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Working Paper

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Title: Climate change and risk to real estate

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Abstract: Climate change will have a significant effect on the built environment - physically, financially and socially. The impacts of climate change will vary across locations but will include changes to the frequency and intensity of extreme weather events (rainfall, drought and bushfires), and will result in physical impacts such as sea level rise and coastal erosion. This will place a substantial burden on economies, having a detrimental impact on real estate (property) across short and long timeframes. Despite well documented scientific knowledge about climate change impacts, there has been limited research in the real estate sector – notwithstanding its major role in the provision of shelter, and the economies of many countries. In this chapter we explore how climate change will affect real estate, and the implications of this. We identify five key challenges that climate change poses for the sector, and from these we identify a critical research agenda.

Key Words: Climate change; risk; mitigation; adaptation; liability, property, real estate

1. Introduction

The progression of climate change will have a resounding effect on real estate (property) and real estate (property) markets.[1] Whilst initial effects are starting to be felt, the limited action to address climate change risks across the sector suggests a lack of foresight of the implications that will evolve overtime. To address climate change, society must concurrently mitigate (reduce) greenhouse gas (GHG) emissions which are the source of climate change, and to adapt to the changes in climate that are already occurring and cannot be avoided. Whilst mitigation and adaptation actions have been addressed in recent years, actions largely fall short of what is required to curtail its impact.

Over 50% of the world's population live in urban areas, with built environments contributing in the order of 40 – 70% of GHG emissions through activities such as those involving the burning of fossil fuels such as electricity and transport UN-HABITAT (2011). Hence the role that the real estate sector plays in urban areas, could make it a key contributor to driving down GHG emissions that are the source of climate change, and thus influence risk reduction. Further, there are significant risks to the real estate sector from climate change impacts. For example, conservative estimates of anticipated global mean sea level rise of 56cm by the end of the century is expected to directly impact more than 48 million people (Rasmussen et al. 2018). Others calculate 4^{o}C of warming by the end of the century with 8.9m of sea level rise and 627million people living below that level based on 2010 figures (Strauss et al. 2015). Given the land and property impacted by climate change, real estate has an important role in adapting to climate change impacts, while minimising loss and damage to existing assets of public and private benefit.

This chapter begins with an overview of key aspects of climate science and demonstrates the need to rapidly reduce GHG emissions over the next decade. The chapter then moves to examine key climate change impacts on real estate, and considers the implications these have. Throughout the chapter we identify 5 key challenges that climate change poses to the real estate sector. We then address these in the conclusion, presenting a crucial future research agenda to understand the challenges of climate change risk, to assist in decision-making now and in the long term, across the real estate sector and beyond.

2. Climate change – the need for substantial and immediate action

Over the past three decades the Intergovernmental Panel on Climate Change (IPCC) has become the authoritative source for the analysis and synthesis of research related to climate change and its impacts across the globe. Their research collates a body of evidence that human activities have contributed to increased GHG emissions responsible for a 1.0^{o}C of warming to date (IPCC 2018). Future expectations of climate change and its implications are not promising, with the consequences of inaction severe. The direct and indirect effects of climate change will be significant, and catastrophic for human societies and for built and natural environments. Whilst locational variations exist, it is anticipated there will be increased extreme weather events, longer periods of drought, increased frequency of temperature extremes, increased bushfire and wildfire risk, and sea level rise. In turn, these impacts will significantly impact human health, wellbeing and economies. Current international agreements, like the *Paris Agreement* (United Nations 2015) seek to limit global warming to 1.5^{o}C above preindustrial levels by 2100, in order to limit risk, and avoid catastrophic climate change (IPCC 2018). However, the current trajectory of global GHG emissions is set to achieve between 3.2 and 5.4^{o}C of warming by 2100 (IPCC

[1] Real Estate is 'real property' and is often referred to in some countries as property. For the purposes of this chapter real estate and property are assumed to be synonymous where real estate is the land and any permanent improvements attached to the land whether natural or man-made.

2015). Additionally, even if the commitments that countries have pledged under the *Paris Agreement* are achieved, it is projected we will still have 3.2°C of warming as detailed by the UN Environment Program (UNEP 2019). Hence the scale and speed in which society must cut GHG emissions is significant, requiring substantial and immediate action.

Without significant action to reduce GHG emissions across all sectors of the economy, the inability to limit warming will leave built and natural environments exposed to the risks associated with rising seas and coastal erosion; increases in extreme weather event intensity and frequency. This in turn has a range of implications on resources, ecosystems, and cities, across cultural, social, environmental and economic perspectives (IPCC 2018). Already the effects of 1°C of warming have resulted in coral reef bleaching, changing weather patterns - increasing periods of heatwaves and droughts, increasing severity and frequency of extreme weather events, and melting glaciers, ice sheets and permafrost (IPCC 2018). The implications for built environments, and specifically real estate, have seen increases in damage costs, insurance premiums (or having assets that are uninsurable), losses in values and revenue as occupiers and investors seek better located or more robust properties or bear the damages to property, infrastructure and agricultural production (Steffen et al. 2019). These impacts are all expected to increase, as warming increases. Even if warming is limited to 1.5°C, there will be significant effects on natural and built environments that will result in ever increasing social, environmental and economic costs.

A summary of anticipated impacts of climate change are detailed in Table 1. Note, much literature focuses on identifying the physical impacts of 1.5 and 2°C warming, and in general notes the significant negative impacts of warming beyond that – the trajectory on which we are headed. Without significant mitigation efforts, it is very likely that by 2100 between 3.2-5.4°C of warming will be realised, with severe and widespread impacts to: unique and threatened systems; substantial species extinction; risks to food security, constraints to human activities, and increased likelihood of triggering critical thresholds (tipping points) (IPCC 2015 p.86). These metrics do not convey the social and cultural impacts of these changes, which will be significant and should be considered (Graham et al. 2013).

Table 1 Impacts of climate change under 1.5°C and 2°C warming scenarios

	Meet *Paris Agreement* Goals*		Higher end emissions
Temperature change*	1.5°C	2°C	4°C +
Hot weather – global (Betts et al. 2018)	16% more hot days	24% more hot days	
Global population facing severe heatwave at least once every 5 years (Dosio et al. 2018)	13.8%	36.9%	
Area burned by wildfires - Mediterranean (Turco et al. 2018)	Up 41%	Up 62%	
Sea level rise			
Sea level rise - conservative (Rasmussen et al. 2018)	48cm	56cm	
Sea level rise - high-end projections (Strauss et al. 2015)	3.1m	4.7m	8.9m
Population below sea level rise - conservative (based on 2010 population figures) (Rasmussen et al. 2018)	46.12 million	48.76 million	
Population below sea level rise - high-end projections (Kulp and Strauss 2019)	190 million		230 million
Annual flood damage losses from sea level rise (Jevrejeva et al. 2018) in trillions of dollars	US $10.2 T	US $11.7T	US 14.3T
Weather extremes			
- Increased flood risk based on % increase in average annual losses for investment portfolios (AAL) by 2050 (UK, North America and Pacific Rim) (Cambridge Institute for Sustainability Leadership (CISL), (2019))		40% - 43%	70%-80%
- For % increase in AAL for residential mortgages in the UK (CISL 2019)		61%	130%
- Increase in residential properties in the UK % increase of properties at significant risk of flooding (CISL 2019)		25%	40%
Frequency of extreme rainfall on land (Betts et al. 2018)	Up 6%	Up 3.5%	

* Note our current trajectory of global warming will see in the order of 3.2°C of warming by 2100 if Paris Agreement targets are met (UNEP 2019)

In examining mitigation and adaptation, it is important to consider these are separate entities, but also need to be integrated to reduce the overall impacts of climate change (Grafakos et al. 2018). In order to minimise the amount of adaptive investment required, the impacts of climate change need to be minimised (through mitigation). There is already a level of locked-in implications of our GHG emissions to date; but there is opportunity to minimise further emissions and further associated impacts. Thus, action is required to mitigate GHG emissions and adapt to future climate change risks in order to be ready for climate change impacts that can be no longer avoided, and prepare for missed mitigation targets (e.g. limiting warming to 1.5°C) and its consequences.

3. Climate change and implications for real estate

Here we detail some implications of climate change for the real estate sector, and identify three key challenges. As detailed in section 2, the impacts of inadequate action to curtail climate change are significant. Climate change impacts, and hence the adaptive actions required to address its impacts, including in the real estate sector, will not be uniform across the globe. Locations within countries, within states, and within cities will bear different effects and impacts from climate change. Yet, much of the data about climate change impacts is at the global scale, hence:

> *Challenge 1: There is a need for detailed understanding of climate change implications on real estate at local scales. This would facilitate more effective adaptation decision making for the sector.*

Additionally, much of the information about climate change has not been translated into a form that is directly applied to real estate sector needs and decision making. We discuss this further by addressing the diversity of climate change impacts across real estate sectors, before detailing actions in the sector that have occurred to date, by adaptation and mitigation potential.

3.1. Diverse climate change impacts across real estate sub-sectors

The real estate sector, and the actors within it are diverse, which is important to recognise when discussing climate change implications for the sector. Climate change presents a variety of risks applicable to real estate. The risks are broad and far-reaching and can affect different real estate types in different parts of the world to different levels. Even the variability of sea level rise will affect different areas at different levels due to proximity to equator, differential heating and salinity changes in various ocean layers, with subsequent effects on population dependent on a nation's stage of development and their current adaption responses (Hinkel et al. 2018; Yin 2010).

The various real estate sectors are often affected in the same way by climate change risks, however, some are more exposed than others. Sea level rises will affect all properties situated in low lying areas, either through complete inundation and loss, or increased flooding risks resulting in more recurrent flooding and associated damages, and as coastal low lying areas are some of the most highly populated locations in the world, it will not just be economic costs felt, but substantial social costs (Warren-Myers, et al. 2018). Further, sea level rises will affect the productive capacity of agriculture and viability of agricultural activities, placing strain on food supply; loss of farming land and increased salt water intrusion into groundwater creating increasing salinity issues and resulting in ruination of crops, damage or loss to live stock, land and infrastructure (Steffen et al., 2019).

It is estimated, if greenhouse gas emissions continue to rise, AU$226 billion of commercial, industrial, road, rail and residential assets in Australia will be at risk of sea level rise by 2100. Increased temperatures and more frequent heatwaves, droughts and bushfires will also affect agricultural land, and for built environments create greater stresses on building infrastructure across the spectrum through increased demands for cooling, placing additional load on energy grids. A heatwave across south-eastern Australia in 2009 saw direct financial losses estimated at AU$800 million, which were primarily a result of disruptions to electricity, transport and emergency services (Queensland University of Technology 2010). Yet real costs are well underestimated, as just the reduction in labour productivity due to heatwaves annually is estimated around AU$8.7billion per year (Zander et al. 2015). The Victorian Bushfires Royal Commission (2010) reported that the 2009 Black Saturday bushfire is estimated to have cost AU$4.4 billion (this includes the calculation of the 173 lives lost a value of AU$645 million). Of this, property associated costs comprised AU$1.2 billion of insured losses. Yet this is likely underestimated as 13% of homes were not insured. Extreme weather events comprising increases to windspeeds, storm severity and precipitation are escalating. This is causing increases in building, infrastructure and land damages and losses, with increasing insurance premiums and an increasing number of properties identified as uninsurable over the coming decade (Furnnell 2020).

> *Challenge 2: There are a diversity of sub-sectors within real estate, with heterogeneous types of real estate, characteristics, actors and associated climate change impacts. Research is needed to understand the climate change impacts across the diversity of the real estate sector, to inform decision making.*

Climate change risks will vary across the diversity of the real estate sector. There are three key types losses that are considered to have direct effect on a property's value and risk profile: direct, indirect, and consequential:

- Direct losses – losses associated with damage or total loss of tangible assets – for example loss or damage to dwellings, offices, buildings, infrastructure or public facilities, increased costs related to materials or resources, increased insurance premiums; (Kron et al. 2012 p. 542)
- Indirect losses – losses associated with the operational aspects of the building, for example loss of rent, loss of revenue from business generation, loss of jobs and costs or losses associated with transport to the building; (Kron et al. 2012 p.543).
- Consequential losses – losses that are essentially considered "secondary costs" and this occurs as a result of repercussions of the event occurring, for example lower direct investment, increased vacancy, loss of demand, loss of competitiveness in the market; (Bienert 2014 p,9)

Additionally, business and regulatory risks will be associated with each of these depending on actions by industry and/or government regulation across both mitigation and adaptation. Regulatory risks pose significant implications for values. For example recent changes to have a minimum level under the Energy Performance Certificate (EPC) has led to a stranding of assets – having a detrimental impact on value and utility (Muldoon-Smith and Greenhalgh 2019). There are two further types of losses. These relate to human loss and injury costs; and costs associated with the loss of natural capital. While they are important considerations, and have broader implications for real estate owners, investors, occupiers and managers for reputational and business risk perspectives, they are outside the direct scope of this chapter. In Table 2 we detail select climate change risks, their implications for real estate, and the loss and value implications.

Table 2 Climate Change risks and how they are translate to loss and value implications for real estate

Climate Change and Related Risks	Implications for Real Estate	Types of Loss and Value Implications
Sea level rise [1]	- Inundation - Increased flooding and damage - Ongoing increased costs: damage and preventative - Uninsurable - Salt intrusion into ground water and coastal wetlands	**Direct:** Total loss of real estate/property and value associated with land and buildings (permanent inundation);increased flood damage costs over time.[1] [3]. **Indirect**: Utility of asset periodically affected or lost entirely, loss of rent/income generated through ownership, lost revenue for businesses, costs associated with jobs or access, subsequent effect on value. [1 **Consequential:** Discounting of property value with reoccurrence of event, lower direct investment, increased vacancy, loss of demand, increased depreciation and obsolescence. [1]. **Value:** Long-term complete loss of property/significantly discounted value due to damage and prevention costs, increased depreciation and obsolescence, uninsurable status. [1]
Temperature changes	- Increased number of days with higher temperatures - Increased capacity requirements of building cooling systems due to higher average temperatures[2] - Higher energy demand (peak), potential black outs[3]	**Direct** – costs of maintenance and replacement, reduced rents[2], retrofitting assets with better thermal qualities (insulation, windows), lower heat generating and energy efficient equipment, and greater capacity air conditioning systems[3]. **Indirect:** may result in periods of rental or income loss**. Consequential**: reduced rentals, increased vacancy, increased obsolescence and lower market values. **Value:** Properties will need to adapt and improve energy efficiency and mechanical ventilation capacity in order to maintain value; failure will result in value discounting by occupiers and investors.
Bushfires	- Increase in number of days with very high and extreme heat and fire danger [3] - Fire damage to property and assets – leading to damages or total loss of property - Increased insurance levies	**Direct:** Total loss of buildings and fire related damage costs. [3] **Indirect**: Loss of rent/income generated through ownership, lost revenue for businesses, costs associated with jobs or access. [3] **Consequential:** Discounting of property as reoccurrence of event, lower direct investment, increased vacancy, loss of demand, increased obsolescence, insurance premiums increase or uninsurable status. [3] [5]. **Value:** Increased risk exposure could lead to property being uninsurable, and exposed to total loss or damage costs.
Extreme weather events	- Increased frequency and severity of storms. - Increased intense rain events - Cyclone frequency may reduce but increase intensity resulting in more severe damage and loss. [3] - Property damage costs from wind, hail, flood	**Direct:** Increased damage costs, from hail, wind, flooding.[2] [3] **Indirect**: Loss of rent/income due to damages, lost revenue for businesses, costs associated with jobs or access. [2] [3]**Consequential:** Discounting of property with reoccurrence of event, lower direct investment, increased vacancy, loss of demand, increased obsolescence, increased insurance costs [3]. **Value:** Increased risk exposure could lead to increased annual property damages (direct and indirect), potential for building to be uninsurable, and exposed to long term value discounting. [2][5]
Regulatory and Adaptation Costs Market Risks Resource Availability Reputation and Competition	- Increased costs associated with regulatory compliance and management. [3] - Increased costs for resources, building materials, energy, water disposal of waste. [3] - Higher adaption costs to protect buildings and make more efficient. [2] [3] - Increased taxes: e.g. GHG emissions; funding adaptation measures[2] - Stranding of assets: exposure to vulnerable areas/locations, or changes in legislation.	**Direct:** Increased compliance and management costs; loss of market share and income; increased construction costs; increased costs associated with taxation like carbon taxation [2] [3]. **Indirect:** Reduction or loss in rental income (rental demand); reputation and brand risk; exposure to declining markets. [3] **Consequential:** Increased obsolescence and reduction in property values if not compliant with regulations and adapting to resource efficiency to mitigate carbon cost implications. [3] **Value:** Increased risk exposure could lead to property being uninsurable, and exposed to total loss or damage costs. Declining market values due to exposure to market risks, reduction in demand, and or regulatory requirements that result in stranded assets.

[1] Warren-Myers et al. (2018) [2] Bienert (2014); [3] Smith (2013); [4] Urban Land Institute and Heitman (2019); [5] CISL (2019)

The preparedness and action of the real estate sector relies on examining and understanding the risk associated with climate change to enable suitable responses in the form of both mitigation and adaptation actions. Physical risk is likely the easiest to model and quantify, however, the other risks which pose an often 'unknown' because they are not usually insured like the direct physical risks, are often considerably larger than first thought. For example, evidence is beginning to emerge that private property owners, are increasingly discounting sea level rise exposed properties up to 7% according to (Bernstein et al. 2019). However, the perceived discounting of property at risk of sea level rise is highly dependent on whether you believe in climate change. Baldauf et al. (202) found that those who were 'believers' discounted properties at risk compared to those in denier neighbourhoods.

Sea level rise is in effect largely a 'future' event, and estimating current effects are challenging as amenities outweigh perceived risk (Atreya and Czajkowski 2014), yet flood risk may be discounted, discounting for sea level rise is not yet evident (Murfin 2020). The growing emphasis of climate change and its role in current natural hazards like hurricanes (cyclones), wildfires and blizzards, is generating strong sceptic behaviour in relation to climate change (Dixon et al. 2019). Yet, evidence is also emerging that certain affected industries, or groups who are feeling the effects of events, are more adverse to climate change risks (Hamilton-Webb et al. 2017). Understanding climate change related risks can be easily expanded by understanding the potential losses associated with climate change. There is already emerging evidence that certain climate change related effects are impacting property through various means. Table 3 provides an overview of some recent events demonstrating vulnerability to these climate change risks and the implications of this now and into the future.

Table 3 Examples of the realisation of Real Estate effects and implications

Climate Change Risk	Location/s	Current Implication for Real Estate	Future implications	Reference
Sea level rise	Kiribati Carteret Islands (Pacific)	- Increased flooding and storm damage – residents have to take refuge - First location in the world to require population relocation due to sea level rise	- Sea level rise Complete loss of land and buildings - Climate refugees. Purchase of land in other countries for migration.	Hermann and Kempf (2017) Connell (2016) James (2018)
Extreme weather events	Fiji Atlantic	- Cyclone Winston – strongest cyclone ever to hit landfall in southern hemisphere - Cyclones have been increasing in severity by 25-30% per degree of warming. - Current losses from hurricanes in the U.S have increased 100% since 1980	- Increasing severity, generation of storm surges resulting in extreme sea levels - Anticipated losses by 2100 will have increased 300%	Walsh et al. (2012) Elsner (2020); Elsner et al. (2008)
Droughts	Cape Town, South Africa	- Without ample water supply, the viability of settlements is compromised - supressed economy, social and health impacts, potential for stranded assets.	- Some locations may no longer be viable for human settlement due to changes in water availability	Wessel (2018) Hurlimann and Dolnicar (2011)
Bushfires	Australia (2019/2020) Russia (2020) California (2019)	- Increased frequency and intensity of bushfire risk days; insurance and damage costs	- Potential for uninsurable property; increased costs of insurance / damages. Loss of property value. - More frequent cycle of damages - Impacts for multiple life support systems	Morris (2020) Shvidenko and Schepaschenko (2013) Mueller et al. (2009)

3.2. The need for better information about climate change impacts for the real estate sector

Since the publication of the IPCC's first assessment report in 1990, there has been increased awareness of climate change and its future impacts. Yet at the same time, there has been an acknowledgement that the largely scientific information presented in these reports, needs to be translated into a format that is suitable to the needs of decision makers working in government and industry. Efforts have been made to publish 'summary reports' for policy makers. Subsequent reports by the IPCC, research and information produced by the Investor Group on Climate Change (2016), industry bodies and organisations like the Urban Land Institute (ULI and Heitman 2019); Royal Institution of Chartered Surveyors (RICS), UN Environment Programme Finance Initiative, and academe, have sought to examine the variability and uncertainty of climate change impacts and implications, gather and generate data and provide scenario analyses for the real estate industry and associated sectors. However, recent research by Hurlimann et al. (2018) and (Warren-Myers et al. 2020a; 2020b) have found that information and data is difficult to attain by many in the Australian construction and property sector, and that barriers are prevalent across information, cost and investment, organisational capacity, regulatory changes and ability to adapt (See Table 4).

Table 4 Barriers to climate change action in the property and construction sectors

Climate Change Risks and Transition Risks	**Information Barriers**	**Cost & Investment Barriers**	**Capacity Barriers**	**Regulatory Barriers**
Sea level rise [1]	Lack of certainty and nuanced modelling for all locations Lack of understanding of the implications of other measures affected by sea level rise, like storm surge, high tides and waves. Ability to identify if your property is at risk and to what extent that risk is	Damage cost estimates for your property Understanding insurance information and the impact of premiums or un-insurance for at risk properties Loss in property values either completely or incrementally over time.	Identifying valid sources of information Having the personnel who are knowledgeable and able to translate the information into operational practices and decision-making	Lack of federal, state and local government action on a policy and implementation aspect Local government attempts to apply through the planning process has been met with widescale criticism
Temperature changes	Information providing detailed forecasting of future hot temperatures Prediction and estimation of exposure to bushfire risks Impact of future hot days, heat waves and impacts on building HVAC systems, and energy power loads	Retrofitting or constructing additional capacity for building to cope with changing environment. Damage costs associated with heat or fire events	Identifying valid sources of information Having the personnel who are knowledgeable and able to translate the information into operational practices and decision-making	Changes to building codes – increases in costs to build (or rebuild) Understanding where prohibited areas for development Government buy back schemes of risky property
Extreme weather events	Prediction and estimates of severity and likelihood changing and varies by location Insurance coverage unknown and unknown what insurers consider for the property	Damage cost estimates for your property Understanding insurance information and the impact of premiums or un-insurance for at risk properties	Identifying valid sources of information Having the personnel who are knowledgeable and able to translate the information into operational practices and decision-making	Changes to building codes - increases in costs to build (or rebuild)
Regulatory and Adaptation Costs	Lack of information about the costs and cost-benefits of new regulatory requirements, or adaptation costs for assets.	Increased costs associated with regulatory compliance and management. [3] Higher adaption costs to protect buildings and to make more resource efficient. [2] [3] Stranding of assets, either through exposure to vulnerable areas or locations, or through changes in legislation.	Changing regulatory landscape and capacity in-house or for out-sourcing of understanding the implications for the organisation and how to develop new strategies to align [3]	Industry associations resistance and public opinion
Market risk, Reputation and Competition	Understanding the effect of inaction on reputation Competitive risk and information required on cost-benefit of strategies and actions	Increased taxes – in terms of carbon and also funding of adaptation infrastructure. [2] Value lost due to stranding of assets, either through exposure to vulnerable areas or locations, or through changes in legislation.	The need to have the right team for business strategy alignment of CSR strategies, rating systems and disclosure requirements Competitive resilience (Teicher, 2018) identifying the potential to utilise CSR, mitigation and adaptation actions as competitive edge, but resources and costs will be associated.	Stranding of assets, either through exposure to vulnerable areas or locations, or through changes in legislation.
Resource Availability	Information about resource costs and consistency of supply into the future, ie energy costs.	Increased costs for resources, building materials, energy, water; and disposal of waste.	Ability to identify new resources and technologies, this may also require different internal skillsets in procurement.	Lack of support for research and development in new technologies and resources. Threat of regulatory changes may cause further cost implications and security of access.

[1] Warren-Myers et al. (2020a) [2] Warren-Myers et al. (2020b)Warren-Myers et al. (2020c); Hurlimann et al. (2018a, 2018b); Hurlimann et al. (2019)

Challenge 3: There is limited accessible information about the direct impacts of climate change for the real estate sector available. There is a need for an increase in the quality, reliability and sharing of data on climate change and its implications.

3.3. Actions to address both climate change mitigation and climate change adaptation in the real estate sector

There is urgent need for more research from a property and property industry perspective in order to engage stakeholders and enact mitigation and adaptative action. There are important considerations that span local to global scales, and reach across the varied sectors within the real estate industry that need to be identified, examined, modelled with the aim of developing possible solutions and avenues for change. Increasing awareness is paramount across the sector. As identified by Warren-Myers et al. (2020a) knowledge and information in the Australian property industry is limited, with similar experiences noted elsewhere (Teicher 2018). Grasping the sector's responsibility and enacting the changes necessary to limit global warming is considerably more difficult as the majority of the industry continue in a 'business as usual' approach. Further, the risks of climate change will wary across locations, and likely the effects and implications may also be localised. As a result, it may not necessarily be a one solution fits all, and more research tailoring to local environments, governance and policy arrangements and economic markets is needed. The timing is also uncertain, and planning exist strategies for flood prone or likely to be inundated properties is as yet a foreign concept.

3.3.1. Mitigation Action in the real estate sector

The *Paris Agreement*, amongst its predecessors, sets GHG emission reduction targets from many of the developed and developing nations around the world. Whilst, there is still uncertainty about the capacity to meet these targets, it and other global commitments have led to various approaches by governments and markets to regulate or enable GHG emission reductions. Given real estate could be considered a major contributor to GHG emissions, the sector has been seen as an area of great opportunity to reduce GHG emissions. Many policies, regulations and voluntary market tools have been developed to engage and reduce GHG emissions in the real estate sector. Some notable policies and tools for commercial and residential property comprise: Energy Star (U.S), Energy Performance Certificates (EPC) (U.K and Europe) and in Australia residential NatHERS and the commercial NABERS. The competitive market has seen significant uptake and engagement with rating tools and systems, particularly where mandatory disclosure has been implemented, which has seen reflection of ratings and improved efficiencies and sustainability in market values and rents across the world in both residential and commercial properties, a sample include Fuerst and Warren-Myers (2018), Fuerst et al. (2015), Newell et al.(2014) and Fuerst and McAllister (2011). However, this competitive market has also meant that information sharing has been limited, and often the 'star' ratings, which are a useful marketing and communication tool, are simplified in order to hide of mask the requirements and actual strategies applied. This is often further complicated by whether the buildings are 'designed' to perform, or whether the reporting is based off actual operational performance information.

There is a broader range of sustainability based tools which have a wider approach to sustainability consideration. These are often targeted at design of new builds and major renovation, however, more tools are emerging that assess the sustainability performance of buildings across the spectrum. The next wave of targets, policy and regulation relates to the concept of 'Net Zero Emission' targets. Whilst in the built environment the adaption of this concept is Net Zero Energy/Emission Buildings (NZEB), which is defined by the World Green Building Council (2020) as '*buildings that are energy efficient, and supply energy needs from renewable sources (on-site and/or off-site) is a more appropriate target for the mass scale required to achieve Paris Agreement levels of global emission reductions.'* This has led to commitments from governments, and individual organisations to commit to net zero emission targets and tools, these include Green Building Councils in France, Canada, Brasil, South Africa, United States, Germany and the U.K. Whilst governments have also created commitments to NZEB (or nearly Zero Energy Buildings).

From an industry perspective, recent announcements from some of Australia's top ASX listed real estate organisations making commitments for their portfolios to achieve Net Zero *operating* emissions across the properties by 2030 including AMP Capital Wholesale Office Fund, Cbus Property, Cundall, Commonwealth Bank, Dexus, Frasers Property Australia, GPT Group and Multiplex, Nightingale Housing and Stockland (Green Building Council Australia 2018). However, often similar to the loop holes noted with the rating tools, the term 'operation' has different interpretation and often only refers to the operational (and in some cases only the base building operational) energy considerations, further there is no consideration of the embodied energy consumed by buildings in their development, and across the whole lifecycle of the building.

Whilst it is apparent many of these tools and schemes are generating behavioural change in the real estate sector reducing GHG emissions, broader and more ambitious action is needed in order to meet *Paris Agreement* targets to limit global warming to 1.5^{o}C. A further challenge of these current schemes, objectives, policies and tools, is the lack of consideration of embodied GHG emissions in property. It is anticipated by (Röck et al. 2020) that an estimated 20 – 25% of annual anthropogenic GHG emission are embodied. In buildings, they can account for between 10 – 97% of emissions across the life cycle (Chastas et al. 2016). In an analysis by (Schmidt et al. 2020) to house Australia's growing population over the next 10 years (to 2030) and 40 years (to 2050) the total lifecycle emissions of new housing will be responsible for 883 $MtCO_2e$ (2030) and 3,654 $MtCO_2e$ (2050) respectively. This is considerably higher than Australia's total emissions optimum target of 441 $MtCO_2e$ by 2030. This demonstrates that the consideration of embodied and operational emissions emitted throughout the lifecycle of built environments have greater impact emissions calculations and estimations, than is commonly considered. Whilst operational energy as previously noted has had an increasing role in mandatory schemes driving change, there are still sectors of the built environment including property, that have limited or very little drivers for change in the development or operation of buildings. In addition, all sectors are presently missing the broader implications of the hidden but still prominent embodied GHG emissions.

> *Challenge 4: For significant GHG emission targets to be met (to limit climate change impacts), further research is required on life cycle consideration of GHG emission and drivers and levers to generate mainstream change across the real estate industry.*

3.3.2. Climate change adaptation Actions in the real estate industry

At present action on the adaptation side, is relatively focused on post-disaster recovery, where federal governments come to the aid of those affected who reside in disaster prone areas. The substantial figures in Australia alone, have an average cost per year including tangible and intangible costs exceeding AU$9 billion (approximately 0.6% of GDP) and are anticipated to increase by 50% to reach

AU$33 billion annually by 2050 (Deloitte Access Economics 2016). When examining the impact of natural disasters extreme events, there was AU$7 billion attributable to the 2009 Black Saturday bushfires (AU$3.1bn tangible and AU$3.9 intangible); and the Queensland Floods in 2011 – 2012 $14.1 billion (AU$6.7bn tangible and AU$7.4 intangible) (Deloitte Access Economics 2016). In the U.S in 2020, to July 8, there had already been 10 extreme weather and climate related events each totalling more than a US$1billion in losses (NOAA National Centers for Environmental Information 2020). In Europe disasters associated with weather (flood and windstorm) that have exceeded 100 deaths or have a minimum US$5billion in losses between 2006 and 2016 comprise seven key events totalling US$55.3 billion (inflation adjusted to 2018)(Kron et al. 2019).

As cumulative totals are realised, and the real costs of inaction are more apparent, the current band aid approach of post-disaster rescue is not a sustainable approach for government, businesses, communities and individuals. Consequently, a reshaped focus on pro-active action is required. However, there would appear to be a range of barriers (obstacles) hindering climate change adaptation action, which can be classified into three key sources: actors making decisions, the context (the place or system) and the exposure to risks associated with climate change (Eisenack et al. 2014). In the context of real estate, multiple climate change risk may affect property in a multitude of ways and it is the actors of which there are many, who are the main barriers to adaptative action. In real estate there are a plethora of actors involved in the various stages of the development process; yet ultimately, the client (owner, developer, investor, occupier) are the key decision-makers. They are restrained by government, and the various levels that place restraints on real estate, yet opportunity exists within these structures to take action, although greater guidance and direction by governments would likely accelerate the process. However, one of the largest considerations for real estate 'clients' is the financial implications of change and how this is seen by the market. Warren-Myers et al. (2020b) in their research investigating the capacity of the real estate industry to take action on climate change, exposed a number of barriers to action which were centred around three main themes, information validity and exchange, financial challenges and market competitiveness, and government role in leading adaptation action. Whilst, the current approaches of governments to focus on disaster recovery, rather than preventative measures is effectively perpetuating the problem (see for example the case of drought in Australia: Hayman and Rickards 2013), and one the suggests a moral hazard. By governments offering aid to affected people in a post-disaster scenario, will in essence continue to encourage people to build and reside in disaster risk areas by providing this 'backup insurance' effectively when disasters strike (Bunten and Kahn 2017).

Challenge 5: Without significant and certain actions to reduce GHG emissions, it difficult to anticipate the type of adaptive action and level of action required to future proof property assets.

4. Conclusion

This chapter has identified five challenges posed to the real estate sector in relation to climate change. We now respond to these through the identification of research needs in response.

Challenge 1: There is increasing need for detailed understanding of climate change implications on real estate at the local scales. This would allow more effective adaptation decision making for the sector.

Research response 1: It would be beneficial for property stakeholders to advocate for, and contribute funds towards conducting research to understand the climate change implications on real estate at locally relevant scales. This information should be provided in a format that is clear, and widely beneficial and applicable for all levels of decision-makers involved in the development, investment and management of property - from renters and home owners to large commercial entities, and governments.

Challenge 2: There are a diversity of sub-sectors within real estate, with heterogeneous types of real estate, characteristics, actors and associated climate change impacts. Research is needed to understand the climate change impacts across this diversity within the real estate sector, to inform decision making.

Research response 2: Research is needed within each of the different real estate sub-sectors and across diverse locations, to better understand 1) the full potential to take climate change mitigation, and 2) to prepare properties and their relevant stakeholders for adaptation actions required to future proof their assets and prevent stranded asset syndrome.

Challenge 3: There is limited accessible information about the direct impacts of climate change for the real estate sector available. There is a need for an increase in the quality, reliability and sharing of data on climate change and its implications.

Research Response 3: There is a need to make research and information about climate change in the real estate sector applicable and available. There is a need to overcome perceived competitive advantage, and begin sharing mitigation and adaptation strategies for the greater good.

Challenge 4: For GHG emission targets to be met and to limit climate change implications, further research is required on life cycle consideration of GHG emission and drivers and levers to generate mainstream change across the industry.

Research Response 4: Research is need is to identify and implement opportunities across the real estate sector to reduce GHG emission in line with achieving the *Paris Agreement* goal of 1.5^0C

Challenge 5: Without significant and certain actions to reduce GHG emissions, it is difficult to anticipate the type of adaptive action and level of action required to future proof property assets.

Research response 5: Research is needed to better understand the range of adaptation levels required for the real estate sector under different scenarios of warming. This would provide greater understanding and transparency of the actions required of different stakeholders, the range of investment decisions and the cost implications of these decisions and adaptative strategies.

These research responses point to areas of research needed to understand the current and future risks that climate change extremes pose. Such information will help to ensure assets are not carbon stranded; inform risk mitigation or divestment strategies; spur changes to due diligence processes and their consequences; and build knowledge and capacity to enact required changes throughout the industry. The current inadequate and limited focus on mitigation is not sufficient to avoid the catastrophic impacts of climate change and its consequences for the real estate sector. To achieve the *Paris Agreement* goals, action is needed across the built environment, and mitigation and adaptation need to be considered concurrently and acted on. Mitigation actions for the real estate sector must be in proportion to the reductions in emissions needed to limit warming to 1.5^{o}C. Adaptation actions must be aware of the impacts of warming at 1.5^{o}C and in excess of this. There will not be a uniform approach and there will be extensive research required to identify a variety and often unique pathways and solutions to the challenges climate change presents. Actors in the Real Estate sector must adapt and adjust to climate change, in order to avoid becoming the frog in the cooking pot.

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