed in 2008 and Phase 2 in 2009. DSG has won numerous awards, both locally and internationally, including the 2006 Smart Growth BC award, the 2008 GLOBE Awards for

[7] https://bit.ly/3UmFCs1

Environmental Excellence, and Top Ten Green Projects from the American Institute of Architects/Committee on the Environment in 2009. Although, major criticisms of the early development were its lack of affordability as the focus was on environmental sustainability and many of the systems and technologies incorporated into the designs were very expensive at the time. After this, construction would pause for over 12 years, initially due to the global financial crisis (*markets, users, and power*) and then because the land and development rights were sold to Bosa Properties. As of 2022, the next phase of the development is for sale.

7.5.2 White Gum Valley—Australia

White Gum Valley (WGV) is a residential development of approximately 80 dwellings on an area of 2.13 ha in a middle ring suburb of Perth, Western Australia. The development is located 20 km from Perth and 3kms from the City of Fremantle. The site was previously home to a school which closed in 2008. WGV includes 23 single dwelling lots, 4 larger lots for multi-dwelling units, and a "Generation Y" demonstration housing lot [50]. The *physical attributes* of the project have been designed to allow all homes to integrate passive solar design principles and other sustainability initiatives. The range of lot sizes and configurations provides opportunities for housing diversity and a range of price points, specifically to support trends towards smaller households for singles, couples, and seniors. The development aims to have an operationally net zero carbon impact on the natural environment and applies the *guiding principles* of the "One Planet Living" framework (see Chap. 6).

Beyond improved performance at an individual dwelling level, the development addresses sustainability across the neighbourhood (*geography*) through water sensitive urban design (e.g., passively irrigated trees and landscapes, communal bore water access, landscaped infiltration basin and onsite storm water retention systems [51]), improving biodiversity outcomes, transport, cultural development, housing affordability and access, and food sourcing [52]. There is a focus on *ethical aspects* through a range of dwelling types, affordable housing typologies and rental/ownership options, and on reducing residents' costs for energy and water [53]. The neighbourhood scale of the project is also considered in the community scale battery storage system and the peer-to-peer renewable energy-trading scheme. The WGV project is structured within multiple policy frameworks including the City of Fremantle's Local Planning Policy 3.15 [54] and the project specific WGV Design Guidelines published by Landcorp WA [52].

7.6 Circular Housing

Globally, the residential sector contributes around 17% of total greenhouse gas emissions and consumes around 19% of total energy demand [55, 56]. Additionally, the housing sector consumes 30–50% of raw and recycled materials for new housing and retrofitting of existing housing [57]. The impact from materials is not only in the construction phase, but also through the generation of waste during construction, through-life (maintenance), and at end of life. While specific data for the residential sector is limited, it has been estimated that an average of 1.68 kg of construction and demolition waste is produced per person per day from the wider construction sector [58] of which the majority is not reused or recycled [59]. The total amount of materials consumed across the construction sector is growing at an increasing rate annually [59, 60].

To ensure that the residential sector contributes to a broader sustainable future, new and existing housing will need to significantly reduce its environmental impacts across all phases of a dwellings life by addressing *physical attributes, knowledge*, and *everyday life and practices*. This includes not only reducing energy and water consumption by occupants, but also through reducing impacts from materials, ensuring we use significantly less raw materials in our construction and maintenance of housing, and designing for deconstruction and reuse at end of life. The idea of the circular economy has emerged in recent decades as a framework that challenges the current linear business-as-usual practices of industries (i.e., extract materials, use materials, dispose of materials as waste) [61]. It has been estimated that a circular economy could address *physical attributes,* such as through reducing CO_2 emissions from building materials by 39% in 2050 [62]. The circular economy framework, which encompasses both *guiding principles* and *knowledge* dimensions, has been increasingly applied by policy makers and businesses (*industrial structures and organizations, markets, users, and power,* and *policy, regulations, and governance*) to a variety of industries, including the residential sector [46, 63].

There is no universally agreed upon definition for circular economy [64]. Geissdoerfer et al. [65, p. 759] describes the circular economy "as a regenerative system in which resource inputs, waste, emissions, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling". However, as others point out, this type of typical circular economy definition does not really engage with social and temporal dimensions or specify other key ideas pertinent for the circular economy (e.g., design for disassembly and reuse and optimizing of sharing which are important in the context of the built environment) [66, 67].

We define circular housing as housing that is produced and consumed utilizing closed loop principles (*guiding principles*), prioritizes local employment (*industrial structures and organizations*), achieves resilient and functional design, provides carbon neutral/energy efficient and regenerative operation (*physical attributes*), and enhances value across the design, construction use, and end of life phases of a dwelling. Circular housing promotes affordable, accessible, fit-for-purpose housing (*markets, users and power*) that is appropriately located (*geography*) so that it addresses social, economic, and intergenerational equity concerns (*ethical aspects*). This can be provided across various scales from the individual dwelling to across a community or city-level (*knowledge*). This leads to a more resilient material supply chain and creates value and opportunities for a range of existing and new businesses involved with the construction sector.

To some degree, new and retrofitted sustainable housing already leans into many of these ideas. However, the circular framing takes these outcomes further by having an increased focus on designing and using materials in a way that not only improves sustainability outcomes but also ensures that we design for deconstructions and reuse of materials at end of life, significantly improving *physical attribute* outcomes [68]. Circular housing is emerging in different jurisdictions around the world (*geography*), driven by *policy, regulations, and governance* stakeholders [46, 64]. Europe, in particular, has been an early leader in the circular economy and housing space, both for new housing and retrofitting of existing housing. Several other jurisdictions such as China and Japan and cities such as Paris and Amsterdam have implemented a range of circular economy strategies, including across the built environment and residential sectors [66, 69]. Table 7.3 highlights some elements that are being provided within a circular housing framing.

A core *guiding principle* within the circular housing framing is to design for disassembly/deconstruction and reuse as a starting point. In doing this, end of life value can be enhanced but it does require the *knowledge* to work backwards to maximize such outcomes. In the UK, BRE (Building Research Establishment) [70] undertook an analysis of design for disassembly of various types of housing. Their analysis showed a variance across

Table 7.3 Examples of circular housing principles in practice across dwelling to neighbourhood scales. Table adapted from [46, 69]

Circular housing principle	Dwelling examples	Neighbourhood examples
Regenerate (*physical attributes, knowledge*)	– Solar PV – Rainwater collection – Native gardens	– Community renewable energy and micro-grids – Community gardens
Social value (*everyday life and practices, ethical aspects*)	– Improved occupant health and well-being – Owning less “stuff”	– Car sharing, appliance sharing – Repair cafés
Minimize and optimize (*physical attributes, knowledge*)	– Low energy/carbon performance – Smart appliances – Raw finishes to reduce materials and ongoing maintenance	– Smart street LED lighting – Smart grids – Optimizing lot layout Large scale retrofit programmes
Closing the loop (*guiding principles*)	– Zero waste construction – Design for disassembly and reuse	– Community recycling and reuse – Community composting facilities – Leaving raw resources in the ground
Exchange and value (*markets, users, and power*)	– Reduced requirement for maintenance and improved durability	– Financial value for reuse of materials

housing types and identified significant opportunity to improve circular housing outcomes, such as design for disassembly. For one example, a traditional 3–4-bedroom brick house on a concrete foundation from a large builder, the analysis calculated a reuse and recycling potential score of 49%, an optimization of deconstruction score of 86%, and an overall design for disassembly potential of 61%. Elements such as internal finishes could largely be removed by hand to reduce damage to the structure and other large building components such as windows, roofing, and framing could be removed with typical machinery (e.g., excavators or cranes).

7.6.1 Circle House—Denmark

There are examples of housing emerging that are designed, from the start, to follow principles of circular economy including design for disassembly. One such example is Circle House in Denmark that consists of 60 social housing units in the city of Aarhus [71]. The residential typologies are a mix of two- and three-storey terraced houses and five-storey tower blocks. In terms of *physical* attributes, the housing is built from the same six concrete elements to ensure not only quick construction time but that more than 90% of its materials can be disassembled and reused at a high value. The use of Gyproc Ergolight system walling is an example of a material that not only reduces CO_2 emissions compared to conventional plasterboard walls by 45% but allows for 90% of the material to be reused at end of life without having to crush it down and recycle it into new boards [71]. The Circular House project also engaged with other *guiding principle*s of the circular economy, including significantly reduced environmental impact and improved quality and durability [71]. The development also aimed to drive new business models, partnerships, and innovation to help change the wider housing *industrial structures and organizations* [71].

7.6.2 SUPERLOCAL—Netherlands

SUPERLOCAL is located in the Dutch municipality of Kerkrade. The project was conceived as a response to a number of socio-economic challenges in the local region including a rapidly declining population and unsuitable housing [46]. The site of the project contained four ten-storey apartment buildings that had been built during the 1960's and were no longer fit for purpose [72]. After demolishing one of the buildings and sending the waste to landfill, it was recognized that this approach was not suitable for a range of reasons, including impact on the local community [46]. In 2014, the project was repositioned to engage with circular economy *guiding principles*. This meant regenerating the existing housing stock and renewing the wider neighbourhood. In terms of *physical attributes*, the project aimed to achieve a greater than 90% reuse of building materials and products from existing buildings for any new construction [46]. There was also a focus on providing on-site solar generation, a closed water cycle, and reducing car use.

The project also included *ethical aspects* such as a strong focus on providing improved social outcomes, including spaces for the community to meet and interact and a range of new affordable social housing for rent and purchase. Some of the new housing was constructed with material waste from previous buildings and designed to be easy to disassemble so that materials could be reused at the end of life. Sustainable materials were also used across the development, with footpaths and cycling paths using recycled concrete from waste out of existing buildings on site. The project has won several awards for the use of sustainable building materials, building systems, and innovation, including the Dutch "Building Prize" (Nederlandse Bouwprijs) in the category building materials and building systems in 2019. In 2021, the project was awarded the title of "Deserving City" from the Guangzhou International Award for Urban Innovation.

7.6.3 Cape Paterson Ecovillage—Australia

The Cape Paterson Ecovillage is located on the outskirts of Cape Paterson, a rural town 120 km south-east of Melbourne (Australia). The project was conceived in the early 2000's with construction starting in 2013 and expected to be completed around 2024 [73]. When completed, there will be 230 detached homes, a small number of short-stay accommodation dwellings, a conference centre with a café, a community building/education centre, and a community urban farm. Around 50% of the site will be open space, and the project has already revegetated more than 440,000 native plants to enhance the local natural environment [73, 74].

The *guiding principles* of the development are focused on maximizing environmental and social sustainability within a longer time frame (100 years+), both at an individual dwelling level and across the development. For the *physical attributes*, the developer created a set of design guidelines that have provided high performance housing, such as setting minimum thermal energy performance and renewable energy generation requirements that go significantly beyond minimum regulatory requirements [74]. To ensure these requirements are met, all house plans need to go through a design review process with a panel of sustainability and design experts. Various stakeholders (*industrial structures and organizations*) involved in the design and construction of housing on the site have worked with various material suppliers to improve sustainability outcomes, focusing on reducing waste during construction, reducing the need for maintenance during the life of the dwelling, and improving design for disassembly outcomes [46].

Ideas of circularity in this development go beyond just the dwelling and extend to providing a more sustainable community, especially with considerations for the social outcomes. For example, in terms of *everyday life and practices*, the large community farm on site aims to provide a range of sustainability benefits including reducing food miles, healthier eating, opportunity for selling produce, and providing a system to compost waste products created on site [75]. Further benefits are not just limited to the development site. A key outcome for this development is *knowledge* sharing, with a range of house designs freely available on the development's website, free for anyone to download and use.

7.7 Innovative Financing for Housing

As discussed earlier in this book, the real and perceived financial cost for providing improved sustainability continues to be a challenge that contributes to the slow uptake of sustainable housing and sustainable communities more broadly. This relates mostly to capital costs, but also in some cases to the ongoing costs (e.g., maintenance) of sustainability inclusions. The challenge of perceived higher financial costs persists despite an increasing amount of evidence (*knowledge*) from research and real case studies demonstrating that the performance of existing housing can be significantly improved through low cost measures (*physical attributes, knowledge*) and that new high performance housing (see Sect. 7.1) can be provided for little, if any, additional cost compared to traditional new dwellings (*markets, users, and power*). However, there continues to be some research and wider discourse which suggests that the costs for sustainable housing could still be anywhere from 10–100% higher than minimum regulatory requirements. This conflicting information creates confusion, not only for consumers, but also for policy makers, the industry, and even researchers!

The question of financial costs for sustainable housing is complex and needs to be addressed. *Policy, regulation, and governance* responses to providing sustainability have often relied on the wider market to determine the value for sustainability outcomes (see Chaps. 2, 3, and 4 for more on this). However, there have been market failures that mean consumers either do not value sustainability, are unable to afford it, or do not understand it, especially within the context of the climate emergency. For example, sustainability elements for housing have often been portrayed by larger regime actors as "add ons" to base designs, which are seen as increasing costs. However, costs for housing are made up of many elements and there are a range of opportunities to address costs during the design and construction of new housing and through the design and retrofit of existing housing, but also through the financing of this work at the household and industry level.

For example, *physical attributes* such as good design and improved consideration and use of materials should be able to improve the overall thermal performance of a dwelling. In this case, if any heating and cooling technology is included, it can be smaller as the house will require less input to maintain thermally comfortable indoor temperatures in many locations. Good design should also improve functionality of a dwelling and reduce wasted space. This is important if we are to address the large house sizes that have emerged in some locations, and the *markets, users, and power* associated with those houses. However, not everything can be designed out. The addition of *physical attributes* like renewable energy generation and storage is something that will have a cost attached to it. Importantly, with low provision of sustainable housing (new and retrofit), costs will likely be higher due to limited stakeholders in that space who are able to do the work, and also because cost efficiencies from economies of scale will not yet be realized across current *industrial structures and organizations*. The cost reduction for solar PV, which have fallen by 96% between 2000 and 2020, is one example of the opportunity available to reduce costs for sustainable housing across the full construction cycle [76]. So, the question of impact on capital costs is a balance between the savings from reduced costs in some areas with potential costs in others. What we see is an emerging number of case studies in various jurisdictions that demonstrate that sustainable housing can be provided for low additional costs, but more is required to provide assistance in relation to addressing the issue of finance.

As there are increasing housing affordability and cost of living challenges in many regions, anything that is perceived to add costs to the construction and purchasing of a dwelling is seen as something that can be done without to ensure we are making housing more affordable for everyone. There are several issues with this premise. Chief amongst those is that sustainability is provided on top of base house costs, rather than thinking about the design and costs as a holistic approach. It also focuses on the capital cost (i.e., the price tag) rather than factoring in the through-life costs of the dwelling. Even if a sustainable house costs more upfront, the *ethical aspects* of reduced living costs, improved occupant health and well-being, and wider social, financial, and environmental benefits have been, time and again, shown to outweigh any initial costs [2, 7, 77–80]. Additionally, most people who buy a dwelling do so through borrowing money from a financial institution. This means that any additional cost is not strictly something that needs to be paid for upfront. Research has shown that improved performance can often offset any impact on additional mortgage repayments and can lead to mortgages being paid off years earlier, saving the household tens of thousands of dollars in interest [77–79].

In an attempt to create a more level playing field and provide a "protected space" for sustainability niches to develop and position themselves to challenge the existing housing regime and market, there has been an increasing use of various financial mechanisms. Perhaps the most widely implemented example across the world has been the use of financial rebates or subsidies through *policy, regulations, and governance* to help reduce the capital cost of installing solar PV (and other renewable technologies). This is typically provided by governments who see this as a way to make certain sustainability technologies more affordable and to help drive uptake. The aim being that, as a greater number of households take up the sustainability technology, the market (*industrial structures and organizations)* will build, driving down costs to a level where government assistance is not required. Governments may offer a rebate which decreases over a period of time to reward early adopters but also to factor in that costs should decline for households over time. The rapid uptake of residential solar PV in Australia from the mid 2000's is an example of where this type of financial innovation, along with generous feed-in-tariffs, has helped drive significant change within the *markets, users, and power* dimension [81]. Battery storage and electric vehicles are also seeing similar financial assistance in many regions. However, this type of financial innovation is not without critique, with concerns about access and equity being raised about such approaches [82–85].

In recent years, a range of financial innovation has developed around the world and there has been an increasing number of key actors (including those from both the *industrial structures and organizations* and *markets, users, and power* dimensions) involved in developing and providing innovative finance and trying to shape markets. No longer is this just the domain of governments, but increasingly financial institutions, organizations and others are becoming involved. There has also been a shift in how finance and value are considered, through *culture, civil society, and social movements*, moving to through-life considerations (given the long life of a dwelling), and also better engaging with wider social, environmental, and financial value [79]. Below, we explore some of these examples to give an understanding of what is occurring and what is possible.

7.7.1 Baugruppen—Germany

Baugruppen—German for “building group”—is a self-developed affordable urban co-housing model that emerged in Germany in the 1990s. This model changes the stakeholders normally found within the *markets, users, and power* dimension of housing. By having a housing community come together to collaboratively engage in the design, construction, and use of housing within a Baugruppen development, a number of process efficiencies can be achieved which results in a reduction in the cost of the housing by 10–30% [86]. For example, having the community commit to owning a dwelling in the community prior to the start of construction can avoid the need for real estate agents, marketing campaigns, and the construction of display suits, as well as wider opportunities for shared amenity [87]. Additionally, the collective of households acts as the developer, reducing the need for developer profits [86]. Baugruppen can be any type of housing, but has largely been provided in multi-storey, multi-family buildings [87]. This model has now spread beyond Germany with examples in locations like North America and Australia (*geography*).

7.7.2 Green Mortgages—Globally

Green mortgages have emerged in recent decades as an approach within the *markets, users, and power* dimension for individual households or developers to address the issues related to the costs of sustainable houses [88, 89]. There are differences to how these are structured across different jurisdictions or companies, but there are common elements to the base intent. For a green mortgage, the lender will offer a reduced interest rate for a dwelling that has gone beyond minimum regulatory requirements (e.g., for thermal performance of base building and/or for the inclusion of sustainability technologies—*physical attributes*). This reduced rate might be for a period of time or the entirety of the home loan. There are also variances on this where the lender may allow for greater borrowing capacity knowing the living costs will be lower [90]. The intent is that it will encourage households to include more sustainability elements with the knowledge that any additional costs will be offset by lower mortgage repayment rates. For the lender, they are reducing the risk of missed loan payments or defaulting on loans as the evidence finds that those who are in more sustainable housing are a lower mortgage risk [79]. A variance on this might be to pause mortgage repayments for a set period of time (e.g., 2 years) to allow the household to save and pay for sustainable upgrades.

7.7.3 Rebates and Subsidies—Globally

As noted above, rebates and subsidies have been used by various governments as *policy, regulation, and governance* mechanisms to help incentivize households or the wider market to provide improved outcomes. This has often been in the form of a direct reduction in the cost of a particular sustainability technology or material, as well as through providing a financial rebate directly to the household or supplier once the sustainability activity has been implemented. Typically, these types of approaches will offer a certain percentage of the cost calculated based on what the government feels is a balance between providing financial assistance while still having some consumer buy-in. Some jurisdictions are going beyond this approach. In Italy, there is a superbonus 110% scheme that entitles households who do certain retrofit and quality upgrade improvements to a tax credit of up to 110% of the cost of the work [91]. Since the scheme launched in July 2020 as part of the country's post-pandemic recovery strategy, more than €21bn of funds have been paid out for more than 120,000 approved applications. However, this type of programme comes with its own sets of challenges related to fraud, problems of governance, and implementation [92].

7.8 Conclusion

This chapter has attempted to demonstrates both real world case studies across key themes of the book and the socio-technical dimensions required for change (see Chaps. 5 and 6). What is clear from these cases is that there is a lot of amazing sustainable housing work being provided around the world and this should give us all hope that a transition to sustainable housing is not only possible, but also that we have the means to be doing things right now. However, the cases also show that, even with these leading examples, there is still room for improvement. These cases have also largely been one-off examples. We need to find ways to scale up these examples and accelerate the transition to a sustainable housing future. In the following chapters, we reflect on what we have covered in the book so far and discuss what this means moving forward.

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8

Facilitating the Sustainable Housing Transition

8.1 Introduction

The evidence makes it clear that the way we are currently providing housing is not sustainable from a range of perspectives. As discussed in the early chapters of this book, current housing provision has a significant impact on the environment, and we need to facilitate a sustainable housing transition if we are to achieve wider emission reduction targets. However, such a transition is not just about reducing the environmental impacts of the housing sector, but also enhancing social and financial outcomes for individual households and our wider society. In those earlier chapters, we discussed the challenges and opportunities we currently face to facilitate this sustainable housing transition. Given these challenges, and the complexities across a range of socio-political-industrial elements, the middle chapters explore the idea of sustainability transitions as an opportunity to address these challenges and help with the accelerated provision of sustainable housing at scale, in both the new housing and existing housing spaces. The previous two chapters explored how this was being addressed in real world examples and case studies across ten different socio-technical dimensions and across key themes identified in earlier chapters of the book.

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In this chapter, we draw upon the preceding chapters to discuss the implications of the evidence and current context for facilitating the sustainable housing transition. We do this across three core sections. In Sect. 8.2, we discuss the importance of drawing upon sustainability transitions theory to inform the sustainable housing transitions. This includes reflections on how we need to extend the theory to align with the unique challenges of the housing sector. Following this, Sect. 8.3 focuses on the sustainable housing transition, including where we are placed in that transition, potential pathways forward, and challenges that still need to be addressed. In Sect. 8.4, we reflect on the types of innovations required across policy, practice, and research to help facilitate the sustainable housing transition. We then build upon this in Chap. 9 by discussing the prospects for a sustainable housing transition and revisiting the core ideas woven throughout the book.

8.2 Sustainable Housing Transitions: Beyond a Niche

Within broader discussions of urban sustainability transitions, housing has long been identified as a niche [1–4]. In part, this has emerged from an understanding that a transition to a low carbon housing future will require more than just a technical solution, and in fact, will require deep structural changes to the way housing is provided and used [5–8]. However, analysis of housing as a niche has been problematic. Housing design, technology, location, quality, performance, and affordability have significant implications for households' health and well-being, liveability, costs, financial gain, and access to jobs, services, and recreation [9–29]. Housing intersects across different housing typologies and characteristics (e.g., new and existing housing), scales, time, and sectors. The idea of a 'niche' as it is typically applied within transitions research does not capture this kind of complexity.

Much of sustainable housing transitions research comes back to the early work of Smith [1, 30]. Smith explored the development of sustainable housing niches and defined the current regime through a socio-technical (or sustainability) transitions framework. This research made an important contribution towards developing an understanding of the contrasting socio-technical dimensions of, and current pressures between, niche actors and the regime. Much has changed in the sustainable housing space since Smith's work, not only in terms of technological innovation but also in relation to improved understandings of the social implications of housing. In addition, sustainability transitions research has evolved with several new areas of focus being put forward to improve understandings and implementation of transitions [31]. We argue it is time to re-visit how we look at housing within sustainability transitions and reflect on how we might approach housing transitions research differently given recent theory and sustainable housing developments.

To do this, we focus on socio-technical dimensions, rather than the niche-regime dynamics of housing. Socio-technical systems are multi-actor processes that consist of multiple elements, such as practices, policies, or technologies. In Chap. 6 we presented 10 socio-technical dimensions for sustainable housing transitions: (1) guiding principles, (2) physical attributes, (3) knowledge, (4) geography, (5) industrial structures and organizations, (6) policy, regulations, and governance, (7) markets, users, and power, (8) everyday life and practices, (9) culture, civil society, and social movements, and (10) ethical aspects. Each dimension begins with a definition followed by an overview of how the current housing regime engages with the dimension and how sustainable housing offers a different approach, ending with a short example of how this is being provided or considered in practice. In Chap. 7, we explored how these socio-technical dimensions intersect across different housing typologies and characteristics, scales, time, and sectors. We organized this around six themes: high performing housing, small housing, shared housing, neighbourhood scale housing, circular housing, and innovative financing for housing. Each theme begins with an overview and is followed by a series of case studies. The aim is to demonstrate ideas from the book in real world projects.

When we evaluate sustainable housing through these socio-technical dimensions, it is clear that there have been some significant changes within the sustainable housing space. For example, in relation to industrial structure and organizations, sustainable housing has shifted from bespoke single buildings with a cost premium to scaling up the delivery of multiple buildings and even whole precincts with little, if any, cost premiums. In addition, new research directions highlight the need to consider ethical aspects within current governance approaches to the sustainable housing transition. Focusing on socio-technical dimensions demonstrates that sustainable housing delivery is not only occurring within the traditional housing industry but with input across other sectors such as energy networks (e.g., with renewable energy generation and battery storage) and transportation (e.g., public transport and electric vehicles). There is also a 'messiness' occurring with different speeds of progress (e.g., new vs existing housing). The outcome is that housing is not well suited to being considered as a niche from a traditional transitions perspective. Without a rethink of housing, the sustainable housing transition cannot truly challenge these deeper structural changes within the current housing regime.

8.3 Facilitating the Transition

If we use wider climate change target goals of achieving near zero emissions outcomes by 2050 as a starting point for change in the housing sector, we have less than three decades to transition to the type of sustainable housing we are advocating for in this book. While this may seem like quite a long time, the reality is that it is not long at all. Looking at policy development around the world, we see that in places like the EU and California it took at least 10 years from the announcement to implementation of zero (or near zero) energy/carbon new housing [32, 33]. These approaches included various step changes[1] at intermittent periods to have a controlled improvement to minimum performance requirements. If other jurisdictions were to take action today, it is likely that we would not see all new housing achieve the standard required for a low carbon future until at least 2035. And that would assume that policies could be

[1] We define step changes in policy as where there is a longer term policy goal set e.g., 10 years, with smaller 'step change' policy identified at various points across the specified time period to help shift the policy and outcomes from where they currently are to the longer term goal.

developed and approved quickly, but as this book has explored, nothing is ever easy when it comes to implementing or improving minimum building performance requirements. We must also recognize that not all countries even have minimum performance requirements which means it may take them longer to first introduce and then improve standards to the level required. Looking at other jurisdictions, it has taken 30–50 years to go from the introduction of some minimum performance or sustainability standards to the point they may be close to delivering the types of housing required [34–36]. We simply do not have the time now to wait for other jurisdictions to take the same type of pathway.

In recent years, we have seen sustainable housing policy attention broaden from new housing to existing housing. In some jurisdictions, there has been the introduction of minimum performance requirements for existing housing. This is typically being applied at the point of sale or lease of a property, where the dwelling must ensure it meets a minimum standard. While a good step forward for ensuring improved performance of existing housing, there are some limitations to this approach. For instance, there is often a ceiling for how much money the dwelling owner must spend on improving performance (which could potentially mean not lifting performance sufficiently to meet new standards if retrofit activities hit the finance cap first), and it is only dwellings on the market for rent or purchase that are being captured (missing most existing housing). Additionally, the requirements for improving quality and performance are generally about incremental improvements, and there is a significant gap between that and what we are advocating for in this book. The existing housing sector is likely several years behind the new housing sector in terms of achieving or requiring quality and performance outcomes for new housing. The challenge remains that it can be more difficult to improve the quality and performance of existing housing due to existing dwelling characteristics and constraints, and not all dwellings will be able to cost-efficiently achieve the types of performance outcomes that new housing can (or will at the very least require different approaches such as the use of more technology).

Clearly there is a disconnect between the current provision of housing and where we need to be for a low carbon future [4, 35, 37]. There is also a significant gap between leading jurisdictions and their requirements for new and existing housing, and what is being provided in the housing sector in other jurisdictions. This highlights the need for different approaches in different jurisdictions.

If we go back to the sustainability transitions phases presented in Chap. 5, the sustainable housing transition is still in the pre-development phase (see Fig. 8.1). There is limited visible change at the systems level, but substantial experimentation and development are occurring at the niche level with pressure for change starting to build on the current regime in some jurisdictions. Perhaps, in some jurisdictions with more advanced minimum performance regulations, it could be argued that they are entering the take-off phase where enough pressure is being exerted on the existing regime and the niche challenger is beginning to destabilize the regime and increase its own diffusion. However, the evidence presented in this book suggests that most jurisdictions are firmly in the pre-development phase of this sustainable housing transition.

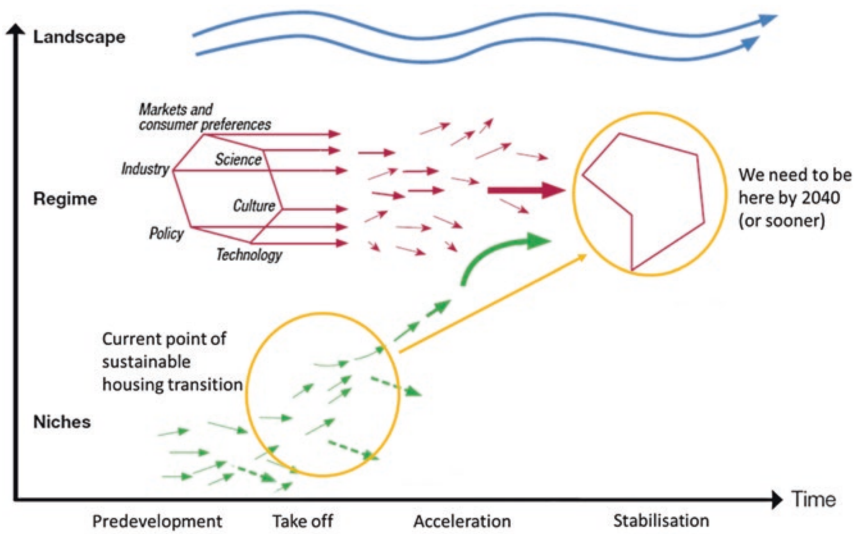

Fig. 8.1 The MLP and interactions between the three nested hierarchical levels with our reflection of where we are in the sustainable housing transition and where we need to transition to

The question is, how do we facilitate the sustainable housing transition to move from that pre-development phase through to take-off, and then into the acceleration and finally stabilization phases?

It would be nice to think consumers and the wider housing sector will naturally start to demand and provide sustainable housing at the levels required, within the timeframe required. However, we have limited confidence that this will be the case given the complexities of housing markets and the way they have been structured. What will be required is a proactive push and pull approach where various policy levers and industry innovations are used to significantly improve the quality and performance of housing and support deep structural changes to the housing industry. This will require a clear pathway that maps out the changes needed over the coming years and decades. To ensure a well-considered approach, any pathway should be developed working backwards from longer term goals and timeframes (e.g., sustainable housing by 2050) and forwards from where we currently are. For example, in Australia more than 8 million dwellings will need to be retrofitted by 2050 meaning that 35 dwellings per hour need to be retrofitted. However, capacity to start delivering this outcome is not available—it needs to be scaled up first. Developing a plan around this scaling up is not just about the number of houses or labour required, but also about supporting supply chains and other industries that are involved.

Based on the evidence of housing regulation development, and the urgency of change required, all jurisdictions should be introducing sustainable housing requirements in accordance with the material in this book by no later than 2030. For this to be successful, jurisdictions need policy pathway plans to determine how to get from where they are now to the targeted 2030 outcome as soon as possible. This will provide transparency and give confidence to the housing industry, other stakeholders, and housing consumers, as well as provide time for the industry to adapt. The policy pathway can also act as a framework for those in the housing industry who want to innovate and go beyond minimum requirements. This will help create a market advantage, drive innovation of design and construction, and work to reduce any costs from the required changes. For those jurisdictions further advanced with their minimum housing quality and performance requirements, they could be aiming to achieve these outcomes even sooner.

The existing housing sector is more complicated than new housing due to reasons discussed earlier in this book. However, the ambition should be to see the majority of existing housing achieve sustainable housing performance outcomes of at least 80% of those of new housing in terms of improving performance through various approaches such as improving insulation and glazing, and updating to energy and water efficient appliances and including renewable energy technologies. This is what wider research says is possible and should be the minimum target for existing housing [38–44]. Many stakeholders have argued we should first focus on improving new housing outcomes to get them right before addressing existing housing, but there is more potential to rapidly improve the sustainability outcomes of housing from the existing housing sector. Therefore, we should be ambitious with pathways for addressing existing housing performance. By 2025, there should be a requirement for mandatory disclosure of building quality and performance at point of sale or lease that includes cost effective opportunities for upgrade and retrofit. To ensure confidence, this information must be robust, reliable, and transparent.

With this mandatory disclosure information in place, jurisdictions should look to introduce minimum performance requirements that are triggered when a dwelling is sold or rented. Using examples from Europe, this approach would first look to capture the worst performing housing (e.g., F and G on the A–G scale) and improve them to a higher standard (e.g., to a minimum of E), targeting the most cost-efficient retrofit opportunities. Following this, there should be a clear plan to improve minimum requirements to higher performance levels across a defined time period so that there is a clear pathway for change. If the above is in place by 2025, it would not be unreasonable to expect that minimum performance requirements could be improved from E in 2025 to D in 2028, C in 2031, and B in 2034 (allowing for 3 years in between minimum performance changes). From 2035 onwards, requirements for existing housing at point of sale or lease could be aligned with new housing requirements. Although, some flexibility would be required to accommodate that not all existing housing will be able to achieve the same outcomes in the same ways, and may require alternative solutions (e.g., if there is no capacity for onsite renewable energy generation, it may need to be located offsite). That would mean there is 15 years from 2035–2050 to retrofit all existing housing to the level required for a low carbon future. Some jurisdictions are starting at a higher level for quality and performance of existing housing and should be able to mobilize and scale up deep retrofit earlier, potentially achieving sustainable housing outcomes for all existing housing by 2040 (or sooner). This more ambitious timeline will help inform and guide other jurisdictions that are further back on their sustainable housing transition, and should not be used as a reason for those laggards to delay improvements, as each jurisdiction must take individual action as part of the global collective.

The above is naturally a broad plan and each jurisdiction would need to develop a specific plan based upon local context, capacity, and skills. However, given that the issue of mitigating climate change is a global challenge, we should look for at least some level of coordination for the sustainable housing transition. This means that there should be global pathways that set expected practices, with some flexibility for jurisdictions to adapt as required. Any pathways must include sufficient policy, industry, and consumer support, and take place at different levels. Globally, there is a need for a coordinated approach, and this must start by bringing together jurisdictions to work through a process to develop and implement a shared global plan, similar to the Conference of the Parties conference events. Every jurisdiction should develop short, medium, and long term goals for improving housing quality and performance, goals that should be linked to wider climate change and other societal targets.

Setting longer term policy is a critical step towards the sustainable housing transition [36]. However, this will only be successful if there is sufficient support in place to allow the transition to occur. This support needs to include education for the existing regime and housing consumers, and potentially financial support to help offset any additional costs from improved performance requirements. If financial support is to be provided (e.g., through rebates for sustainable materials or technologies), these should be a clear phase-out plan so there is an incentive for stakeholders to innovate and drive down costs. There are also challenges around the globe with a lack of labour and supply chain issues. These will also need to be addressed to ensure that we can scale up the sustainable housing transition without delays or choke points in the system. Governments should also provide support for further research and development of retrofit solutions that can be delivered at scale and across different housing types. This could open opportunities for retrofits to be delivered to a greater number of dwellings more quickly, more efficiently, and at a lower cost, rather than addressing retrofits one dwelling at a time.

Improving performance of new or existing housing at the individual dwelling level is important, but it is not the only focus in the sustainable housing transition. To fully unlock the potential of the sustainable housing transition, we need to have housing stakeholders engage with stakeholders in other related sectors such as energy and transport. The energy network in many countries has been developed as a centralized system whereby energy is generated at fossil fuel generation plants and transported large distances to the places where energy is used. The move away from fossil fuel energy, and the balance between the scaling up of dwelling and larger scale renewable energy generation, should provide the opportunity for innovations in the energy network to help facilitate the sustainable housing transition. For example, decentralized energy networks could help share renewable energy between neighbouring houses. The role of electric vehicles and the development of two-way batteries in these vehicles also open up different opportunities for energy management at a dwelling level.

While this book has largely been focussed on developed countries, a global sustainable housing transition must include developing countries. The housing challenges in developing countries are often different to those in developed countries, and we must ensure that the sustainable housing transition in developing countries can help address some of those wider housing and social challenges in those locations. Much like with the global climate change approach, we will need developed countries to help support developing countries with the sustainable housing transition. This can be through sharing of knowledge, skills, materials, technologies, and research, but also likely through financial support to help such countries change their housing industries.

8.4 A Time for Reflection

In the previous section, we outlined pathways to facilitate the sustainable housing transition for new and existing housing. This was largely a pragmatic exercise working through a visualization and back casting process to map out a pathway for how we can achieve a sustainable housing transition by 2050. This process was focussed on regulatory and policy changes to drive the transition as this has been found to be the most successful way for improving minimum quality and performance outcomes across the housing sector. As such, the pathway takes an overarching view of the transition and assumes that more nuanced changes at various levels under the policies (e.g., changes to construction practices) will also be included.

Furthermore, there is no discussion in the above pathway around the type of housing we are providing or if it is sufficient for our housing needs today and into the future (not just from a quality and performance perspective, but in terms of the characteristics of our housing). There is a need to challenge wider considerations of housing to ensure we are not just bolting on sustainability to existing ideas of what housing is. Instead, we need to take this opportunity to reconceptualize housing and housing needs. In many housing markets, consumers have been provided with housing based on what the housing sector has deemed consumers want. We need to ask if this is really what consumers want, and we need to provide them with information about their choices and encourage them to explore alternative options. The opportunity to reconceptualize housing should be done within the wider social, financial, and environmental challenges seen across the housing sector.

For example, affordable housing issues are increasingly prevalent in many jurisdictions [45–47]. Exploring opportunities to address sustainable housing could also help address affordability issues [4, 48, 49]. Some of the case studies we presented in Chap. 7 highlight how this can occur. Co-housing and Nightingale Housing are two alternative ways to provide housing where elements of a traditional house are shared, helping to reduce environmental impact and construction costs. To provide this type of housing at a larger scale, it is not just about changes in the design and construction process but will also require households to let go of their perceptions of what should be included within a dwelling. Changing social understandings of housing and housing needs will be necessary if we are to successfully facilitate a sustainable housing transition.

We also need to encourage a range of stakeholders to think in a more visionary way to unlock different ways to reconceptualize housing and help create different options across the housing sector. It is interesting to look at TV shows or movies set in the future and see how they are providing housing. Are there lessons we can learn from those imagined futures to help us with our sustainable housing transition?

It is not just imagined futures that can help us reconceptualize housing. Climate scientists are telling us with increasing certainty what the changes to the climate will be into the not-so-distant future. We need to use this information to inform the provision of climate resilient housing moving forward. There are multiple elements to this, including that we need to use climate projections to inform the design of our new housing and retrofit of our existing housing. As we noted in earlier chapters, the evidence is already showing that the performance of housing is changing with the climate. We must use climate data from at least the midpoint of the assumed life of a dwelling to ensure that the performance is suitable for that climatic future.

We also need to use this information to ensure we stop building in locations that are at higher risk of climatic events in the future. This will mean that areas we have already built in, or are expanding into, may not be suitable for communities to live in as our climate changes. Increasing fire, flood, and other climatic events in recent years have exposed poor planning of housing, and there is already an impact on households, the wider community, and governments. For example, in Australia in 2022, repeated floods in a region of New South Wales led the state government to announce a buyback programme for up to 2000 dwellings as the risk of exposure and damage to further flood events was deemed too significant [50]. There are going to be increasing examples of this around the world where whole communities may have to be relocated due to climate change impacts. Who will pay for this, and how will decisions be made about who is moved (and to where), and who is excluded from any move? These are questions most policy makers and society have not had to ask, but it is important we start asking now.

Additionally, we need to ensure that the sustainable housing transition does not just occur for those who can afford to participate, but that everyone is included. The evidence finds that vulnerable households face a range of financial, social, health, and well-being impacts from the housing they live in, and that they are often living in poor quality and performing housing [48]. It is critical that there is a focus on how to ensure vulnerable housing cohorts are included, if not prioritized, in this sustainable housing transition. This will likely require different approaches and collaborations to help vulnerable households compared to what approaches might work for the wider housing community. To help facilitate this, there needs to be a shift in considering housing from an upfront capital cost to the through-life impact of housing on households (and the wider environment and society). For example, including health and well-being benefits in the considerations of policy changes will ensure that improved value is not just about the financial bottom line, but about wider impacts [51].

Throughout this book, we have acknowledged that we are in a climate emergency and, as such, need to urgently address the quality and performance of housing. Time is of the essence in relation to wider environmental impact, but also increasingly due to the rising cost of living and other emerging social impacts related to our current housing. In Sect. 8.3, we mapped out what we believe to be a realistic but pressing pathway that will require significantly quicker progress for many jurisdictions. However, while the sustainable housing transition is time sensitive, we must ensure we do not create unintended consequences by moving too quickly. In this regard, our pathway above sets out short-medium term policy actions to ensure a scaling up of the provision of sustainable housing, and to give clear guidance to the wider housing industry and consumers about what will change and when the change will occur. This will help ensure everyone is working towards the change.

A challenge with scaling up sustainable housing quickly will be ensuring that such housing is actually provided and that shortcuts are not taken. This will require rigorous checks and balances throughout the design and construction (or retrofit) process to give consumers confidence that what they are paying for is what is provided. The disconnect between design intent and actual performance is already an issue in many jurisdictions and must be addressed moving forward [35]. This will mean a higher number of random checks by independent experts throughout the construction process, as well as stronger legal protection for households. In many countries, there is a lack of opportunity for consumers to seek redress for housing that fails to meet expected standards of quality and performance.

Innovation will also be important the help facilitate the sustainable housing transition. Technology innovation has been a significant area of focus within the wider housing sector over recent decades, but there is a need for more innovation across all phases of a dwelling from the design through to end of life. This innovation is not just for physical attributes like materials and technologies, but also the processes involved for providing housing. Throughout earlier chapters, we have noted a number of innovations being attempted in the planning system that are trying to find ways to improve the provision of sustainable housing, such as through encouraging higher density housing in suitable locations. However, there are opportunities for other innovations or the expansion of existing mechanisms and approaches, which could help address some of the challenges we discuss in this book. For example, upfront cost and a lack of hands-on experience have been raised by some in the residential construction industry as holding back the provision of sustainable housing.

Inclusionary zoning is a planning mechanism that requires a certain percentage of housing provided in a development to be set aside for affordable housing. This approach is used in some jurisdictions and it helps to provide more housing that is affordable to those who typically could not afford such housing. A similar approach is being used to require developments to be built to a significantly higher standard compared to regulated minimums through green building re-zoning processes. Increasing the use of these types of policies would help to give those in the housing construction industry incentive and experience building to a higher standard (helping to negate the lack of experience challenge) and would help provide more sustainable houses (helping to address cost challenges).

We need to find ways to bring together a range of different stakeholders and expertize to think about innovations that could help facilitate the sustainable housing transition. It will be by working together than we can ensure this transition is as effective and efficient as possible.

8.5 Conclusion

The evidence presented in this book makes it clear we need a sustainable housing transition. Earlier chapters presented sustainability transitions theory as a useful framework for helping to understand and facilitate such a transition. However, as we explored in this chapter, the sustainable housing transition will require us to extend this theory and our understanding of how to apply the theory in practice. In extending the theory, there are a number of practical outcomes that will be required to facilitate the transition. For example, we must come up with global and local plans for how this sustainable housing transition can occur. Having a global approach will allow a collective and shared response to the issue of housing quality and performance and ensure that efficiencies are maximized through global supply chains. With varied local housing contexts and different starting points, each jurisdiction will need to adapt this global plan to ensure we can efficiently and effectively deliver upon the sustainable housing transition. As we discuss in this chapter, we must also take the opportunity to ask key questions of our housing and housing needs.

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9

Prospects for a Sustainable Housing Transition

9.1 Introduction

By this stage of the book, it should be clear that housing is critical for our society for a range of reasons. Housing primarily provides us with a place to shelter from the elements and gives households their own private space, and the provision of adequate housing is a basic human right. The UN states that adequate housing must address security of tenure, availability of services, materials, facilities and infrastructure, affordability, habitability, accessibility, location, and cultural adequacy [1]. Many of these basic housing requirements can be addressed through the provision of sustainable housing, as we have described in earlier chapters. Given the climate emergency and wider social challenges related to housing, we believe that environmental and social sustainability considerations of housing must be included within the basic elements of housing promoted by the UN.

Despite knowing the importance of housing, there are significant environmental, social, and financial issues with the current provision of housing in many jurisdictions [2–8]. Current housing has a significant negative environmental impact, it is making people sick, and it is increasingly unaffordable to own, rent, and live in [9–19]. Globally, we have an increasing number of examples (see Chaps. 6 and 7) where the type of

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sustainable housing we are advocating for in this book is already being provided, for both new and existing housing and at different scales and through different approaches. While not all examples are perfect, they demonstrate that we can be doing significantly more right now. There is no need to wait for more technological innovation, for design knowledge, or for evidence of performance to provide sustainable housing; we just need to get on with doing it.

In this final chapter, we revisit the core ideas woven throughout the book. We summarize the current situation and how the current provision of housing will not meet our environmental or societal needs moving forward. Despite the mounting evidence of the benefits of sustainable housing, we still face key challenges that need to be urgently addressed to ensure we can deliver a sustainable housing transition that includes everyone. We discuss the prospects for change and explore where that change needs to occur. We finish the chapter with some concluding reflections.

9.2 Sustainable Housing: Current Context, Future Challenges

Following decades of fragmented or limited action on climate change, we are in the middle of a climate emergency [20, 21]. Already, we are experiencing the impacts of a changing climate on our built environment. For example, there is an increase in the frequency and severity of extreme weather events (e.g., heatwaves) and disasters (e.g., fires, floods), and this is predicted to get worse moving forward [20, 22]. The consensus among climate and environment scientists is that we will need to reduce our global emissions by 80% or more by 2050 to mitigate catastrophic climate change [20, 21]. Our individual and collective response to this climate emergency will shape our short-term future and have impacts for future generations.

However, in relation to environmental sustainability, it is more than just needing to significantly reduce carbon emissions. We have known for more than 50 years that we were not sustainably consuming resources and we have been consuming non-renewable resources at a rate faster than they can be regenerated [23]. Recent data suggests that we are consuming our earth's resources at the rate of 1.75 planets per year and there is limited evidence that this is changing any time soon [24]. Clearly, we are not living within the means of our one planet and have not taken the significant steps required to address this, despite the plethora of warnings for what is likely to occur should we not heed these warnings and respond to them.

There has been some promising global progress in recent years towards addressing climate change and other environmental and societal challenges. UN Climate Change Conferences of the Parties in 2021 and 2022 moved the global discussion forward with agreements for more stringent and urgent action. However, there are many sustainability advocates who argue these recent agreements do not go far enough given the current climate emergency. The UN's Sustainable Development Goals are another global initiative and have also helped focus attention on delivering key improvements across their 17 goal areas [25]. However, as researchers and other advocates have argued, incremental policy and practice change is not sufficient for addressing the climate emergency; we need to do much more across a shorter timespan if we are to avoid the most catastrophic of climate change outcomes [3, 26, 27].

The housing sector has a critical role to play in delivering a more sustainable future. Globally, the housing sector contributes around 17% of total greenhouse gas emissions and consumes around 19% of total energy demand [3, 28]. Additionally, the housing sector consumes 30–50% of raw and recycled materials for building new housing and retrofitting existing housing [29]. The impact from materials occurs through the use of materials and the generation of waste during construction, through-life (maintenance), and at end of life. Given that housing is a long-life infrastructure, any transition to a low carbon future must include sustainable housing.

In this book, we define sustainable housing as dwellings with a zero carbon impact that, where possible, contribute to regeneration initiatives that support wider sustainability. Sustainable housing is housing that 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).

Sustainable housing is about more than just reducing environmental impact. It is about addressing a range of wider social and financial issues across the housing sector in many regions of the world. Housing is imperative to meet our basic human needs [1] and should provide us with safe, secure places to live, and improve social outcomes like health and well-being. Despite this, we continue to see challenges with the provision of adequate housing around the world. For example, more than 1 billion people live in slums or informal settlements, and more than 100 million people are estimated to be without homes entirely [30]. There are also significant housing affordability issues for many who do have access to housing, with the cost of purchasing and renting increasing at a faster rate than incomes in many jurisdictions over recent decades [6]. As a result, housing is precarious for a growing percentage of the population and this is being exacerbated by rising cost of living (e.g., costs for energy).

It is not just the provision of housing that is important. Research demonstrates that good design, quality, and performance can improve a range of outcomes for households including improving their health and well-being, reducing living costs, and adding resale value, in addition to reducing environmental impacts [31–35]. Conversely, poor design, quality, and performance have been found to negatively impact these outcomes [2, 7, 11, 15, 17, 18, 34, 36–40]. When replicated at a larger scale, the benefits go beyond individual dwellings to the wider community. For example, the use of vegetation can help improve thermal performance of a single dwelling, but large-scale urban greening can help reduce air temperatures in heatwaves by 15 °C or more [41–44]. This not only helps make our climate more comfortable, but it also reduces the need for mechanical heating and cooling and reduces health and mortality outcomes.

While each climate zone has nuances in terms of how to deliver sustainable housing, the evidence from around the world shows there are some broad rules we should all be following [45–47]. These relate to new housing, but many are also relevant for existing housing. At the individual dwelling level, this includes (but is not limited to):

- Optimizing orientation to maximize passive solar performance,
- Improving thermal performance of the building envelope through improved material use and insulation,
- Sealing up gaps and cracks,
- Block out curtains/blinds for windows,
- Improving window performance through advance glazing solutions,
- All-electric houses with heat pump technology for heating, cooling, hot water,
- Energy efficient appliances,
- Smart homes,
- Renewable energy technologies (e.g., solar PV and batter storage), and
- Utilizing nature around the dwelling to help regulate thermal performance.

Despite the benefits of sustainable housing, only a small percentage of the current housing market achieves design, quality, and performance outcomes in line with what is required for a low carbon future [4]. This low uptake points to significant neo-classical market failures. The current housing regime operates on the idea that sustainable housing can be left to the wider consumer market to drive demand and create competition, innovation, and cost efficiency. This idea has been widely criticized and been shown to not deliver the type of outcomes needed at the speed required. However, there is a small section of the market that is using information about dwelling design, quality, and performance to improve decision making, with emerging research suggesting a tangible financial value for more sustainable houses. Energy Performance Certificates used throughout Europe and elsewhere are an example of this information provision, although at this stage, the speed of consumer change does not match what is required to deliver a low carbon future [48].

To address these market failures, governments around the world have typically used minimum design, quality, and performance requirements by way of regulations [49, 50]. These regulations have arguably had significant success in raising the design, quality, and performance of the bottom of the market, but generally fall short of what is required for a low carbon future. According to the IEA, only around 85 countries have mandatory or voluntary building codes with specific energy requirements, highlighting the challenge in introducing these [4]. Other issues are evident such as ensuring regulations are enforced, as well as the implication of minimum standards being good, rather than being the legally mandated bare minimum. However, leading jurisdictions like the EU and California have introduced a range of advanced regulatory requirements in recent years and now require all new housing to be delivered to a performance level near our definition of sustainable housing [51, 52]. In locations where mandatory requirements are not adequate, or where none exist, the use of voluntary standards like Passive House and Living Building Challenge offer a framework to provide significantly higher design, quality, and performance [53, 54]. Unfortunately, there are many in the wider housing industry who push back against the need for improved regulations or changes through planning systems, saying that such changes add red tape and ultimately add costs to consumers. However, as the evidence and case studies presented in this book indicate, we are now able to provide sustainable housing for little, if any, additional costs for consumers.

Another important lever in the provision of sustainable housing is the use of planning systems. Before a dwelling or community is constructed, land use planning has a critical role to play in terms of determining the ease of delivering improved outcomes for sustainable housing [55–57]. For example, if vacant housing lots are planned to optimize dwelling performance, it can result in significant improvement to thermal performance and/or reduce the costs for achieving higher standards. Statutory planning can facilitate other elements related to sustainable housing, such as where housing is located, the types of housing in an area, and considerations of general or specific amenities.

There has also been an increasing use of alternative mechanisms to help address wider market failures and drive the provision of sustainable housing. Examples include consumer education about energy and water efficiency, product labelling programmes, rebates, and tax incentives or subsidies for sustainability technologies or building practices.

A number of challenges are prevalent with the provision of standard housing. Once a dwelling is constructed, the performance and environmental impact has been locked in for many decades. This means it is critical that we ensure all new housing meets much higher standards. To do this we need to focus on the design stage, where the old rule of thumb estimates that around 80% of a dwelling's impacts are locked in during the first 20% of the design process. Failure to ensure new housing performs to a higher standard means that much of housing not yet built will likely need to undergo expensive retrofits. Research from around the world calculates that it could cost approximately £20,000 or more to provide deep retrofit [58, 59].

New housing is almost the easier housing type to address. With new housing, there are less constraints and more opportunities to provide much more significant outcomes when they are designed in from conception. Addressing the existing housing stock is more challenging. An existing dwelling has a range of constraints that may limit what opportunities are possible to improve sustainability outcomes. If we are to achieve a low or zero carbon housing stock by 2050 (at the latest), it will require significant action on existing housing [2, 3, 59].

Another challenge is how to account for housing and household trends. For example, in some jurisdictions, there has been an increase in the floor area of dwellings over time [60]. This increase in floor area has been found to offset increases in energy efficiency requirements and has occurred while the average number of people per dwelling has been decreasing. Additionally, this increase in floor area means we have more stuff in our homes, further creating complexities in how we provide sustainable housing. The way we use our homes is changing, which can impact the performance of a dwelling. For example, during COVID-19, many people were required to work from home (where possible) despite many dwellings not being designed for such a situation [61, 62]. This created challenges for liveability (e.g., shared work/living spaces with no boundaries between areas) and performance (e.g., at home for more hours therefore consuming more energy for work activities as well as things like heating and cooling).

Scale is also important for understanding and providing sustainable housing, particularly the dwelling scale, neighbourhood and city scale, and state, national, and international scale. This is because each scale presents different opportunities to provide sustainable housing, and we need to leverage these different scales to ensure optimal outcomes are delivered. For example:

- At the dwelling scale, planning to establish lot layouts and the design of the dwelling are important for optimizing dwelling performance. This allows for improved opportunities to reduce material impacts and integrate sustainability technologies for individual dwellings.
- At the neighbourhood and city scale, it is about identifying how and where to house populations and opportunities to reduce urban climate change, as well as implementing shared infrastructure between or across dwelling borders.
- At the state, national, and international level, it is about the larger coordination of addressing climate change, addressing wider social challenges (e.g., affordable housing, fuel poverty), and governance. Additionally, ensuring larger scale infrastructure is in place to support the transition to sustainable housing at an individual dwelling or neighbourhood scale. For example, if energy networks are not able to cope with an increase in small scale renewable energy, it will potentially curtail sustainable housing opportunities.

9.3 Prospects for Deep Structural Change

Throughout this book, we have highlighted the significant challenges limiting the scaling up of the provision of sustainable housing around the world. As touched on in Sect. 9.2, there are various factors contributing to this. What the current context and wider evidence suggests is that, in order to provide sustainable housing at the scale required, we need to challenge the current provision of housing and the existing housing regime. In doing so, we can create deep structural change across the housing sector and the entrenched resistant stakeholders. Building upon the work of other sustainability transitions researchers, we argue that there are ten key socio-technical dimensions that must be addressed if we are to achieve a sustainable housing transition [63]. These socio-technical dimensions are:

1. guiding principles,
2. physical attributes,
3. knowledge,
4. geography,
5. industrial structures, and organizations,
6. markets, users, and power,
7. policy, regulations, and governance,
8. everyday life and practices,
9. culture, civil society, and social movements, and
10. ethical aspects.

We have provided numerous case studies in Chaps. 6 and 7 that demonstrate how these socio-technical dimensions are already being addressed in real world, sustainable housing projects. These case studies demonstrate what is possible. While we do not argue that all these case studies are perfect, they do offer significant insights into how we are (and can) already be providing housing that is much more sustainable. The case studies provide us with an opportunity to move the sustainable housing transition from the pre-development phase, through to the take-off phase, ultimately leading to an acceleration phase, and then stabilization of a new sustainable housing regime. These case studies, and our reflection of sustainability transition theory, extend recent research exploring the sustainable housing transition and how to facilitate the scaling up of solutions [27, 31, 50, 63–80].

The reality is that we have no other option than to transition to a sustainable housing future. The question is how can it be achieved, over what time frame, and how do we ensure no household is left behind? The current approach of housing provision will leave sustainable housing in the pre-development phase, to those who can afford to obtain it. Those without the financial resources will be left behind. This will create an even wider divide of housing quality and performance based on a household's financial position. However, a more coordinated approach could ensure that those who are more vulnerable in our society are also able to engage with sustainable housing and the benefits that such housing provides. It is vulnerable and lower-income households who will benefit most from a sustainable housing transition in terms of the day-to-day impact of improved health and well-being outcomes and reduced living costs.

The case studies in this book offer hope that we can achieve a sustainable housing transition and a template for what we can provide. However, many of these cases have had challenges in getting to where they are now. For example, the Cape Paterson ecovillage in Australia will have taken almost 25 years from initial conception and purchase of the land, navigating the planning approval process, and construction of the site [81]. This is simply too long a time frame if we are to deliver on sustainability goals by 2050. What we need is a coordinated approach across a range of stakeholders.

Policy makers need to implement significantly stronger regulations to lift housing quality and performance. These regulations should be developed with a pathway to delivering sustainable housing by no later than 2030 for all new housing. Policy makers must also ensure that a pathway for retrofitting existing housing is developed, with sufficient support for households and the wider housing construction industry to help facilitate a scaling up retrofits. This should be based on evidence about the existing housing stock's quality and performance, with the worst quality and performing housing addressed first.[1] Where evidence is not available, governments should prioritize collecting robust data sets on the condition of existing housing. Retrofit policies should be planned to scale up to ensure that the industry can develop required skills and capacity, and retrofit targets should be based on longer term sustainability goals. As a worst-case scenario, retrofits for all existing housing should be completed by 2050, but we would argue for a more ambitious timeframe of no later than 2040.

Housing construction industry stakeholders have a significant opportunity to drive the sustainable housing transition. Because of their size

[1] We note that not all existing housing will be suitable for quality and retrofit improvements due to resources outweighing the benefit of a new build, or where there are strategic decisions to improve density e.g., by replacing a single dwelling with multiple.

and reach, key stakeholders such as large-scale housing developers and builders have the opportunity to lead by example and create significant change. Such stakeholders should be able to leverage their existing (or new) supply chains with economies of scale to ensure that any costs for the transition are kept low. There are significant market advantages for early adopters in that they will likely establish themselves as the authorities in the industry. However, this is easier said than done with significant resistance to change being an ongoing challenge. Education and support for housing construction industry stakeholders will be required to help create wider change, but it may not be enough on its own. Innovative financing or other options like fast tracking planning approval processes may also help drive an incentive for stakeholders to go beyond minimum standards.

Housing consumers need to become more educated about the decisions they make with their housing choices. While many people will not have many (or any) choices (e.g., renters in constrained housing markets), there are others who can use their decision making power to help influence the wider housing sector. However, given the complexity of some elements of sustainable housing (e.g., technologies), consumers should not be expected to understand all the details of a house—much like we would not know all the complexities of a TV or car we were purchasing. It is critical that the provision of information about the performance of a dwelling is clear, robust, and verifiable. There are examples already available that demonstrate this, such as the Energy Performance Certificates across Europe which are providing consumers with better information. However, these certificates will need to evolve to align with developments in the sustainable housing space (e.g., how to deal with two-way batteries in an electric vehicle). Perhaps the most important thing for consumers is to demand to be placed at the centre of housing decisions. It is these consumers who will live in the dwelling and feel the impacts of poor quality and performance. They should not be an afterthought.

Researchers also have a critical role moving forward. Robust evidence will be required to inform the sustainable housing transition and help guide policy making and industry changes. This needs to include both the successes and failures of sustainable housing. Research is required to drive innovation of design, materials, and technologies, but also to better understand how sustainable housing performs in the real world. There needs to be improved connection between technical and social research as there is limited benefit from scaling up technology if it is not being used appropriately by households. Social research can also provide necessary information about changing demographics and cultural practices, as well as support stronger equity considerations in housing provision and outcomes. While there is a significant amount of evidence already available, researchers need to be better at translating this evidence for policy makers, the housing sector, and consumers. We also encourage researchers to be more ambitious with their research, especially in discussing the implications of their research. As a research community, we must look beyond short-term research and at longer time horizons. Let us challenge the research community to be a key driver of sustainable housing (and wider sustainability). To do this, we need to move beyond the conservative nature of our research and challenge policy makers and the housing construction industry to do more.

In Chap. 8, we provided some thoughts on what an ambitious but realistic pathway would look like. In summary, we suggest all jurisdictions:

- Introduce a policy pathway that sets out short to medium term policy goals to deliver new sustainable housing by no later than 2030. This will provide all stakeholders confidence on the future direction of housing quality and performance.
- Introduce a requirement for mandatory disclosure of a dwelling's quality and performance to be used at point of sale or lease for existing housing by 2025. This information must be robust, reliable, and transparent to ensure confidence.
- Set a lifting of minimum performance requirements that are triggered when a dwelling is sold or rented. These requirements should increase over a clear period of time. Drawing upon the European Energy Performance Certificate rating scale, it would not be unreasonable to expect that minimum performance requirements could be improved from an E in 2025 to D in 2028, C in 2031, and B in 2034 (allowing

for three years between minimum performance changes). From 2035 onwards, requirements for existing housing at point of sale or lease could be aligned with new housing requirements.

While this book has largely been focussed on developed countries, a global sustainable housing transition must include developing countries. The housing challenges in developing countries are often different from those in developed countries, and we must ensure that the sustainable housing transition in those locations can help address some of these different challenges. Much like with the global climate change approach, we will need developed countries to help support developing countries with the sustainable housing transition. This can be through sharing of knowledge, skills, materials, technologies, and research, but also likely through financial support to help such countries transform their housing industries.

9.4 A Final Reflection

While it may seem like a monumental task to provide the types of housing we talk about in this book, the evidence and case studies throughout the book offer us hope and guidance. There are policy makers, housing construction industry stakeholders, and housing consumers who have worked within their systems to drive change, as well as those who have pushed to create new ways of doing things. There are jurisdictions around the world banning the use of fossil fuels and incentivizing the electrification of dwellings. There are developers and architects straying from the path and delivering radically different and more sustainable housing options. There are consumers advocating for change and demonstrating alternative ways to live. But we only have a short window of time (perhaps no more than 15 years) to ensure that we change the way we provide housing. It is imperative that we scale up, embed, and mainstream these changes and alternatives, and leverage this progress to facilitate a global transition to sustainable housing. We also need policy makers, housing construction industry stakeholders, and housing consumers to collaborate to ensure the sustainable housing transition is undertaken in the most efficient and effective way. This might seem like a challenge, but as the evidence and case studies demonstrate, this type of housing future is possible.

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