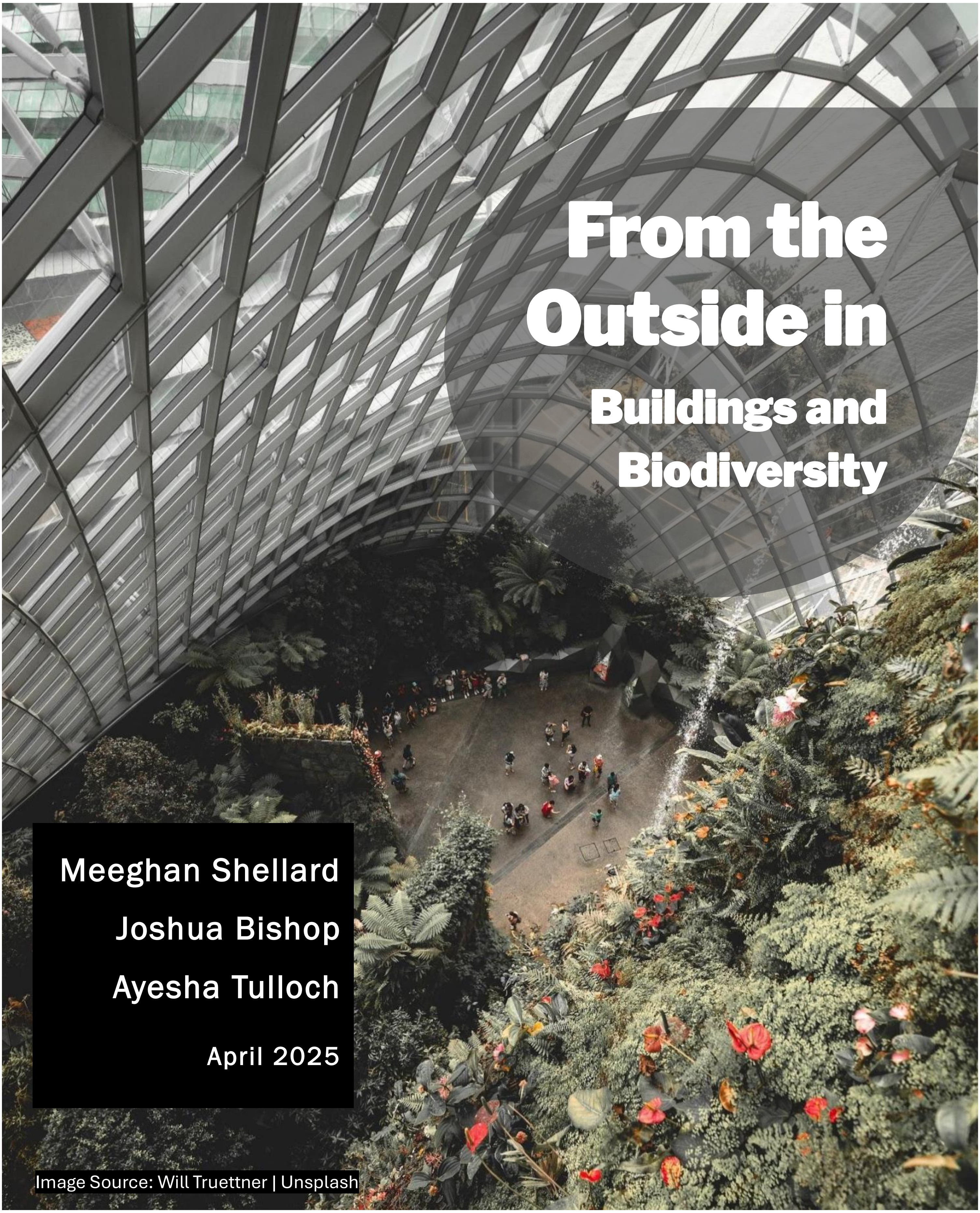

From the Outside in

Buildings and Biodiversity

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April 2025

Image Source: Will Truettner | Unsplash

Executive Summary

Shelter is a basic human need and right. Buildings protect us from exposure to heat and cold, wind and rain. Infrastructure makes our lives safer and more productive. By design, buildings and related infrastructure limit our contact with nature. Their construction also involves a range of impacts on nature, from direct habitat and species loss on building sites, to indirect impacts in the supply chain for construction materials, equipment and furnishings, not to mention the long-term impacts of occupancy and eventual demolition.

Nature is in retreat everywhere and our buildings are part of the reason. At the same time, direct experience of nature - time spent outdoors - is a small part of most peoples' lives, with serious consequences for our mental and physical health. So how can we bring nature into the built environment, while also reducing the adverse impacts of buildings on the natural world?

Understanding the impacts of buildings on biodiversity is crucial as urbanisation continues worldwide. This report explores how the construction industry shapes our ecosystems and our experience of nature. We identify specific areas and stages of the building life cycle that contribute to biodiversity loss, while also examining tools and approaches available to address these impacts and increase human contact with nature in the built environment.

The study encompasses an extensive literature review, aimed at identifying published evidence of biodiversity impacts throughout the building life cycle. Additionally, we investigate current and emerging tools and approaches to mitigate these impacts and to promote sustainability within the built environment more generally. The research is complemented by a qualitative analysis of interviews with selected industry stakeholders, to identify barriers and enablers to the adoption of sustainability initiatives within the Australian built environment.

We explore how buildings affect biodiversity through multiple pathways, both direct and indirect. Direct impacts include habitat destruction, species displacement, and ecosystem degradation at construction sites. Other impacts arise throughout the building life cycle, including in the supply chain, from raw material extraction to waste disposal. While impacts tend to be concentrated during construction, all stages of the building life cycle contribute to biodiversity loss to varying degrees, depending on project-level and site-specific factors.

Stakeholder interviews highlighted key barriers to implementing biodiversity-sensitive practices:

- Limited awareness and understanding of biodiversity impacts across the industry
- High costs (real or perceived) of *Green Building* / product certification and practices
- Knowledge gaps and lack of standardised guidance for biodiversity conservation
- Opacity across building material / product supply chains
- Lack of clear metrics and tools for biodiversity reporting
- Regulatory fragmentation and inadequate policy frameworks

Solutions suggested by interviewees commonly focused on:

- Government support for market transformation and sustainable design innovation
- Stronger environmental regulations and improved policy coordination
- Enhanced green financing tools and economic incentives
- More standardised, independent verification of sustainability performance
- Better guidance on biodiversity conservation and restoration
- Improved industry education and capacity building

The report concludes that creating nature-positive buildings requires a fundamental shift in how we conceive, design, construct, and operate our built environments. This should include:

- Adopting whole-systems thinking approaches
- Integrating biodiversity considerations throughout the building life cycle
- Strengthening collaboration between stakeholders
- Developing better metrics and reporting frameworks
- Creating supportive policy and regulatory environments
- Fostering a culture that values nature and biodiversity

We provide 27 recommendations organised under five major themes in an attempt to offer practical guidance for stakeholders across the building and construction industry to advance nature-positive outcomes. Our recommendations are summarised below.

Reducing Threats to Nature

Recommendations focus on addressing both direct impacts and indirect drivers of biodiversity loss in the construction industry. Key actions include avoiding high-biodiversity areas, prioritising building reuse, adopting circular economy principles, using sustainable materials, managing construction impacts, controlling pollution, and reducing fossil fuel use.

Conserving and Restoring Biodiversity

Recommendations emphasise understanding and working with local ecosystems through comprehensive site analyses, retrofitting buildings using green infrastructure, protecting native vegetation, designing for wildlife habitat, and compensating for unavoidable environmental impacts through verified restoration projects and offsets.

Innovation and Knowledge Sharing

Recommendations focus on advancing sustainable practices through research into nature-based solutions and materials, sharing data and knowledge openly, promoting environmental education and human-nature connections, and designing climate-resilient buildings using passive design principles and nature-based solutions.

Governance for Nature

Recommendations outline management approaches that include setting science-based biodiversity targets, fostering multi-stakeholder collaboration, reforming harmful policies, implementing economic incentives and penalties to stimulate the adoption of sustainable practices, and establishing robust monitoring systems to track biodiversity indicators.

Fostering a Nature-Positive Culture

Recommendations in this final theme address the fundamental cultural shift needed, calling for professional training in biodiversity and ecological ethics, challenging outdated practices, encouraging deep reflection on environmental values, advocating for biodiversity conservation in decision-making, recognising nature’s intrinsic rights, and fostering cross-disciplinary processes that include *Indigenous Knowledge* and perspectives.

Contents

List of Acronyms

BASIX	Building Sustainability Index (NSW, Australia)
BBOP	Business and Biodiversity Offsets Programme
BREEAM	Building Research Establishment Environmental Assessment Method
C&D	Construction and Demolition
CBD	Convention on Biological Diversity
CBD	Commercial Building Disclosure
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ESD	Ecologically Sustainable Development
ESD	Environmentally Sustainable Design
ESG	Environmental, Social and Governance
GBCA	Green Building Council of Australia
GHG	Greenhouse Gas
IEQ	Indoor Environmental Quality
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
LCA	Life Cycle Analysis
LEED	Leadership in Energy and Environmental Design
NABERS	National Australian Built Environment Rating System (Australia)
NatHERS	The Nationwide House Energy Rating Scheme (Australia)
NGO	Non-governmental organisation
NCC	The National Construction Code (Australia)
NG	Net Gain
NNL	No Net Loss
NPI	Net Positive Impact
NSW	New South Wales, Australia
SDG	United Nations Sustainable Development Goals
VSS	Voluntary Sustainability Standard/s

List of Text Boxes, Figures and Tables

Authors’ Preface

This report has been a long time coming. What started as a student project has evolved into a labour of love, in an ambitious attempt to review the interactions between buildings and biodiversity, focusing on Australia while drawing on theory and practice from other countries.

During the long gestation of this report, the world has not stood still. More and more organisations are thinking about how to integrate nature and industry, including in the built environment. This trend has been stimulated by the *Kunming-Montreal Global Biodiversity Framework* (GBF), agreed by world governments in 2022, along with growing interest in the concept of ‘Nature Positive’ as a global, national and organisational goal.

Our own thinking has likewise evolved in the process of writing this report, including:

- An embrace of whole systems thinking and Regenerative Design as fundamental principles for analysis and action;
- A shift in focus from simply mitigating adverse environmental impacts to also enhancing the contribution that the built environment can make to nature regeneration and human wellbeing;
- Broader consideration of biodiversity that recognises the diverse values and valuations of nature by different stakeholders, as well as the intrinsic rights of biodiversity to exist; and
- More emphasis on flexible standards and context specific, community-driven solutions, without compromising the ultimate goal of nature-positive and socially beneficial outcomes.

We began this project with a few simple but broad questions: *‘what are the impacts of the built environment on biodiversity? At which stage of the building life cycle do the worst impacts occur? What is being done about it? Is this enough? And how can buildings be better for biodiversity?’*

The first step involved a review of literature, covering a range of different scales in the built environment (cities, neighbourhoods, individual buildings), and the different ways that human settlements interact with nature, both directly and indirectly (from individual building sites to urban landscapes, to the sources of building materials and the use of natural resources from forests, rivers, and quarries). These different scales and interactions were considered first in terms of ecological impacts, then from an impact avoidance and mitigation perspective, and finally from a more holistic, regenerative perspective.

Additionally, we considered how these impacts and interactions change during the building life cycle, which can last centuries in some cases. This added another layer of complexity to analysing both the problems and solutions that the construction industry faces when grappling with sustainability and urban development.

Given the vast scope of issues under consideration, we make no claim to be comprehensive or conclusive. Our aim rather is to present a general introduction to the role of the built environment in the climate and biodiversity crises, and the responses to date from governments, industry and other stakeholders. Wherever possible, we include Australian-specific information. One unique contribution of this work is a record of the opinions of a diverse range of stakeholders working in the Australian building design and construction industry and related sectors, obtained through one-on-one interviews, which may be of special interest to Australian readers.

The interviews, in particular, have reinforced our enormous respect for all stakeholders in the built environment, including those in the wider supply chain, who choose to act for sustainability. They have opened our eyes, challenged our assumptions, and helped us to gain valuable insight into the multilayered nexus between the built environment and nature as separate, yet interdependent complex systems.

Australia today is often described as being in the midst of a housing affordability crisis. This has led to calls for lower mortgage interest rates, faster development planning approvals, an enlarged construction workforce, and vastly increased housing supply. While politicians' promises of new homes may not be fully realised, the push to train new construction workers and increase the pace of home building in Australia creates both challenges and opportunities for conserving biodiversity and bringing nature into the built environment. We hope this report will provide encouragement to those who are already engaged in green building design and construction, while offering food for thought to those who are impatient to see new homes built around the country.

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April 2025

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Expert insights on the subject matter of this report were generously shared and are discussed in Chapter 5, based on interviews conducted with: Nicolette Boele, Judy Bush, Dominique Gill, Dominique Hes, Jeff Elliott, Katherine Featherstone, Monique Gay, Peter Graham, Laura Hamilton-O'Hara, Mary Holmes, Peter Hunt, Rikki-Lea James, Karen Lambert, Russ Martin, Alicia Maynard, Paul Osmond, David Palin, Caroline Pidcock, Pooja Rao, Davina Rooney, Paul Sabatini, Judith Schinabeck, Lucy Sharman, Tim Wheeler, Dean Willemsen, and Guy Williams.

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Chapter 1 - Introduction

This report explores the potential to integrate biodiversity impacts and management in buildings and construction, with a focus on the following questions:

- Where in the building life cycle do significant impacts on biodiversity occur?
- What mitigation actions can reduce biodiversity impacts in the construction industry?
- What policies, standards and certifications are available to verify and/or motivate the mitigation of adverse impacts on biodiversity in the construction industry?
- What are the main barriers and enablers for the construction industry to consider biodiversity impacts, and to participate in voluntary green building initiatives?
- How can we strengthen consideration of biodiversity in the built environment?

1.1 Background and Overview

The recent decline of biological diversity ('biodiversity') is well-documented (IPBES, 2019; van Goethem and van Zanden, 2021). According to recent analysis by the Worldwide Fund for Nature, monitored wildlife populations decreased by a catastrophic 73% between 1970 and 2020 (WWF, 2024).

The reasons for biodiversity loss are also clear. Over the past half-century, the human population has doubled in size; the global economy has quadrupled in value; and international trade has expanded tenfold, resulting in surging demand for food, energy and materials (IPBES, 2019). Increasing economic activity and associated pressures on natural resources have significant adverse impacts on biodiversity (Baillie et al., 2008; UNEP, 2021b). Human beings and our livestock currently account for almost 96% of mammal biomass on Earth (Pörtner et al., 2021).

The greatest direct impacts of human activity on biodiversity loss are attributed to the way we use the land and oceans to produce food, fuel and fibre (Irwin & Bockstael, 2007; IPBES, 2019). Other major drivers of biodiversity loss include the extraction of natural resources (Crawford, 2011), freshwater depletion (Rees, 1999), material waste (Duan & Li, 2016), human driven changes in environmental conditions (Gangolells et al., 2009), and pollution (IPBES, 2019). The direct drivers of biodiversity loss are all exacerbated by anthropogenic climate change (Almond et al., 2020; Bradshaw et al., 2021; Butchart et al., 2010; Pörtner et al., 2021; Stern, 2007).

The expansion of human settlements, through urban growth and construction, is yet another driver of biodiversity loss, both directly and indirectly. Although the built environment occupies a relatively small area of land, especially when compared to agriculture, our urban infrastructure and buildings account for a large share of global freshwater consumption (Treloar et al., 2004) and generate substantial volumes of waste and pollution (Crawford, 2011). The building and construction sector is also a large contributor to climate change, accounting for more than a third of total energy demand and CO2 emissions (UNEP, 2022). The construction industry alone is a major consumer of energy and resources, including land for buildings as well as material for construction and fitout (Kaza et al., 2018; OECD, 2015; Ürge-Vorsatz et al., 2014).

In recent years, 'sustainable development' principles and practices have gained traction in all economic sectors, including the building and construction industry (WGBC, 2013; Zengkun, 2021). The threat of climate change, in particular, is increasingly seen as a priority for governments and the private sector alike, illustrated by the *Net Zero Carbon Buildings Commitment* (WGBC, n.d.). Green building design and other sustainable urban planning and design practices, mainly intended to mitigate or adapt to climate change, can help to alleviate negative impacts on biodiversity by reducing resource consumption and pollution, by providing wildlife habitat onsite, or through the restoration of ecosystems.

Despite these and other opportunities, the construction industry's response to biodiversity loss arguably lags behind that of other industries. For example, in agriculture, forestry, fisheries and mining there are numerous voluntary initiatives to assess and manage adverse impacts on biodiversity, as well as detailed government regulations and a range of incentives intended to secure biodiversity outcomes, e.g. restrictions on land use or resource extraction, subsidies for habitat creation, and mandatory offsets (OECD, 2018; OECD, 2020).

One area where the building and construction industry is starting to address biodiversity more systematically is through the development and adoption of *Voluntary Sustainability Standards* (VSS) for green buildings and construction materials. In the best cases, VSS can encourage industry to go beyond minimum regulatory requirements and begin to mitigate or even reverse impacts on biodiversity, supported by independent verification of performance (Ade & Rehm, 2020). VSS also provide an opportunity to test and validate the feasibility and effectiveness of sustainable practices, and to win over sceptics, smoothing the pathway to regulatory reform.

1.2 Purpose, Scope and Structure of this Report

The purpose of this report is to support efforts to integrate biodiversity considerations more systematically in the building design and construction industry[1]. A key first step is to identify the most significant impacts on biodiversity related to the construction and use of buildings. Adverse impacts on biodiversity can also occur in the wider built environment, due to the construction and use of roads, railways, bridges, ports or other urban infrastructure. However, this report focuses on the individual building scale.

This report considers direct and indirect impacts of buildings on biodiversity, at all stages of the building life cycle. We explore impacts arising during the construction and use of buildings, on the site where they are located, as well as off-site impacts in places where raw materials are extracted, construction materials are sourced, processed and manufactured, and demolition waste is discarded. We also consider activities closely related to building and construction, including development planning, regulation and finance.

The report is based on evidence obtained through a review of relevant literature, as well as interviews with stakeholders from the building and allied industries. Throughout the report, we attempt to adopt a systems thinking approach, recognising the complexity of the built environment and its many-layered connections to biodiversity.

The report is structured as follows:

- **Chapter 1** - this introduction, background and overview.
- **Chapter 2** - key links between biodiversity and the built environment, with a snapshot of the status of and trends in biodiversity.
- **Chapter 3** - an overview of the drivers of biodiversity loss, with a focus on the role of the building and construction industry.
- **Chapter 4** - responses to biodiversity loss, including efforts to address biodiversity impacts in the building and construction industry.

[1] This report uses the terms 'building industry' and the 'construction industry' interchangeably, to refer to the design and construction (or renovation) of residential and commercial buildings and their surrounding landscapes, related work by licensed builders and tradespeople, and activities related to the structures people live and work in. Parts of the construction industry remain out of scope, notably civil/engineering works, infrastructure, mining, large-scale earthworks and utilities.

- **Chapter 5** - barriers and enablers to considering biodiversity impacts in building design and construction, as expressed by industry stakeholders.
- **Chapter 6** - strategies for biodiversity-friendly, nature-positive buildings, focusing on the potential of systems thinking and including several case studies.
- **Chapter 7** - recommendations for the construction industry to improve the integration of nature and biodiversity in the design, construction and operation of buildings.

Chapter 2 - Biodiversity: importance, status, trends and conservation action

Biodiversity is the variety of animals, plants, fungi, and microorganisms that make up our natural world. There are many reasons to protect and conserve biodiversity – from maintaining the provisioning, regulating, supporting and cultural ecosystem services that it provides, to preserving biodiversity for its own intrinsic worth.

Major declines in biodiversity have occurred around the globe as a result of human-driven changes in land and sea use, exploitation of organisms such as hunting, climate change, pollution, and invasion of alien species. Fortunately, there is increasing recognition by governments and businesses that there is a strong case to invest in conservation and sustainable use of biodiversity, to minimise economic and business risks and costs associated with biodiversity loss. The *Kunming-Montreal Global Biodiversity Framework* (GBF) sets out 23 action-oriented global targets for the decade to 2030, including enabling businesses to monitor, assess and disclose their risks to and impacts on biodiversity.

Efforts to conserve biodiversity are being implemented around the world, supported by various environmental agreements and global targets, as well as national, regional and organisational policies and investments. Whilst the protection of ecosystems remains an important action to prevent loss of remaining ecosystems, other steps are necessary to maintain and improve remaining species and ecosystems, including ecological restoration, acknowledging and supporting the benefits that nature provides to humans, particularly in urban and densely populated areas, and stimulating behavioural change towards more sustainable, nature-conscious choices. A mix of environmental regulations and policies, financial lending requirements, certification standards, reporting requirements, and internal drivers such as enhancing business reputation and market advantage through environmental performance, motivate engagement of businesses in biodiversity conservation and adoption of more sustainable practices.

Effective monitoring and reporting of the outcomes of investments in biodiversity remains challenging due to the diversity of genetic, species and ecosystem components, and the many ecological linkages between different components of biodiversity. There is still no universal measure of biodiversity change to report on the impacts of human activities and enable more sustainable actions. The concept of 'nature positive' has emerged as a guiding principle to promote actions that not only halt and reverse biodiversity loss but also to actively enhance the resilience and regenerative capacity of ecosystems, which is essential for achieving the ambitious targets set by the GBF.

2.1 The Importance of Biodiversity

The United Nations Convention on Biological Diversity (CBD) defines biological diversity (biodiversity) as 'the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems' (UN, 1992, p. 3). In short, biodiversity describes the sheer variety of life on earth.

Biodiversity provides the basic building blocks for functioning ecosystems. The more biodiverse an area, the healthier and more abundant in life it is. Several studies have shown that areas with higher diversity of species, genes and ecosystems are more productive, more resilient to change, and function better than those with lower diversity (Tilman et al. 2012).

Reasons to value nature and conserve biodiversity are sometimes expressed using the concept of ecosystem services, which are the benefits that people derive from nature (Millennium Ecosystem Assessment, 2005). These are commonly divided into three or sometimes four categories:

- **Provisioning services** which deliver benefits in the form of tangible products, such as food, cotton, and timber;
- **Regulating services** which are the benefits of natural ecological processes, such as crop pollination and natural pest control, water supply and flood protection. Importantly, this includes the role of ecosystems in mitigating and adapting to climate change;
- **Cultural services** which are the non-material benefits provided by ecosystems, such as contributions to education, recreation, identity and spiritual renewal; and
- **Supporting services** which underpin the other three categories of ecosystem service, such as habitat formation, nutrient cycling and soil conservation. Recent studies focus on the first three categories of ecosystem service, to avoid confusion and double counting (Boyd & Banzhaf, 2007; Fisher et al., 2009).

Biodiversity is necessary to provide food, water, and shelter – all essential requirements for human survival. We rely on biodiversity and ecosystem services, such as insect / animal pollination of food crops, natural water treatment and fertile soil for agriculture. Human beings, as a species (Homo sapiens), are also part of biodiversity.

In addition to the utilitarian benefits that biodiversity provides to humankind, many argue that nature should be conserved for its intrinsic worth, apart from, or in addition to, the value that people may derive from it (Rose et al., 2018; Callicott, 1999; O'Connor and Kenter, 2019; Dudley, 2024).

In short, there are many reasons to protect and conserve biodiversity (Pearson, 2016):

- **Aesthetic** - biodiversity is appreciated for its beauty, which may be experienced directly in nature or through various media;
- **Affinity** - as social animals, many people identify viscerally / emotionally with wildlife;
- **Culture** - people's identity and sense of belonging may be linked to certain natural places or species;
- **Morality** - some people feel a strong duty to be responsible stewards of nature;
- **Precaution** - conserving nature is like buying insurance; we do it partly to hedge against uncertain ecological risks;
- **Spiritual** - beyond the basic aesthetic response, many people feel a sense of awe and love in the presence of nature; and
- **Utility** - biodiversity provides a range of benefits in our daily lives, both directly and indirectly, including for the economy and people's health.

The importance of conserving biodiversity is increasingly understood by businesses around the world as biodiversity loss and ecosystem collapse can lead to greater operational risks, higher input costs and disruption of value chains, not to mention potential erosion of brand reputation and the social license to operate. Biodiversity loss was rated the fourth highest risk to the global economy and society over the coming decade in the World Economic Forum's Global Risks Perceptions Survey, outranked only by climate-related risks (World Economic Forum, 2023).

In response, many companies have begun to acknowledge and evaluate their impacts and dependencies on biodiversity and ecosystem services (or 'nature' and 'natural capital') within their strategy and operations. A range of tools, networks and other initiatives have emerged to support businesses in assessing and addressing biodiversity risks (Natural Capital Coalition, 2016; World Business Council for Sustainable Development [WBCSD], 2024). Related initiatives include:

- *Global Partnership for Business and Biodiversity* (https://www.cbd.int/business/gp.shtml), under the leadership of the CBD;

- *Science-Based Targets Network's* guidance for companies and cities on setting targets for nature (https://sciencebasedtargetsnetwork.org);
- *Taskforce on Nature-related Financial Disclosures* (https://tnfd.global);
- *Business for Nature* coalition (https://www.businessfornature.org/);
- and the *European Commission's Business @ Biodiversity Platform* (https://ec.europa.eu/environment/biodiversity/business/index_en.htm), among others.

2.2 Biodiversity Status and Trends

The current rate of global decline in biodiversity is unprecedented in human history. Even conservative estimates suggest that the average global rate of vertebrate species extinctions over the past century is up to 100 times higher than the background or normal rate, defined as the number of species that would be expected to go extinct over a period of time, based on non-anthropogenic (non-human) factors (Ceballos et al. 2015). Similarly, the average rate of global plant species loss over the last century is up to 25 times higher than the background rate (Humphreys et al. 2019). As a result of multiple anthropogenic (human-driven) drivers, 75% of the global land surface has been significantly altered, 66% of the ocean area is facing increasing cumulative impacts, and over 85% of wetland area has been lost (IPBES, 2019).

A decline in biodiversity results in weakened ecosystems and changed environmental processes. While nature can be resilient and adaptive to changing conditions, increasing human use and exploitation of natural resources, land and water, together with the impacts of climate change, risk the collapse of entire ecosystems (Dasgupta, 2021). The risk of biodiversity loss applies to every country and every human endeavour, including construction and human habitation of the built environment.

2.3 Drivers of Biodiversity Loss

The drivers of change in biodiversity include a range of factors that cause positive or negative changes in natural conditions and ecosystem services. Drivers may be direct or indirect, natural or anthropogenic (human caused). Natural drivers include environmental processes and hazards (e.g., earthquakes, drought and floods), whereas anthropogenic drivers include the impacts of human activities, such as land-use change and pollution. The *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES) identifies five direct drivers of change that result in biodiversity loss: change in land and sea use; direct exploitation of organisms; climate change; pollution; and invasion of alien species (IPBES, 2019). The following sections examine each of these direct drivers and their impacts on biodiversity in more detail.

Change in land and sea use is driven largely by agriculture, forestry and urbanisation, and results in vegetation loss, fragmentation, and ecosystem degradation. Habitat loss and degradation is identified as a main threat to 85% of all species described in the *International Union for Conservation of Nature*'s *Red List of Threatened Species* (*IUCN Red List*) and is caused by conversion of land cover (e.g. deforestation), change in ecosystem management (e.g. intensification of forest harvesting) or change in the spatial configuration of the landscape (e.g. fragmentation of species' habitats by construction of linear infrastructure such as roads) (Doughty and Hammond, 2004; Tulloch et al. 2019). Human use of seascapes also causes degradation and loss of marine ecosystems, through activities such as dredging, dumping, and mining. To date, around 77% of land (excluding Antarctica) and 87% of ocean area have been modified by the direct effects of human activities, resulting in the loss of 83% of wild mammal biomass and 50% of plant biomass (Pörtner et al., 2021). Loss of vegetation affects the ecosystem services that humans rely on (e.g., soil erosion which degrades the productivity of agricultural land), and contributes to climate change, accounting for over 10% of anthropomorphic greenhouse gas (GHG) emissions (van Toor et al., 2020).

Direct exploitation of organisms also affects more than 80% of all species listed as threatened or near-threatened on the *IUCN Red List* (Maxwell et al., 2016), through the harvesting of species from the wild, at rates that cannot be compensated for through natural reproduction or regrowth. Direct exploitation, particularly overexploitation of fish, shellfish and other marine organisms has had a significant impact on the world's oceans. Over 55% of ocean area is subject to industrial fishing and 33% of global fish stocks are classified as overexploited (Pörtner et al., 2021). Harvesting of living biomass (e.g., crops, fish) to meet both domestic and export demand is highest in developing countries and rapidly increasing. Taken together, land- and sea-use change and direct exploitation account for over 50% of the global impact of human activities on land, fresh water, and oceans (IPBES, 2019).

Climate change affects biodiversity and ecosystems directly and indirectly. Melting of sea ice, ocean acidification, rising temperatures, changes in rainfall patterns and drought, as well as extreme weather events such as flooding and wildfires, can all adversely impact biodiversity (Secretariat of the CBD, 2009). Climate change displaces species from habitats, alters the timing of plant flowering, and affects migration patterns and the distribution of species worldwide (Secretariat of the CBD, 2020). Climate change affects around 19% of species listed as threatened or near-threatened (Maxwell et al 2016), and it is estimated that 2°C of global warming could put 15-40% of global species at risk of extinction (Stern, 2007). Climate change also exacerbates the other drivers of biodiversity loss. For example, climate change accelerates the spread of invasive alien species (sometimes referred to as exotic or non-native, e.g. weeds), which invade an area where they historically did not occur and out-compete native biodiversity for resources such as sunlight, shelter, food and water. It has been projected that climate change will become as important, or more so, than other drivers of biodiversity loss in the coming decades (Almond et al., 2020).

Climate change and ecosystem health are inextricably linked. On one hand, ecosystems are at risk of deterioration and collapse due to changing environmental conditions caused by climate change (IPBES, 2019), and on the other hand reduced ecosystem health can directly contribute to, and accelerate, the effects of climate change[2]. This means that the decline of biodiversity is not only dependent on climate change, but also contributes to it (Weiskopf et al., 2024). One implication is that biodiversity conservation should be seen as a priority in efforts to mitigate climate change. In fact, one study in 2017 found that, to stabilise global warming to below 2°C, 'Natural Climate Solutions' could provide over one-third of the cost-effective climate mitigation needed between the time of writing and 2030 (Griscom et al., 2017).

Pollution affects around 22% of species listed as threatened or near-threatened on the *IUCN Red List* (Maxwell et al., 2016). Impacts of pollution on species and ecosystems include deposition of excess nutrients into soil and water by agricultural practices (e.g. nitrogen and ammonia), domestic and industrial waste, and atmospheric deposition of airborne pollutants. Pollution, for example, from untreated urban and rural waste from industrial, mining, and agricultural activities, oil spills and toxic waste dumping, and GHG emissions, degrades the quality of soil, freshwater, marine water, and the global atmosphere. While air pollution is highest in least developed countries, the negative impacts of nonpoint-source pollution (e.g., from the use of fertilisers) are highest in developing countries. Accumulation of plastic pollution in the oceans is also a major concern due to impacts on marine

[2] In 2005, annual GHG emissions from deforestation accounted for over 18% of global emissions, which, at the time, was greater than the total global emissions produced by the transport sector (Stern, 2007).

ecosystems, while the implications of plastic pollution on other ecosystems is largely unknown (Secretariat of the CBD, 2009).

The *IUCN Red List* indicates that **invasive species and disease** are the most common threats associated with extinctions of amphibians, reptiles and mammals, especially on islands. Invasive alien species are *'animals, plants or other organisms that are introduced by humans, either intentionally or accidentally, into places outside of their natural range, negatively impacting native biodiversity, ecosystem services or human economy and well-being'* (IUCN, n.d.). Globally, the threat of invasive species is at the highest point in recorded history, and accelerating. Since 1980, cumulative records of invasive species have increased by 40% due to increasing trade flows and human movements around the globe (IPBES, 2019). Invasive species and diseases can cause declines and losses of native species, either by out-competing native species for key resources, through direct mortality (e.g. predation), or by degrading the quality and quantity of food and shelter resources.

Indirect drivers can alter and influence the direct drivers listed above. Societal values and behaviours, including human population dynamics, production and consumption patterns, migration and urbanisation demographics, trade, governance and finance, and technological innovations are all considered indirect drivers of biodiversity loss (Almond et al., 2020; IPBES, 2019). While indirect drivers may not affect the state and trends in biodiversity in their own right, they can influence the level, direction or pace of direct drivers.

2.4 Measuring Biodiversity Change

Measuring change in biodiversity is complex due to the sheer diversity of genetic, species and ecosystem components, and the many ecological linkages between these components (Pereira et al., 2013; Schmeller et al., 2018). As described in Box 2.1, much effort has been expended to develop accurate methods and indicators to assess biodiversity change in bio-physical terms (e.g. Bayraktarov et al., 2020; Collen et al., 2009).

Analysis of trends in species abundance over time is one way to identify biodiversity changes at local, regional, and global scales (Butchart et al., 2010). Broad-scale indicators that use this approach include the *Wild Bird Index* (Gregory et al., 2005), the *Living Planet Index* (Collen et al., 2009), and the *Australian Threatened Species Index* (Bayraktarov et al., 2020).

However, aggregate indicators are generally not well-suited to evaluating the impacts of human activities and conservation interventions at local scales. In such cases, human-driven impacts on species have historically been evaluated using either indicators of community richness and composition (Box 2.1) or by tracking the occurrence or abundance of a few easy-to-measure or 'indicator' species, which are thought to respond clearly to human interventions (e.g. Lindeijer et al., 2000; Tulloch et al., 2013).

Differences in the rate and direction of change in species' populations, in response to human activities, can make it necessary to track more than one species or group at a time, so critical changes are not missed (Butchart et al., 2010). For example, species richness (number of individual species) at a site may decline following disturbance (e.g. conversion of native vegetation for urban development), while total abundance of several disturbance-tolerant species increases in the same place (e.g. due to invasion of the site by weeds).

Biodiversity changes are more complex than simply species loss or gain (Dudley & Alexander 2017; Tulloch et al., 2016). Ecosystems may be fragmented and degraded long before being completely lost (Hill et al. 2016). Ecosystem-level measures of the amount, condition and quality of species' habitat can help us understand these changes**. Habitat area assessments** measure how much vegetation remains after a land-use change and indicate the extent to which a species' habitat has changed, and along with it, how its access to food and shelter resources may have changed (Geyer et al 2010). Measures of the **density of vegetation**, or its complexity (e.g. representation of different structural levels like ground, shrub and canopy cover) can represent the quality or condition of a species' habitat.

Box 2.1 Selected Measures of Biodiversity and its Health

Allelic (genetic) diversity: the number of differences in the genetic makeup of a species or population (Allendorf, 1986), indicating long-term potential for adaptability and persistence.

Traits: biological characteristics of organisms, such as morphology, behaviour, physiology, and phenology, which can influence ecological performance (Gallagher et al. 2021).

Body condition: average health of individuals in a population, measured using indicators such as body mass (scaled by body size), or the body mass index (BMI), indicating the condition and energy reserves of organisms (Krebs & Singleton, 1993).

Reproductive success: effectiveness of offspring production, encompassing events such as calling/singing, mating, ovulation, egg laying/spawning, flowering, pollination, egg hatching, and seed dispersal. Size at first reproduction has been proposed as a useful measure of population health, because larger individuals are usually more fertile, and produce more propagules of better quality with higher survival prospects (Loyau, Sorci & Jalme, 2005).

Survival rate: average probability that an organism will stay alive between two points in time. Survival is a fundamental parameter supporting population dynamics and species persistence, as it is highly sensitive to environmental change (Caswell, 2001; Morris & Doak, 2002).

Phenology: annually recurring life-cycle events, such as the timing of migration or flowering. Changes in phenology can be the first indicators of important ecological changes.

Abundance: number of individuals of a species in a population. Local abundance can affect a population's extinction risk (Lande, 1993) and genetic diversity (Masel, 2011). Changes in the abundance of some species affect ecosystem functioning (Winfree et al.,2015).

Range or distributional dynamics: changes in species distributions through time, space and shape. Range declines are associated with reduced resilience, species declines and increased extinction risk (Moritz & Agudo, 2013).

Community composition, richness and diversity: richness describes the total number of biodiversity components (generally, species or subspecies) in a particular location, whereas diversity is a measure of variability in this component across space and time. Decreased diversity and richness are often associated with reduced ecosystem resilience and function (Clavel, Julliard & Devictor, 2011).

Ecosystem structure: landscape pattern indicators represent human-perceived patterns in a landscape (diversity, patch size, and configuration of habitat and vegetation cover).

Because biodiversity is closely linked to ecosystem health and human wellbeing, additional methods have been developed to assess how changes in biodiversity affect the **quality or quantity of ecosystem services**, such as provision of freshwater (Boyd and Banzhaf, 2007; Nelson et al., 2009; Zhang et al., 2010). Market prices or non-market valuation techniques may be used to measure the value of these ecosystem services, or the natural capital that underpins such services, in monetary or economic terms (Box 2.2).

A range of methods have also been developed to measure how changes in land use affect biodiversity targets (Christie et al., 2012; Eftec, 2015; IPBES, 2022a; Salles, 2011). One tool that is widely used to assess changes in biodiversity at a micro or project level, for buildings as well as in other industries, is *Environmental Impact Assessment* (EIA) (Morgan, 2012). Variants of EIA include Strategic Assessment, for policy and programme level actions, *Ecological Impact Assessment, Social Impact Assessment*, and *Biodiversity Impact Assessment*, each of which focuses on particular issues of concern (IAIA, 2023). Efforts to incorporate indicators of biodiversity loss (or gain) in impact assessment methods have made considerable progress in recent years, although gaps remain (Bigard et al., 2017). The use of EIA for assessing biodiversity impacts in the construction industry is discussed further in Chapter 3.

Box 2.2 Natural Capital, Ecosystem Accounting and Nature's Values

The term natural capital describes the stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people. Natural capital accounting is a framework that provides a systematic way to measure and report on stocks and flows of natural capital, including individual environmental assets or resources (such as water, minerals, energy, timber, fish), as well as ecosystem assets (e.g. forests; wetlands), biodiversity and ecosystem services. Different natural capital accounting approaches have been developed to measure business risks, impacts and dependencies on nature, which may be expressed in physical or monetary terms (Capitals Coalition, 2022). This information can be used for planning and operational decisions, or external reporting.

The UN System of Environmental and Economic Accounts (SEEA) provides an accounting framework to organise information about gains and losses of environmental assets (e.g. wildlife habitats, landscapes, ecosystem services), and linking this information to economic and other human activity at a regional or national scale (Hein et al., 2020; United Nations et al., 2014). Ecosystem accounting complements and builds on Natural Capital Accounting (NCA) and may be expressed in monetary terms so that ecosystem contributions to human well being can be compared to traded goods and services. Similar tools have been developed to measure and track changes in ecological assets at the organisational level (Jones, 2003; Natural Capital Coalition, 2016).

Accounting and reporting systems for biodiversity and ecosystems have not progressed as far as they have for some other aspects of environmental health (e.g., air and water quality), ecosystem services (e.g., GHG emissions and climate risk) or traded natural resources (e.g., timber, minerals). One barrier is the inherent complexity of biodiversity. Some people raise philosophical objections to measuring nature's benefits in monetary terms (Sagoff, 2011). Nevertheless, environmental economic accounting and the integration of biodiversity values in economic decision-making, including values 'which can be quantified in monetary terms', is called for in the CBD Global Biodiversity Framework (https://www.cbd.int/gbf/targets/14). Such information is especially useful wherever trade-offs arise between environmental and other socio-economic values (Fenichel et al., 2024; Laurans and Mermet, 2014; Navrud and Pruckner, 1997; TEEB, 2012).

A report commissioned by the United Nations Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) surveyed the available information on nature's values and valuation methods, drawing on over 50,000 scientific publications, policy documents, and Indigenous/local knowledge sources (Pascual et al., 2023). The report focused on how the consideration of nature's values and valuation methods can influence policy making, and how this information can help promote more equitable treatment of human communities (Ibid). The authors offer a typology of value based on: worldviews (how people engage with the world), general values (ethical principles), specific values (e.g. judgments about the importance of nature in particular situations), and indicators of value (quantitative and qualitative measures of nature's contributions, including physical, economic, or socio-cultural attributes). Valuation methods were likewise grouped into four categories: nature-centred, expression-based, behaviour-based, and integrated valuation. While progress has been made in the first three categories, the authors argued that more work is needed to integrate the diversity of values, behaviours, and environmental effects.

Despite advances in the measurement of biodiversity, such as those mentioned above, current approaches often have important limitations. These include a tendency to assess biodiversity status relative to already degraded modern baselines, rather than in relation to historical or intact ecosystem references, along with an emphasis on measuring improvements at individual sites, while neglecting broader cumulative and remote impacts. Additionally, contemporary biodiversity measurement methods often struggle to distinguish between improvements at specific locations and genuine gains across ecosystems, ecological communities or species. They also fall short in evaluating whether interventions truly result in net positive outcomes for biodiversity across spatial and temporal scales.

Combining different accounting and evaluation tools to develop an overall indicator of biodiversity change is another unresolved challenge. Even today, biodiversity is not routinely incorporated into assessments of the impacts of human activities unless policy triggers are activated, and no globally accepted measure of human impacts on biodiversity exists (de Baan et al., 2015; Milà i Canals et al., 2007; Schenck, 2001). Indicators to assess the impacts of human activity on biodiversity remain poorly developed relative to indicators to assess chemical pollution, water use and GHG emissions (Curran et al., 2016; Souza et al., 2015; Curran et al., 2011). Some authors suggest that in many cases it may be more feasible and practical to assess and value individual components of biodiversity than attempting to characterise biodiversity as a whole (Fenichel et al., 2024).

2.5 Responding to Biodiversity Loss

Efforts to conserve biodiversity are guided by international environmental agreements and global targets, as well as national, regional and organisational policies and investments. Conservation action is ultimately delivered by both public (government) and private entities (businesses, non-governmental organisations, private foundations, and individuals).

Biodiversity risks are typically identified in terms of, and regulatory responses are informed by, official or widely-accepted lists of threatened species and ecosystems (e.g., the *IUCN Red List of Threatened Species and Ecosystems; Australia's Environment Protection and Biodiversity Conservation Act, List of Threatened Fauna*). These lists may be supplemented by spatial prioritisation (mapping) of wildlife management and protection actions[3], project-level biodiversity impact assessments, or scenario modelling.

Although diverse responses to biodiversity loss are possible, best practice generally involves avoiding further loss wherever possible. Habitat protection is an effective means to conserve biodiversity (McKinney, 2002; Pedersen Zari, 2014). Conservation strategies at regional and national levels have long relied on land use zoning, legal designation of protected areas (e.g. *UNESCO World Heritage Sites*), as well as incentives for setting aside private land (e.g., as green reserves).

However, habitat protection alone is not sufficient. Greater effort is also required to halt the flow of toxins and waste materials, while simultaneously restoring and recovering lost or degraded ecosystems. Ecological restoration may include rewilding (i.e., reintroducing plant or animal species that have vanished from an area), revegetation of cleared landscapes, controlling and eradicating invasive species, or restoring natural flooding regimes to wetlands.

[3] Spatial prioritisation involves identifying, mapping and prioritising sites for on-ground conservation or restoration action. Maps may be used to show different activities (e.g., a map showing priority areas for revegetation will be different from a map prioritising areas for control of invasive weeds).

A complex mix of environmental regulations and policies, funding criteria, certification standards, and reporting requirements, are among the tools used to motivate adoption of more sustainable or 'biodiversity-friendly' management practices. In addition, businesses may be motivated by internal drivers of change, including potential operational efficiencies that can reduce costs while also reducing or avoiding environmental damage, enhancing business reputation and market advantage through better (verified) environmental performance, or simply the motivation to be seen by customers and other stakeholders as an environmentally responsible business. These and other drivers have led some businesses to recognise the importance of understanding and measuring their impacts and dependencies on biodiversity (Addison et al., 2018).

Business initiatives for environmental sustainability and biodiversity conservation may include employee engagement in conservation where staff can connect with nature (e.g., workplace tree planting days); landscaping around business premises to enhance the direct experience of nature; and community engagement and social development (e.g., commitments to socially responsible investment) (Addison et al., 2018; IPBES, 2019; Smith et al., 2019; WEF, 2019).

Halting biodiversity loss and restoring ecosystems requires change in how people use land and other natural resources. This may include restrictions on human activity in certain areas, controls on wildlife harvest and/or trade, mandatory environmental performance standards for industry, stringent compensation requirements for habitat loss and damage, as well as the promotion of more efficient technologies and practices to reduce the adverse environmental impacts of development, production, and consumption. The transition to sustainable production and consumption can be reinforced using a range of market-based approaches, such as taxes on environmentally-harmful activities; payments to resource users or owners who provide verified conservation benefits or ecosystem services (i.e. *Payments for Ecosystem Services* or 'PES'); subsidies for developing or deploying less harmful production technologies; and/or social marketing to reduce consumer demand for scarce resources and boost demand for sustainable products (e.g. certified timber).

2.5.1 Global Biodiversity Policy

The overarching international agreement for the conservation and sustainable use of biodiversity is the *United Nations Convention on Biological Diversity* (CBD; Box 2.3). In 2020, the CBD concluded a ten-year period of investment and action, guided by a *Strategic Plan* agreed at the 10th *Conference of the Parties* (COP) held in Nagoya, Japan, in 2010. The *Strategic Plan* included 20 *Aichi Biodiversity Targets*, many of them relevant to the built environment.

Box 2.3 The Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD; www.cbd.int) is a multilateral treaty that entered into force on 29 December 1993. The CBD has three goals: *'the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources'* (CBD, n.d.).

The CBD is concerned with biological diversity ('biodiversity') at all levels: from ecosystems, species and genetic resources, to biotechnology, as well as issues directly or indirectly related to biodiversity and its role in human development (e.g., science, agriculture, business, culture, politics, education).

The CBD's governing body is the *Conference of the Parties* (COP), made up of all governments (or Parties) that have ratified the treaty. 196 nations are currently Parties to the CBD, including Australia.

The COP typically meets every two years to review progress, set priorities and commit to work plans to achieve positive outcomes for biodiversity. Technical support to the CBD and governments on key definitions, practical guidance for implementation and related matters is provided by various subsidiary bodies, as well as by the *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES).

All Parties are expected to develop national or sub-national biodiversity conservation strategies and action plans that align with the CBD *Global Biodiversity Framework* and Targets. The CBD also calls on businesses to align their strategies and policies with these global Targets. Business engagement is facilitated by a *Global Partnership for Business and Biodiversity* (https://www.cbd.int/business/gp.shtml), which is supported by national and regional governments as well as the CBD Secretariat (Secretariat of the Convention on Biological Diversity [CBD], 2021).

Disconcertingly, none of the 2010 Aichi Biodiversity Targets were achieved by the deadline of 2020 (Secretariat of the CBD, 2020; Science, 10 May 2019, p. 517). In response, the CBD developed a new *Strategic Plan* and a new set of targets (Díaz et al., 2020). In December 2022, at COP 15, governments adopted the *Kunming-Montreal Global Biodiversity Framework* (GBF) to guide international biodiversity conservation efforts until 2030, as a stepping stone towards a goal of living 'in harmony with nature' by 2050 (Secretariat of the CBD, 2022).

The GBF has 23 action-oriented targets for the decade to 2030, grouped under three headings (Ogwal & van Havre, 2020):

- ***'Reducing threats to biodiversity'*** (Targets 1-8) – includes addressing major drivers of biodiversity decline discussed in Section 2.3 above (i.e., land/sea use change, climate change, pollution, over-exploitation, invasive species) through biodiversity-integrated spatial planning, ecosystem restoration and protection, sustainable use of wild species, management of invasive species, and minimising the impacts of pollution and climate change.
- ***'Meeting people's needs through sustainable use and benefit-sharing'*** (Targets 9-13) – includes sharing the benefits of biodiversity related to the provision of food, water, ecosystem services, and human health, by restoring, enhancing and maintaining nature's contributions to people.
- ***'Tools and solutions for implementation and mainstreaming'*** (Targets 14-23) – includes laws, policies, regulations, financing, and behaviour changes to improve the sustainability of production and consumption, biosafety measures, capacity building and development, knowledge building and information sharing, inclusion of Indigenous Peoples and local communities in decision-making, and gender equity.

The GBF includes integration of biodiversity considerations into the built environment, particularly in **Target 12** ('Significantly increase the area and quality and connectivity of, access to, and benefits from green and blue spaces in urban and densely populated areas sustainably, by mainstreaming the conservation and sustainable use of biodiversity, and ensure biodiversity-inclusive urban planning, enhancing native biodiversity, ecological connectivity and integrity, and improving human health and wellbeing and connection to nature and contributing to inclusive and sustainable urbanization and the provision of ecosystem functions and services'; Secretariat of the CBD, 2022) and **Target 14** ('Ensure the full integration of biodiversity and its multiple values into policies, regulations, planning and development processes, poverty eradication strategies, strategic environmental assessments, environmental impact assessments and, as appropriate, national accounting, within and across all levels of government and across all sectors, in particular those with significant impacts on biodiversity, progressively aligning all relevant public and private activities, fiscal and financial flows with the goals and targets of this framework.'; Secretariat of the CBD, 2022). The GBF also calls for efforts to increase awareness of and education about the importance of biodiversity and the ways in which it is affected by human activities, including those related to the building and construction sector.

Target 3 of the GBF ('Ensure and enable that by 2030 at least 30 percent of terrestrial, inland water, and of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures, recognising indigenous and traditional territories, where applicable, and integrated into wider landscapes, seascapes and the ocean, while ensuring that any sustainable use, where appropriate in such areas, is fully consistent with conservation outcomes, recognising and respecting the rights of indigenous peoples and local communities, including over their traditional territories' Secretariat of the CBD, 2022) also has significant implications for urban development and the built environment, particularly in areas that may be identified as critical for conservation or serve as ecological corridors between protected areas.

A cornerstone of the GBF, and the key to achieving Target 3, is the 30x30 initiative, which commits Parties to protect 30% of Earth's land and ocean areas by 2030. Achieving 30x30 requires rethinking how we plan, build, and manage urban areas to better integrate conservation goals with development needs. This means moving beyond traditional urban planning to more holistic approaches that recognise cities as part of larger ecological systems. Several other international policy initiatives and agreements either address or have important implications for biodiversity conservation. These include:

- the *UN Sustainable Development Goals* (SDGs), adopted in 2015;
- the *UNFCCC Paris Agreement* to limit climate change (2015)*;* and
- the *United Nations Global Compact* (UNGC), which encourages and assists companies to adopt sustainable and socially responsible policies and practices.

In addition, several global initiatives and agreements focus specifically on biodiversity conservation and may have implications for the built environment, including:

- the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES);
- the United Nations Forum on Forests (UNFF) Strategic Plan for Forests 2017–2030; and
- the United Nations World Water Development Report (WWDR).

These and other initiatives provide platforms for governments, civil society, and the private sector to collaborate and share experience, develop common targets and approaches, and agree on indicators and methods to monitor progress.

2.5.2 The Concept of 'Nature Positive'

The GBF is very comprehensive, with 23 different targets to achieve by 2030, which makes the framework challenging to deliver. Moreover, while some GBF targets can be assessed at a global or national level, or on a regional or local scale, they can be difficult to interpret or implement at the organisational level. In an effort to win wider support and stimulate broad-based action on biodiversity, while also influencing the negotiation of global targets under the CBD, the concept of a 'Nature Positive' world was developed and promoted in the runup to COP 15 (WWF, 2020).

The notion of Nature Positive was partly inspired by the widespread embrace of 'net zero' GHG emissions as an overarching target for climate action (Locke et al., 2021). The origins of Nature Positive can also be found in earlier work on applying the environmental mitigation hierarchy to biodiversity loss (see Section 2.5.3, below), along with growing recognition of the need and opportunity to go beyond like-for-like compensation of biodiversity losses to deliver 'net positive' outcomes for nature (IUCN, 2016b).

Nature Positive has been expressed as a societal goal to *'halt and reverse nature loss by 2030 on a 2020 baseline, and achieve full recovery by 2050'* (Nature Positive Initiative, 2023; Zurita et al., 2022)[4]. This definition is supported by research into the feasibility of halting and reversing biodiversity decline during the 21st century (Leclère et al., 2020). Importantly, the concept of Nature Positive includes a commitment to improving social as well as environmental outcomes (WWF, 2022). Related initiatives are described in Box 2.4.

The concept of Nature Positive represents an important evolution in environmental thinking, even though current definitions and frameworks may still be too narrow to address the larger ecological crisis. Efforts to achieve ecological 'net gain' or 'net positive' outcomes at a site or jurisdictional level can distract from the ongoing degradation of global ecosystems (Bull & Strange, 2018; Díaz et al., 2020; Maron et al., 2018). Similarly, place-based restoration projects, while valuable in themselves, cannot easily counterbalance the systemic drivers of ecological decline (Defries & Nagendra, 2017; Simmonds et al., 2020), especially when considering cumulative impacts across landscapes and supply chains, and the overarching threat of climate change.

Box 2.4 Steps Towards a 'Nature Positive' Economy

There have been many efforts over the years to 'internalise' biodiversity values into economic decision-making. These range from political statements to broad macroeconomic policy reforms, climate-focused or sector-specific frameworks and tools, new business ventures and consumer campaigns.

At the political level, for example, the heads of state and government of 96 nations agreed in 2020 to the *Leaders Pledge for Nature*, vowing to reverse the decline of biodiversity by 2030 (WWF, 2022). Similarly, in 2021, the leaders of the G7 large economies issued their *2030 Nature Compact*, which includes a commitment to a net-zero and nature-positive future (G7, 2021).

Some environmental initiatives seek to harness market forces to reverse nature loss and improve the status of biodiversity, while creating new jobs and industries based on the conservation, restoration and sustainable use of biological resources. More ambitious efforts aim to shift entire national or local economies to circular or 'regenerative' systems of production and consumption.

These efforts are supported by various tools and frameworks, including accounting, reporting and certification systems that make environmental dependencies and impacts more explicit to decision-makers, as well as economic incentives intended to make it more costly to harm the environment and/or more profitable to protect and restore nature.

In 2021, for example, the *Taskforce on Nature-related Financial Disclosures* (TNFD) was established to assist organisations to identify, report and act on nature-related dependencies, impacts, risks and opportunities (TFND, n.d). The ultimate aim of the TNFD is to support a shift in financial flows toward nature-positive outcomes. TNFD requirements for nature-related disclosures are structured around governance, strategy, risk and impact management, with specific metrics and targets for each.

Other prominent nature-positive initiatives include the development of Nature-based Solutions (NbS), defined as 'actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits' (IUCN, 2019); the creation of the Science Based Targets Network (SBTN), which supports businesses to measure impacts on nature and set targets

[4] Some definitions are less precise. For example, the Australian federal government defines Nature Positive as 'a term used to describe circumstances where nature – species and ecosystems – is being repaired and is regenerating rather than being in decline' (DCCEEW, 2022). Although the intent is similar, this definition does not mention a specific deadline, nor does it refer to a baseline from which to assess progress.

to reduce adverse impacts (Science Based Targets, n.d.); and the Nature Positive Initiative, which seeks to build awareness and consensus on the meaning and application of the 'nature positive' concept (naturepositive.org, 2023).

Examples of nature-positive action at a national level include *Australia's Nature Positive Plan* (https://www.dcceew.gov.au/environment/epbc/publications/nature-positive-plan) and the UK policy on *Biodiversity Net Gain* (BNG; https://www.local.gov.uk/pas/environment/biodiversity-net-gain-bng-local-planning-authorities). The former calls for institutional reforms, stricter environmental standards, and a new system to certify and register biodiversity conservation projects to attract private finance (DCCEEW, 2022). The latter (BNG) requires all new development projects to deliver a 10% net increase in biodiversity, using in-kind compensation with standardised metrics in terms of habitat size, condition, distinctiveness, and location (Planning Advisory Service, n.d.).

2.5.3 The Mitigation Hierarchy and Offsets

The concept of *Nature Positive* builds on earlier efforts to define and promote 'net positive impact' on biodiversity as a guiding principle for national and corporate action (IUCN, 2016b). *Net Positive Impact* (NPI) is a goal for businesses and projects to have a positive effect on the environment and society, which derives in turn, from the *mitigation hierarchy*, which underpins the policy and practice of assessing and addressing biodiversity loss.

The mitigation hierarchy calls for avoiding and mitigating impacts, as a matter of priority, with compensation or offsets used 'as a last resort' for 'unavoidable' or 'residual' impacts. Entities deemed responsible for impacts are encouraged, or in some circumstances required by law, to use standardised methods (e.g. *Impact Assessment*) to assess the potential adverse environmental and social impacts of their activities, and to follow the mitigation hierarchy to avoid, minimise and/or compensate for these impacts (Box 2.5). The mitigation hierarchy is a touchstone of environmental policy in many countries including Australia (DCCEEW, n.d.).

Box 2.5 Impact Assessment, the Mitigation Hierarchy and Biodiversity

The mitigation hierarchy is a widely used framework for reducing adverse environmental impacts, often combined with *Impact Assessment* (IA). Both tools have a long history and are are embedded into numerous government, lender, and corporate policies around the world (Business and Biodiversity Offsets Programme [BBOP], 2012; Gardner et al., 2013; International Finance Corporation [IFC], 2012; IUCN, 2016a; Rainey et al., 2014).

The mitigation hierarchy was originally codified under the *National Environmental Policy Act* (1969 and as amended) in the USA (*The President's Imposition of New Environmental Mitigation Regulations, 2016*; Stevenson and Weber, 2020)[5]. *Impact assessment* (IA) is mainly a diagnostic tool, intended to identify and assess the likelihood and severity of potential impacts of a given project. Variants of IA include environmental, social and strategic impact assessment, each of which is designed to address specific issues of concern or scales of development (International Association for Impact Assessment, n.d.).

[5] The term 'mitigation' has specific meaning in the context of climate change, namely to avoid GHG emissions or enhance carbon removals (see: https://unfccc.int/topics/introduction-to-mitigation). This differs from the terminology of the environmental Mitigation Hierarchy, which distinguishes four steps: (1) avoid, (2) minimise, (3) remediate (or restore), and (4) offset (compensate).

Based on the information provided by IA, the mitigation hierarchy guides responses to avoid, reduce, or compensate for potential environmental harm. The first priority is to **avoid** environmental damage, especially if there is a risk of irreversible harm to unique or highly threatened species / assets. For example, if the IA reveals that a project would have negative impacts on areas of high biodiversity value, the mitigation hierarchy proposes that such areas should be set aside and protected from harm.

For impacts that cannot be completely avoided, the mitigation hierarchy requires efforts to **minimise** the intensity, duration, and/or extent of impacts (including direct, indirect and cumulative impacts). For impacts that cannot be completely avoided and/or minimised, effective **mitigation** measures must be taken to address negative impacts. In addition to impact avoidance and mitigation actions, on-site rehabilitation or **restoration** efforts can be undertaken to try to repair degraded ecosystems or cleared vegetation.

Offsets are typically seen as the final step in the mitigation hierarchy, to **compensate** for residual damage that cannot be avoided, minimised, or restored locally. Biodiversity offsets *'can take the form of positive management interventions such as restoration of degraded habitat, arrested degradation or averted risk, protecting areas where there is imminent or projected loss of biodiversity'* (BBOP 2012, p 1).

Application of the mitigation hierarchy to biodiversity conservation and restoration has emerged in recent years as a powerful, widespread and also controversial approach (Arlidge et al., 2018). **Biodiversity offsets** typically involve 'in-kind' or 'like-for-like' compensation and are intended to achieve an outcome in which there is (at least) *No Net Loss* (NNL) of the impacted biodiversity due to a particular project (Bennett & Gallant, 2017; Bull, Gordon, Watson, & Maron, 2016; IUCN, 2016a). Offsets that aim to deliver *Biodiversity Net Gain* (BNG) are intended to produce an outcome that is ecologically superior to NNL. This might include, for example, restoration of land adjacent to a development that had been previously degraded due to human activities[6]. Furthermore, offsets that seek to achieve *Net Positive Impact* (NPI) are sometimes associated with 'trading-up' (i.e. impacts are offset by investing in the conservation or restoration of a different ecosystem, which is considered to have greater ecological value) (Moilanen & Kotiaho, 2018).

Policy and advocacy to go beyond NNL, whether described as BNG or NPI, can be seen to reflect growing support for restoring damaged ecosystems and improving the state of nature, rather than simply maintaining the status quo. Nevertheless, despite their use as a response to development impacts, the practical effectiveness of biodiversity offsetting has been questioned[7]. Even where governments mandate biodiversity offsets or compensation for adverse impacts, compensation is often considered a 'second best option' that cannot and should not be used to justify the damage caused to natural ecosystems. For these and other reasons, some argue that the use of offsets should be excluded or strictly limited when undertaking or reporting on 'nature-positive' activities (Maron et al., 2024; WEF, 2022; Waterford et al., 2024).

[6] Restoring native ecosystems can be a challenging process, and usually requires long periods of time before evidence of recovery is substantial. Many ecological restoration projects have a considerable way to go before they can achieve the levels of biodiversity, ecosystem functioning, and delivery of ecosystem services of intact ecosystems (Catalano et al., 2021).

[7] Biodiversity offsetting may fail due to poor implementation, inappropriate definition of the size and kind of offset required, exaggeration of the risk of loss (for averted loss offsets), or other reasons (Maron et al., 2015; May et al., 2017; Moilanen & Kotiaho, 2018; Grimm, 2020; Catalano et al., 2021).

2.5.4 Voluntary Sustainability Initiatives and Standards

While impact assessments and adherence to the mitigation hierarchy are required by law in many jurisdictions, most commitments to deliver the GBF or nature-positive outcomes are voluntary[8]. Hence, efforts to promote, implement or report on biodiversity action at an organisational level often rely on voluntary frameworks and standards to define terminology, methods and metrics, and to verify results. Fortunately, there is a rich tradition of voluntary initiatives on which to construct guidance and assurance for investments in biodiversity.

Voluntary initiatives such as *Environmental, Social and Governance* (ESG) rating tools have been developed to help investors assess the sustainability of asset managers or specific companies, while other tools have been developed to help consumers make more informed purchasing decisions, typically by disclosing details of product sourcing, production and properties (e.g., absence of harmful chemicals). Voluntary initiatives provide both practical guidance and rigorous standards to incentivise sustainable practices, promote innovation and collaboration, and foster a culture of sustainability among industry professionals, corporate clients and investors, and customers. Well known examples include the *Forest Stewardship Council*[9] (FSC); *Global Reporting Initiative*[10] (GRI), and the *Carbon Trust*[11].

Voluntary Sustainability Standards (VSS) are a special category of voluntary initiatives that are typically developed by industry groups, non-governmental organisations (NGOs), and/or private organisations. The *UN Forum on Sustainability Standards* (UNFSS)[12] defines VSS as:

'Standards specifying requirements that producers, traders, manufacturers, retailers or service providers may be asked to meet, relating to a wide range of sustainability metrics, including respect for basic human rights, worker health and safety, environmental impacts, community relations, land-use planning and others' (UNFSS, n.d., p. 4)

Hundreds of VSS are currently available (ITC, n.d.; UNFSS, 2022). At the time of writing, one international directory of ecolabels has identified over 450 labels used in 199 countries by 25 major industry sectors (Ecolabel Index, n.d.). Some VSS focus on particular industries or sectors (e.g. agriculture, mining, forest management, fisheries), while others focus on specific environmental or social issues (e.g., water use, biodiversity, GHG emissions, energy efficiency, waste management, workers' rights). Some VSS encompass the full range of environmental impacts throughout a product's life cycle, whereas others focus on certain stages of production. Some VSS identify and encourage best practice; others advocate continuous improvement or seek to combine both approaches.

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[8] One exception is corporate sustainability reporting. Some jurisdictions are developing laws on mandatory corporate reporting, with penalties for false claims (e.g. European Commission, n.d.). Companies that claim to be 'nature positive' could be subject to legal sanction if those claims are invalidated by the courts.

[9] The *Forest Stewardship Council* (FSC) was established in 1993 to promote the responsible management of the world's forests. The FSC runs a globally recognised voluntary certification and eco-labeling scheme for forests and forest products.

[10] The *Global Reporting Initiative* (GRI) provides voluntary guidelines for organisations to assess and report on their economic, environmental and social performance. Known as the GRI Standards, the guidelines are based on the principle of materiality, meaning that organisations are encouraged to report on sustainability issues deemed most relevant to them and their stakeholders.

[11] The *Carbon Trust* offers services such as carbon footprinting, sustainability consulting and certification. The *Carbon Trust* also offers certifications against a proprietary standard, which recognises organisations that demonstrate a commitment to reduce their GHG emissions.

[12] UNFSS is coordinated by a Steering Committee representing the UN Conference on Trade and Development (UNCTAD), the Food and Agriculture Organisation of the UN (FAO), the International Trade Centre (ITC), the UN Environment Programme (UN Environment), and the UN Industrial Development Organization (UNIDO).

VSS can enhance the transparency and accountability of an organisation's progress towards sustainability goals, while also providing a credible framework to demonstrate a commitment to sustainability to both internal and external stakeholders.

More generally, VSS may be used to:

- identify social and environmental risks in operations and/or supply chains;
- define sustainability baselines, targets and deadlines relative to their peers;
- monitor the sustainability performance of suppliers, facilities or the organisation;
- inform and attract environmentally-conscious investors, employees or customers;
- demonstrate an organisation's commitment to environmental and social best practice, especially in the absence of mandatory standards and enforcement (Smith et al., 2019).

VSS typically require that organisations, facilities, products and/or services meet specified performance criteria. The effectiveness of VSS implementation is often evaluated through independent (third party) certification (e.g., ISO[13] HACCP[14]). The requirements for certification may involve assessing an entity or product's quality or attributes, and/or production and processing methods, including transportation.

VSS can help organisations to align their sustainability efforts with the *Global Biodiversity Framework* (GBF) and transition to a nature-positive future. To make this possible, however, many existing VSS will likely need to:

- incorporate biodiversity metrics and targets that correspond to GBF goals, strengthening the link between local and organisational actions and global or national biodiversity objectives;
- adopt more comprehensive approaches to measuring biodiversity impacts, moving beyond avoidance of harm to actively promote ecosystem restoration and enhancement;
- strengthen their scientific foundations by incorporating the latest ecological research and monitoring techniques, which would also strengthen VSS credibility and effectiveness; and
- increase standardisation and comparability across different sectors and regions, facilitating more meaningful benchmarking and progress tracking.

Additionally, integrating nature-based solutions and *circular economy* principles more fully into VSS frameworks would help to align them with the holistic approaches needed to achieve nature positive outcomes and the GBF targets.

Many products and materials assessed by VSS are widely used in buildings and construction, from structural building materials to interior textiles. Voluntary rating tools have likewise been specifically developed for green buildings, as discussed in Chapter 4.

[13] ISO (*International Organisation for Standardisation*) is a global organisation that develops and publishes international standards for various industries, including food safety.

[14] HACCP (*Hazard Analysis and Critical Control Points*) is a food safety management system that focuses on identifying and preventing potential hazards throughout the food production process.

Chapter 3 – Biodiversity and the Built Environment

The built environment, including infrastructure and buildings, generally has a negative impact on ecosystems and the species that exist within and around them. Impacts to biodiversity from buildings and construction include destruction or degradation of natural habitat for wildlife, mortality of animals due to collisions, roadways that increase the spread of invasive species, pollution of soil, water and air, and exploitation of rare and threatened species as building materials (e.g. old growth timber).

The construction of buildings and infrastructure requires materials that are typically sourced and transported from far away from the site. As a result, the biodiversity impacts of the built environment often arise a great distance from the building site itself. Buildings also generally have long lifespans, and whilst impacts on biodiversity may be concentrated during the construction phase, all stages of the building life cycle, from raw material extraction, processing and manufacturing, to occupancy and end of life, contribute to biodiversity loss.

In response to these impacts, the building and construction industry, supported by governments and civil society organisations, has developed a range of initiatives to manage biodiversity. Following the mitigation hierarchy, these include novel methods to integrate biodiversity conservation in urban planning and building design, practical tools to help the industry anticipate, avoid, reduce and/or compensate for adverse impacts, as well as standards and certifications that enable investors, owners, and tenants to recognise low environmental impact, high quality sustainable buildings. Maintaining and improving biodiversity in the built environment has many benefits, including opportunities for recreation, maintenance of cultural values, improving people's wellbeing, and reduction of GHG emissions.

3.1 Defining the Built Environment

Urbanisation is a worldwide trend occurring at a rapid pace (Seto et al., 2014; World Health Organization [WHO], n.d.). The global urban population is projected to increase by an additional 2.5 to 3 billion by 2050, accounting for up to 69% of the world's population (WHO, n.d.). Most of this population will live in cities, the largest urban settlements, which are known for their highly developed built environments, specialised economic activities, and concentration of social and cultural diversity.

Human settlements can be analysed at various scales, from macro to micro. At a macro scale, the main distinction is between rural and urban settlements. Rural settlements are characterised by dispersed and isolated houses, typically surrounded by agricultural land, whereas urban settlements are characterised by relatively high population density and a mix of residential, commercial, and industrial land uses.

At the meso (or intermediate) scale, the built environment encompasses the arrangement of neighbourhoods, the configuration of lots, and a mix of land uses, urban blocks and open spaces. Importantly, the meso scale includes physical and social components, including the layout and density of buildings, the provision of public amenities, and infrastructure connections between different regions.

At a micro scale, the built environment consists of individual buildings and the spaces between them. At this scale, the architectural design of buildings (whether residential, commercial, public or community structures) generally considers factors such as accessibility, connectivity, and the relationship between the building and its immediate surroundings, including the street and landscape. Additionally, urban design at the micro scale involves the creation of spaces between buildings, such as sidewalks, parks, and plazas, which support community cultural life and encourage social interaction.

Key features of buildings at the micro scale include their physical characteristics, such as size, shape, and materials used in construction. These characteristics also play a role in buildings' contribution to climate change and other environmental impacts. For example, larger buildings typically require more energy for heating and cooling, although they may be relatively efficient per unit area or per occupant. Design decisions such as the selection of building materials used in construction, insulation, window placements, and building orientation can also affect energy use and climate-related impacts. Similarly, buildings can vary in terms of their impacts on biodiversity, as discussed below.

3.2 Benefits of Biodiversity in the Built Environment

Efforts to conserve and restore biodiversity in urban settings are important for many reasons, not least because over half of humankind lives in cities (United Nations Department of Economic and Social Affairs, 2019). In Australia, around 90% of the population live in urban areas (Australian Bureau of Statistics, 2019).

Some benefits of urban biodiversity are obvious. Natural components of the urban environment, such as parks, urban forests, street trees, cultivated land, wetlands, lakes, and streams, generate a range of benefits to people. These include: microclimate regulation, air filtration, stormwater drainage, noise reduction, natural sewage treatment, as well as recreational, social and cultural benefits (Bolund & Hunhammar, 1999). These connections between humans and nature reflect the **biophilia** hypothesis – the idea that humans have an innate tendency to connect with nature and other forms of life, developed through our evolutionary history.

Many studies have found that access to natural environments such as urban green space can maintain or improve people's mental and physical health (Bratman et al., 2019; Dzhambov et al., 2019; Twohig-Bennett & Jones, 2018; Wang et al., 2019). There is also some evidence of a positive association between species diversity and human wellbeing (psychological and physical), and between ecosystem diversity and immune system regulation (Aerts et al 2018). Perceived beauty of natural environments and associated positive emotions are known to enhance wellbeing, with the mere visual presence of plants found to have stress-reducing effects (Grinde & Patil, 2009). There is also the satisfaction of knowing that wild nature continues to thrive and will remain available for the enjoyment of future generations.

Less obvious benefits of biodiversity to urban residents and visitors include the value of conserving biodiversity in places far removed from the urban environment. For example, urban residents rely on food that is mostly produced in rural agricultural areas (Li et al., 2022), and there is increasing recognition that agricultural biodiversity is essential for sustainable food production (Frison et al., 2011). The same is true for the production of many materials used in the construction industry, from those used to construct dwellings (e.g., timber), through to the fabric of the furniture we use (e.g. cotton). In fact, cities function because of their reliance on, and connection to, hinterlands or 'bioregions' (Doughty & Hammond, 2004). For example, one study estimated that the ecological footprint of the 29 largest cities within the Baltic Sea drainage basin in northern Europe (around 22 million inhabitants at the time) required, for their consumption of wood, paper, fibre, and food, an area of forest, agricultural, and marine ecosystems approximately 200 times the area of the cities themselves (Folke et al., 1997).

3.3 Impacts of the Built Environment on Biodiversity

The built environment, and its associated infrastructure and buildings, have direct impacts on ecosystems and the species that exist within and around them. As the built environment occupies physical space that might otherwise offer habitat for wildlife, impacts inevitably occur as a result of the development of a site (unless the project is built on a previously developed or 'brownfield' site). Consequently, in situ biodiversity is affected by land-use change, habitat loss and fragmentation (Irwin & Bockstael, 2007; McKinney, 2002), as well as by altered environmental conditions (Gangolells et al., 2009).

Although the spatial footprint of the built environment is small relative to agriculture, for example, human settlements have historically developed in locations that are characterised by unusually high natural biodiversity and productivity, such as coastal floodplains and the mouths of major rivers. Cities are often located in naturally productive, species-rich, and fertile land regions. Yet, while the land-use changes required for city development can result in local species population losses and even extinctions of wildlife, some cities and urban environments still retain endemic native species and often host a high richness of plants and animals, including endangered species (Aronson et al., 2014, Ives et al., 2016). However, these remnant species are faced with a range of anthropogenic stressors that accumulate in built environments, such as predation by household pets, disturbance of breeding sites, and collisions, that can increase pressure on already vulnerable or threatened populations and ecosystems.

Moreover, urban and metropolitan areas are growing. Urban sprawl occurs with the rapid geographic expansion of towns and cities, and is often characterised by low-density residential housing, single-use zoning, and increased reliance on vehicular transportation. Urban sprawl can be attributed to the need to provide housing for a rising urban population, however, it also reflects a desire for larger living space and other residential amenities (Rafferty, n.d.). Due to the increase in the physical environmental footprint of metropolitan areas, urban sprawl leads to destruction and fragmentation of wildlife habitats, as well as increased natural resource usage, and pollution as a result of larger homes and increased transport. Sprawling urban development can also result in isolation or fragmentation of ecosystems, reducing the ability of wildlife to move and migrate across landscapes, and impeding connectivity-facilitated population recovery from disturbances, thereby decreasing ecosystem resilience to change (Oliver et al., 2013).

Beyond land-use change and habitat disturbance, the built environment may increase the risk from extreme weather events, such as flooding. In many cities, vast expanses of impervious surfaces (e.g., roofs, roads, pavement, and parking lots) have replaced water-absorbing vegetation and permeable soils. Consequently, stormwater and snowmelt runoff can pool in areas of low elevation, increasing the risk of local flooding, as well as exacerbating the damaging effects of flooding events. Furthermore, chemicals present on impervious surfaces are also carried with runoff, polluting waterways, reducing water quality, and threatening aquatic ecosystems downstream. There is also evidence that the built environment may increase exposure to extreme wildfire events (Penman et al., 2014).

Buildings as physical structures can have other adverse impacts on biodiversity. Cumulatively, billions of birds per year are killed worldwide as a result of collisions with buildings (Klem, 2009). Depending on where they are located, buildings can also cause species displacement, leading to increased competition and pressure in other locations. Construction activities may also lead to increased disturbance, harm, and the risk of vandalism to nature on adjacent undeveloped land caused by unregulated access and ancillary development and operations (such as access roads, pipelines and dredging).

Development impacts on adjacent areas (including natural environments) are increasingly significant. Within and near built environments, biodiversity may be adversely affected by changes in natural resource availability (e.g. water use and depletion; Rees, 1999), modification of microclimates (e.g. urban heat islands in cities with dense concentrations of buildings and impervious surfaces, such as pavements and roads, that absorb and retain heat), introduction of exotic and invasive species (e.g.

domestic cats and dogs; Box 3.1), pollution of air, soil, and water, and increased levels of light and noise pollution (Doughty and Hammond, 2004; Newman, 2006; Rees, 1999; Duan & Li, 2016).

The construction of houses, utilities, and roads requires materials that may be sourced and transported over long distances. As a result, the negative environmental impacts of the built environment often occur far from the building site. Demand for natural resources and raw materials such as minerals, rocks, timber and fossil fuels for construction activities can destroy large areas of species' habitat, causing loss of biodiversity (Opoku, 2019). Globally, the construction industry is estimated to account for 40% of all raw material extraction and use (Ulbrich, 2021), 55% of wood cut for non-fuel uses (Roodman & Lenssen, 1995), and 20% of freshwater consumption (Vatalis et al., 2013). The broader construction industry also generates a large share of global solid waste, with an estimated 13-30% of waste going to landfill composed of construction and demolition waste (Thongkamsuk et al., 2017).

Human behaviour within and surrounding the built environment also directly impacts biodiversity. One study found that human activities attributed to encroachment on wildlife habitat were the main cause of 31,626 native animal admissions to a Wildlife Rehabilitation Centre in Beerwah, Queensland, Australia between 2006 and 2017. Casualties due to car strikes were the most common reason for native animal admission (34.7%), with other common reasons being dog attacks (9.2%), entanglements (7.2%), and cat attacks (5.3%) (Taylor-Brown et al., 2019). Mortality rates of admitted wildlife were highest following dog attacks (72.7%) and car strikes (69.1%) (Taylor-Brown et al., 2019).

Box 3.1 Invasive Species in Australian Built Environments

Urbanisation and urban sprawl contribute to, and in some cases exacerbate, the impacts of invasive species. For example, roads can act as linear structures for vehicles to disperse weed seeds, accelerating the dispersal and invasion of exotic species and leading to the spread of invasive species on a regional scale (Chichizola et al., 2021).

Residential garden landscaping often includes introduced exotic plants with the potential to negatively impact biodiversity if they spread to other locations. In NSW alone, hundreds of native plants are threatened by weeds, of which about 65% are due to the uncontrolled spread of garden plants such as lantana (Coutts-Smith and Downey 2006).

The spread of invasive species is a major concern in many countries, due to their high environmental and economic costs. For example, in Australia, the main burden caused by invasive species is attributable to weedy plants, with mitigation estimated to cost around AU$4 billion per year for the agricultural sector alone (Bradshaw et al., 2021). However, with regards to single species, some of the highest costs of invasive species in Australia are attributed to exotic mammals, particularly cats and rabbits (Bradshaw et al., 2021).

In Australia, pet cats outnumber feral cats (3.77 million pet cats versus 2.8 million feral cats; Legge et al. 2017) and, in urban areas, have a predation rate 8–52 times larger than feral cats in natural environments (Legge et al., 2020). Cat attacks impose serious impacts on populations of birds, reptiles, and microbats (Taylor-Brown et al., 2019). Moreover, cats not only prey on native wildlife but may also out-compete native predators (e.g., quolls) for food resources (Denny & Dickman, 2010), resulting in further (indirect) negative impacts on Australian native fauna. Dog attacks in urban areas are another common cause of adverse impacts on native fauna in Australia, which can result in high wildlife mortality rates (Taylor-Brown et al., 2019).

At the same time, cities, neighbourhoods, and buildings can contribute positively to biodiversity conservation and the delivery of ecosystem services. For example, 'green corridors' in urban landscapes, parks, gardens, and green roofs and façades on buildings can provide habitat for local wildlife and sanctuary for migrating species. Additionally, new developments on brownfield sites can present opportunities to restore previously contaminated land or rehabilitate ecosystems through landscaping.

3.4 Impacts of a Building over Time

The environmental impacts of buildings pose a major challenge to the construction industry (Polster et al., 1996; Khasreen et al., 2009; Crawford, 2011). However, construction projects are rarely evaluated across their entire life cycle or across all biodiversity impacts (Edwards, 2010; Opoku, 2019). In most cases, building impact assessments focus on a few selected issues (e.g., minimising the environmental impacts of timber products; Adhikari & Ozarska, 2018), or on specific stages of development (e.g., the carbon implications of end-of-life management of building materials; Dodoo et al., 2009). While impacts on biodiversity from urban development and building projects may be concentrated in the construction stage, they also accumulate over time throughout a building's life cycle.

Buildings can have very long lifespans, enduring for decades or even centuries. The lifespan of a building commences in stages and progresses, in simple terms, from (0) *Project Planning and Design*, through (1) *Raw Material Extraction*, (2) *Processing and Manufacturing*, (3) *Construction*, (4) *Occupation and Maintenance*, to eventual *End of Life* ((5) *Decommission, Deconstruction, Demolition* and (6) *Disposal*). Figure 3.1 illustrates these stages, with an additional stage for *Recovery* (7) including reuse and recycling of the existing building, materials and/or products).

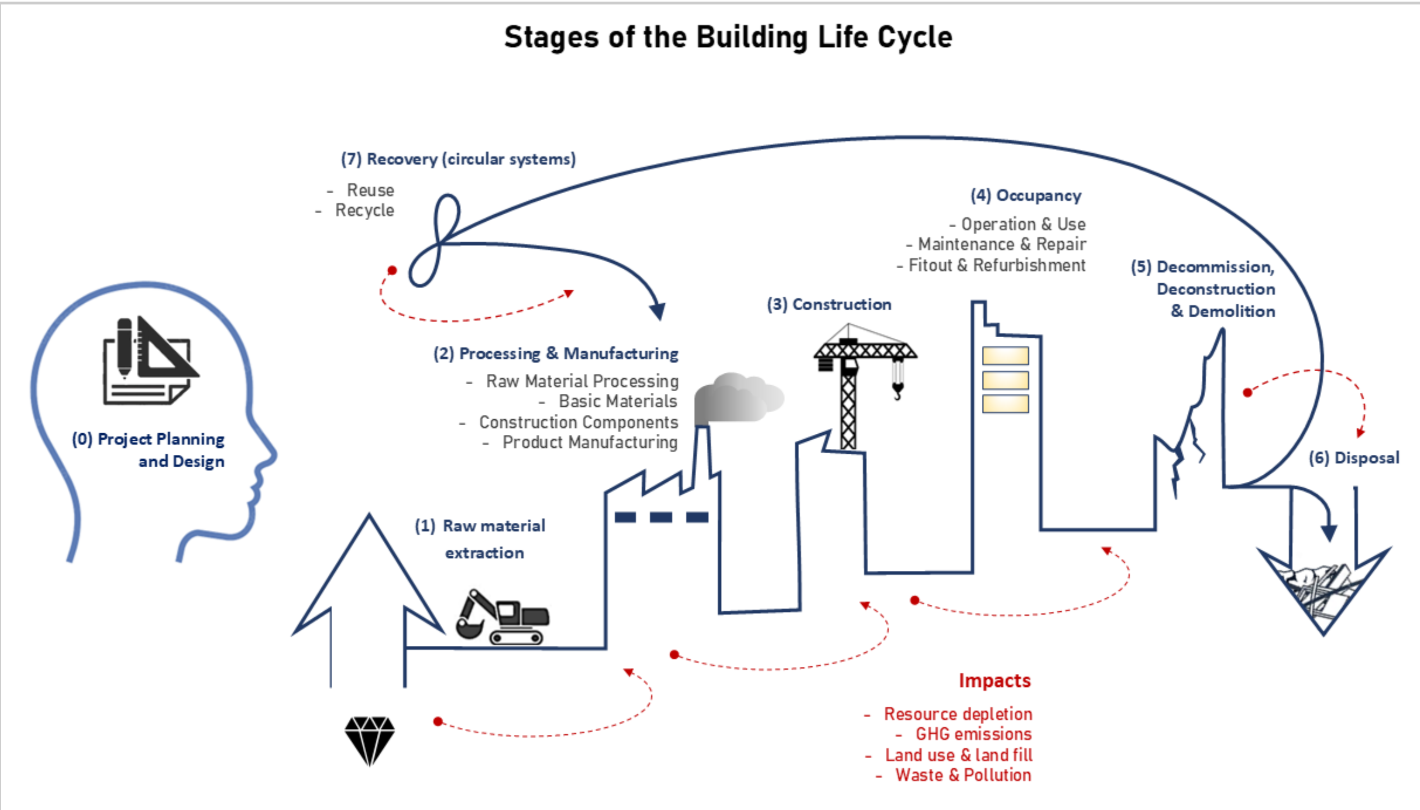

Figure 3.1 The Building Life Cycle: A Schematic View

We conducted a review of the scientific literature to investigate the impacts of buildings on the environment and biodiversity across the building life cycle (Box 3.2). We found that very few studies focus on biodiversity impacts, with most dwelling instead on issues such as GHG emissions and waste (Figure

3.2). Nevertheless, buildings can have multiple impacts on biodiversity at all stages of their life cycle, as shown in Figure 3.3.

Box 3.2 Assessing the Impacts of Buildings on Nature: A Literature Review

By searching the *Web of Science* platform using keywords related to the main drivers of biodiversity loss (Appendix 1), we identified 1163 publications that consider the environmental impacts of the construction industry across the building life cycle.

Studies focusing on climate or carbon were most prevalent (38% of papers reviewed), followed by studies focusing on pollution and waste (28%). Just 24% of the studies reviewed referred to the impacts of buildings on habitat, ecosystems or land, but few studies referred specifically to biodiversity (5%), and even fewer referred to the problem of invasive species (6 studies or 1%), despite its importance as a driver of biodiversity loss (Figure 3.2).

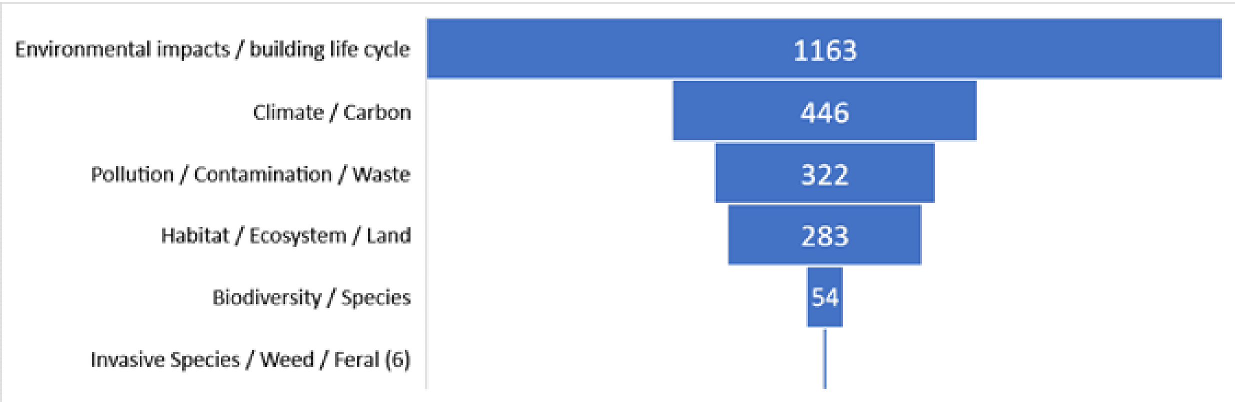

Figure 3.2 *Web of Science* search results showing the number of publications found for subsets of key words related to biodiversity impacts from the construction industry

One reason why the construction industry's impacts on biodiversity are seldom discussed in the literature may be the relative complexity of assessing biodiversity impacts, and/or a lack of appropriate data and indicators (Khasreen et al., 2009; Nolan et al., 2009). Furthermore, the physical attributes of each building (e.g., scale, type, and building materials used) are highly variable and each project site is unique, from an ecological perspective. This variability can make it challenging to assess the impact of the built environment on biodiversity.

Stage 0: *The Project planning and design stages* of a building do not typically account for any direct impacts on biodiversity. However, this is the most crucial time in the building's life cycle from an impact perspective. Decisions made during planning and design stages will determine everything from location of the site, to building scale, materials and products used, construction practices and contractors hired. The results of these decisions will affect, either directly or indirectly, how much energy the building consumes, the selection of building materials including where they are sourced from and what they are made of, as well as how much waste and pollution is likely to be generated during the building's construction and occupation over time. These decisions all have significant implications for nature and biodiversity.

Stage 1: *Raw material extraction* (for building materials) is the first stage in a building's life cycle and often where the greatest direct impacts on the environment occur[15]. Raw materials such as iron ore, sand and stone, timber, and water are extracted from the natural environment to produce building materials, which are used to construct the building. The extraction of raw materials typically results in the destruction or damage of habitats, due to excavation, clearing, logging, discharges and tailings, other indirect impacts such as debris, noise and light pollution, and emissions caused by the extractive and logistics processes involved.

Extractive activities often occur in biodiversity-rich areas (Murguía et al., 2016), and may have long-term negative environmental impacts. For example, disposal of tailings (waste by-products of mining processes) can contaminate the surrounding environment and local waterways with unnaturally high concentrations of chemicals and minerals. Land clearing for open-cut mines or timber harvesting from forests can lead to erosion, forest degradation and loss of wildlife habitats (Crawford, 2011). Extractive processes also contribute to climate change (Box 3.3).

Stage 2: After the ***processing*** of raw materials, the ***manufacturing*** of building materials, components, and products, i.e., from basic building materials (e.g., cement and steel), to manufactured products (e.g., brick and glass), to components made from different materials (e.g., windows, precast concrete, or composite wall panels) also result in impacts on biodiversity in one way or another. Environmental impacts at these stages of the building life cycle are both direct and indirect.

Significant environmental impacts occur during the manufacturing stage, where basic materials are converted into more complex components and products, while industrial processes for building materials are usually resource, energy, and water intensive, and generate substantial waste and pollution[16]. Notably, of the 75.8 million tonnes of solid waste that was generated in Australia in 2018-19, the manufacturing sector was responsible for almost 17% (12.8 million tonnes), and was the largest contributor of hazardous materials (1.9 million tonnes) – accounting for 24% of total hazardous waste – as well as the second largest contributor to plastic waste (15%) (Australian Bureau of Statistics, 2020).

Stage 3: *The Construction stage* is typically when the most significant direct impacts on biodiversity occur. This is due to activities on the building site and changes to the landscape (particularly if the building is situated on a previously undeveloped greenfield site). During the construction stage, environmental impacts may include, but are not limited to: atmospheric emissions (from fossil fuel-based vehicles and equipment); water consumption (for concrete production, wet bricklaying and plastering trades, cleaning, hydro demolition); water contamination (above, from runoff, and/or underground from leaching substances); noise and vibration; dust generation; soil alteration; resource consumption (through use of energy and materials); waste generation (from packaging and materials wastage during construction, as well as demolition of existing structures); and physical harm to wildlife.

Stage 4: Whilst construction is relatively short in duration (months or years, depending on project size), the ***Occupancy stage*** (or in-use / operation and maintenance stage) of a building can span decades or longer, resulting in repetitive or continuous impacts on the environment. Impacts that occur during building occupancy are mostly indirect and range from ongoing energy use (e.g., electricity for lighting,

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[15] Out of the 10 countries with major extractive industries in 2017, Australia had the highest material extraction per capita at 93.3 tons - over two and a half times the second highest (Canada with 36.7 tons per capita), and nearly four times China's per capita rate (UNEP IRP, 2019).

[16] The construction industry is increasingly aware of the part it plays in driving environmental impacts through the demand for building materials, particularly in regard to climate change and carbon emissions. This growing consciousness has led to the development of various responsible sourcing initiatives, and increasing consideration of embodied carbon in materials. *Environmental Product Declarations* (EPDs) are an example of publicly available documents that certify construction materials that minimise or avoid environmental impacts (e.g., through eliminating the use of toxic chemicals in their production).

heating, cooling, and cooking); resource consumption (e.g., paper, wood, products); freshwater use (human consumption, cleaning, irrigation, and sanitation); atmospheric emissions (from fossil fuel-based vehicles, machinery, cooking, and appliances); land contamination in landfill sites due to disposed waste (toxic or hazardous substances, food and organic materials, textiles, inert waste); and other impacts due to the effects of building maintenance, repair and renovation.

Whilst impacts on the environment during building occupancy are predominantly indirect, they accumulate over time. Long-term impacts associated with this stage of the building's life cycle include GHG emissions. Waste generation during this stage is also significant. In 2018-19, Australian households alone were responsible for 16% of total waste (12.4 million tonnes), and were the largest contributors to plastic waste and organic waste – accounting for 47% (1.2 million tonnes) and 42% (6.4 million tonnes)[17], respectively (Australian Bureau of Statistics, 2020).

Stage 5: *Decommissioning, Deconstruction, Demolition and Disposal* occur at the ***End of Life stage***. This is usually the shortest stage in duration, and impacts on biodiversity are mostly indirect. Similar to the construction stage, there may be some direct short-term impacts on biodiversity at the building site (if any biodiversity is present) during demolition works (e.g., noise and/or light pollution and dust emissions). Offsite impacts on biodiversity may occur due to disposal of solid waste in landfill sites, where it can contaminate soil and release GHG emissions.

In Australia, of the 75.8 million tonnes of solid waste generated in 2018-19, the construction industry was responsible for 12.7 million tonnes (16.8%) (including 8 million tonnes of masonry materials, alone) – an increase of 22% since 2016-17 (Australian Bureau of Statistics, 2020).

Sometimes at the end of the occupancy stage, as the building approaches the end of its useful service life, it may be feasible to refurbish, renovate or adapt it for reuse (as an alternative to decommissioning, demolition and disposal). As reuse of an existing building avoids demolishing it for the purpose of rebuilding a new development, the potential environmental impacts of both the demolition and new construction stages can be avoided. Even though the reuse of a building may entail significant structural changes through its renovation and/or adaptation, which can result in negative impacts on the environment, retaining some of the building fabric and the reclaiming, reusing, and recycling of materials means that the overall impacts are reduced (compared to demolishing and rebuilding on the site) and existing embodied carbon can be sequestered.

Likewise, when products and materials are reused, disassembled, and reconfigured, or recycled (e.g., through manufacturing products that incorporate recycled material content, or product stewardship initiatives such as buy-back schemes), negative impacts to the environment will also be decreased as there is less demand for new or virgin materials. However, recycling processes can have their own adverse environmental impacts, for example, the use of toxic or harmful chemicals in the process of wastewater treatment for recycling (Crawford, 2011).

Indirect impacts on biodiversity that occur beyond the building construction site (i.e. offsite) due to the extraction of raw materials, transportation and waste, are rarely assessed as part of a development project (Brachet et al., 2019). Furthermore, impacts on biodiversity on adjacent or neighbouring sites are also not considered in most environmental assessments (Tulloch et al., 2019). Other offsite impacts include, but are not limited to: (i) downstream impacts (e.g., impacts on wetlands from chemicals discharged into upstream river systems); or (ii) upstream impacts (e.g., extraction of raw materials for development).

[17] 37% was food waste (Australian Bureau of Statistics, 2020).

Table 3.1 summarises the potential direct and indirect impacts to biodiversity likely to occur throughout the stages of the building's life cycle. The *Construction* and *Occupation / Maintenance* Stages are the only two stages likely to have impacts directly situated on the building site. Biodiversity impacts at other stages generally occur offsite.

Box 3.3 Greenhouse Gas Emissions Throughout the Building Life Cycle

Globally in 2018, the building and construction sector was estimated to account for 36% of final energy use and 39% of energy- and process-related emissions (Teh et al., 2019; Dadzie et al., 2018; UNEP IRP, 2019). The carbon footprint of buildings includes substantial GHG emissions from construction (e.g., onsite energy generation, fossil fuels used for transport); embodied carbon emissions from electricity supply and from upstream supply chains (Teh et al., 2019). In Australia, buildings are thought to account for about 130 million tonnes (Mt) of GHG emissions annually, or around 23% of Australia's total GHG emissions (Holz & Sigler, 2016).

Energy consumption and GHG emissions occur at every stage of the building life cycle:

***Extraction and Processing* of raw materials and fuels:** Based on data from 2018, extraction and processing of metals and other minerals accounted for 26% of global emissions (UNEP IRP, 2019). Mining of iron ore, for example, is energy intensive and results in emissions of nitrous oxide, carbon dioxide, carbon monoxide, as well as sulphur dioxide from diesel generators, vehicles, and other equipment (The World Counts, 2022). The world's top engineering and construction metal is steel, which is responsible for almost 6% of global energy demand, or one quarter of global industrial emissions (Pandit et al., 2020).

***Manufacturing*:** Around 10% of global energy-related GHG emissions are linked to the manufacturing of construction materials (UNEP, 2021a). In Australia, which manufactures around 30 Mt of building products annually, the largest contributors to embodied GHG emissions are cement, lime, plaster and concrete products (39%), iron and steel products (38%), and wood products (7%) (Teh et al., 2019). Although building materials such as concrete and timber have low embodied energy intensity, they are consumed in very large quantities. Conversely, more expensive materials with relatively high energy content (e.g. *stainless* steel) are typically used sparingly in comparison.

Construction: GHG emissions arise from construction processes and activities such as land clearing, excavation and filling, fencing, installation of a tower crane, concrete mixing and pouring, pre-casting, as well as from the fuel engines used for transportation, crane and mortar operations. Due to the relatively short duration of the *Construction* stage, emissions generated during construction only account for around 2% of the total GHG emissions through the building's entire lifespan (Biswas, 2014).

***Occupancy*:** Once built, it is necessary to power lighting and heating, ventilation, and air conditioning (HVAC) systems for the duration of a building's functional lifespan. In 2018, GHG emissions from power generation for electricity and commercial heating / cooling accounted for the largest share of energy-related emissions in the buildings sector, or around 68% of total buildings-related emissions from energy consumption (UNEP IRP, 2019). Throughout the life cycle of a conventional building, an estimated 80-90% of total energy is consumed during the *Occupancy* stage (Sartori & Hestnes, 2007; Biswas, 2014).

***End of Life*:** Waste in landfill sites accumulates throughout the building's *Construction* and *Occupation* stages and from disposal of materials at the building's *Demolition* and *Disposal* (*End of Life* stage). Construction and demolition (C&D) waste often represents the largest proportion of solid waste in many countries. In Australia, C&D waste represents around 42% of total generated waste, of which 43% goes to landfill (Crawford, 2011). Emissions from organic waste in landfills contribute around 3% of total net GHG emissions in Australia (Karimipour et al., 2019).

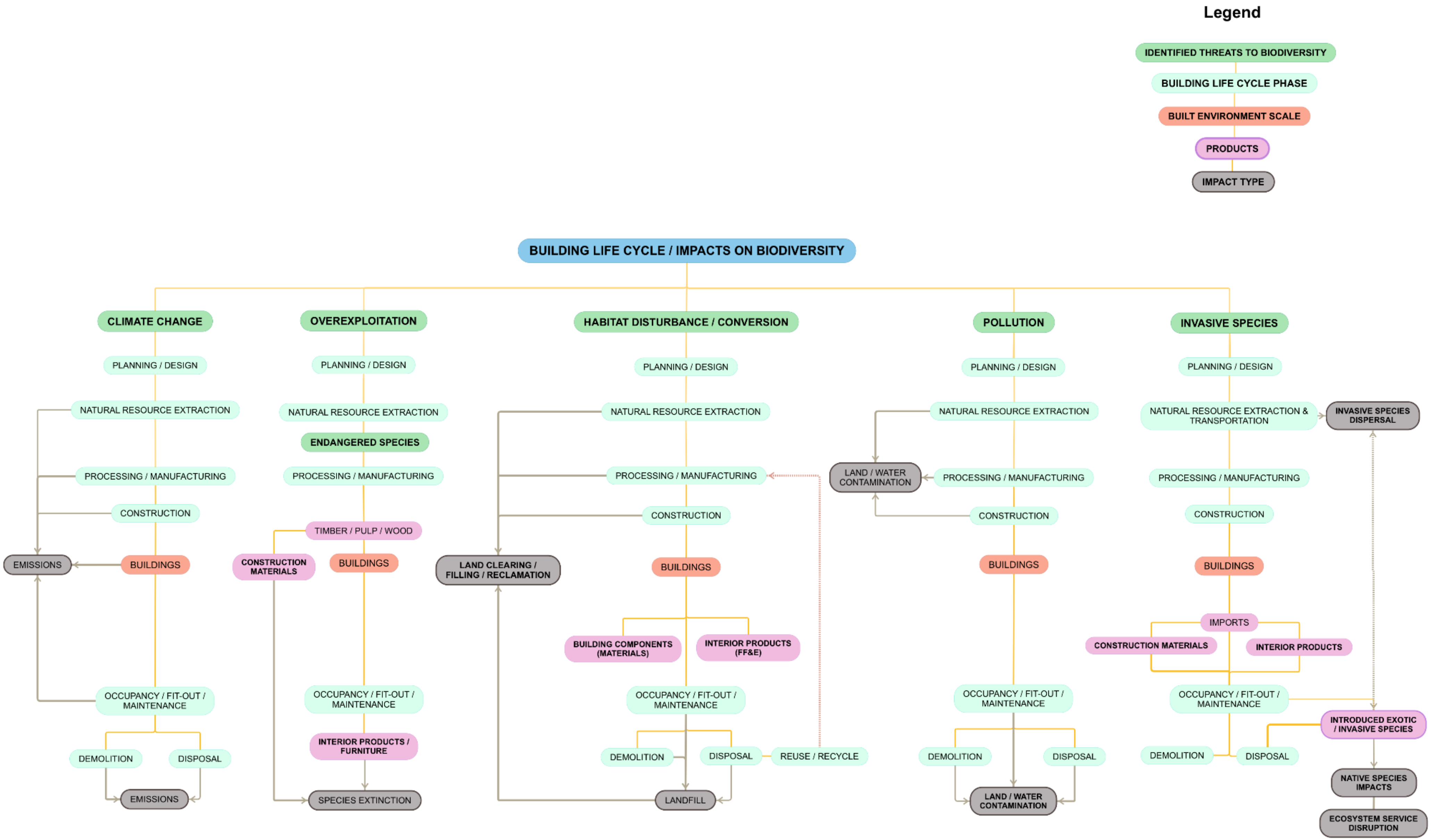

Figure 3.3 Schematic of Threats to Biodiversity Along the Building Life Cycle

Table 3.1 Assessing Impacts on Biodiversity at Different Stages of the Building Life Cycle

Where in the building life cycle do impacts on biodiversity occur?			IMPACTS ACROSS THE LIFE CYCLE							
Drivers of Biodiversity Loss	Impact Categories	Description / Examples	Raw Materials / Manufacture		Construction		Fitout / Occupancy		End of Life	
1. Habitat disturbance & conversion	Terrestrial Habitat loss / degradation	Land use change due to raw material extraction, on-site vegetation removal, earthworks, levelling, land filling, impervious surfaces, soil compaction.	○			●		●		●
	Waste accumulation (land use)	At extraction, processing and disposal sites.	○	●	○	●	○	●	○	●
	Aquatic Habitat loss / degradation	Water for raw material extraction and processing, draining and filling wetlands, construction wet trades, water use by building occupants, hydro demolition.	○			●				
	Alteration of hydrology	Construction of seawalls, water channelling, draining wetlands, impervious surfaces, stream water cut-off, alterations to aquifers and watertables.	○		○	●	○	●	○	
	Noise and vibration	Earthworks, blast machinery, pile drivers, sawing, tree felling, pneumatic tools, combustion engines.	○		○	●		●	○	●
2. Climate Change	GHG emissions from fossil fuels	Fossil energy used in building operations, industrial / manufacturing processes, transportation, equipment / machinery use.	○		○	●	○	●	○	●
	GHG emissions from vegetation clearing	Emissions of CO2, methane, N2O, NOx and soot from burning, disposal or decomposition of cleared vegetation.	○	●	○	●	○	●		
	Other GHG emissions	Soil disturbance / extraction, breakdown of solid and organic wastes at extraction / landfill sites, burning, toxic materials, HVAC systems, VOCs, CFCs.	○	●	○	●	○	●	○	●
	Microclimate impacts	Urban 'heat islands'.			○	●	○	●		
3. Pollution	Pollution / eutrophication of soil / air	Mining, quarrying, logging, industrial / manufacturing processes, earthworks, cutting operations, fertilisers, pesticides, solvents, acid rain.	○		○	●	○	●	○	●
	Groundwater contamination / eutrophication	Soil leaching from surface pollution, drilling.	○		○	●	○	●	○	●
	Surface water pollution / eutrophication	Wastewater dumping, backflow, runoff, fertilisers, pesticides, solvents, surface-treatment liquids, soil erosion, pollution of waterways.	○		○	●	○	●	○	●
4. Over-exploitation / Un-sustainable Use	Endangered species used as building materials	Structural timber sourced from rare / endangered tree species.	○							
	Endangered species used for fit-out	Furniture made from rare / endangered tree species.	○							
5. Invasive Species	Habitat invasion by weeds or non-native species	Timber extraction and exotic species plantations can accelerate weed invasion and/or facilitate the spread of alien invasive plants.	○							
	Untreated timber / wood products	Construction materials and furniture may inadvertently harbour plants and animals that are invasive at the destination.	○		○	●	○	●	○	
	Accidental introductions	Invasive plants or animals may be transported in nooks and crevices of machinery / vehicles / clothing / shoes.	○		○	●				
	Deliberate introductions	Introduced invasive / non-native plant species in landscaping or by building occupants (soil, mulch, or gravel may also spread pest plants and pathogens).				●		●		

Note: *Closed circles indicate direct impacts while open circles indicate indirect impacts, based on assumption. The intensity, scale, and/or magnitude of impacts are not quantified. Potential impacts are grouped by the main drivers of biodiversity loss. The Project Planning and Design stages are not shown, as these activities do not normally generate significant physical impacts on the environment.*

3.5 Measuring a Building's Impacts on Biodiversity

The impacts of a building on nature can be measured both onsite, where the building or other infrastructure is constructed, as well as offsite, e.g., along the supply chain, or due to the spread of impacts across the wider landscape (Tulloch et al., 2019).

Several factors determine the impact of the built environment on biodiversity. These include: the exact geographic location of the building and the resources it uses; the intensity and type of activity; the original biodiversity that existed before the land was developed; the ability of existing species in the region to live in the modified (built environment) settings; land use surrounding the building development, and building design attributes that may or may not support biodiversity conservation.

Assessment and reporting of impacts on biodiversity by land owners or developers occurs through regulatory mechanisms (e.g., *Environmental Impact Assessment* (EIA), often required as part of Development Application proposals), as well as voluntary processes (e.g., natural capital accounting, nature-related risk analysis, *Life Cycle Assessment* (LCA)). However, as in other industries, developing a methodology for assessment, planning, and biodiversity conservation holds many challenges (Ferrier, 2002; Margules & Pressey, 2000). There are major information gaps in knowledge of wildlife habitat and species occurrence that challenge evaluation of building site impacts on local biodiversity, and there is also a lack of understanding about how the built environment and human societies affect species movements and behaviours.

Different frameworks have been developed for measuring environmental impacts in the built environment, at different stages of the building's life cycle. Prior to construction, during the planning approval phase, an *Environmental Impact Assessment* (EIA) enables potential effects of proposed development activities on the environment and biodiversity to be identified, and pinpoints possible measures to mitigate these effects (Glasson et al., 1999). It is usually required by government and council authority and decision makers before approving certain projects to proceed (Sutherland, 2001).

EIA usually starts with a screening process to identify projects that require an assessment (e.g., those with a development footprint that overlaps nationally listed threatened species). Then the main issues that need to be addressed are identified, and findings presented in an *Environmental Impact Statement* (EIS) (Glasson et al., 1999).

Other voluntary planning tools are also available, such as the *AECOM (2011) Index of Biodiversity Potential* (IBP), which enables developers and planners to assess the potential for urban development projects to support biodiversity. Assessing biodiversity potential enables developers to expand the opportunities for biodiversity-friendly design, beyond threatened species, to support nature and healthy ecosystems as a whole (Kirk et al. 2024, in press). This frames biodiversity as an asset to be enhanced, rather than a problem to avoid.

During construction, environmental quality may be monitored to assess onsite measures to report on and control dust generation (Yan et al., 2023), water contamination, noise pollution. Less frequently, aspects of biodiversity health are also measured such as surveys to detect and relocate vulnerable species at the construction site away from harm, most often mandated as part of the EIS process (Richardson et al., 2017).

Following construction, an evaluation of the construction process or the building's operational impacts on the environment can be undertaken. *Life Cycle Assessment* (LCA) is one way of measuring whole-of-supply-chain (i.e. offsite) impacts on the environment (Ciambrone, 1997). LCA is a rapidly evolving science that uses a 'cradle-to-grave' approach beginning with raw material extraction through to the end of life when materials are returned to the earth. LCA is most commonly used to quantify the environmental effects arising from material inputs and outputs over the life cycle of a product, but is also frequently used to assess material flows for whole buildings (U.S. General Services Administration, n.d.). Other similar approaches aimed at measuring whole-of-system impacts include ecological footprint analysis (e.g. Galli et al., 2020) and ecosystem services valuation (Gómez-Baggethun & Barton, 2013).

Biodiversity is typically not included explicitly in most LCAs (see Box 3.4), although several methods have been proposed to incorporate the impacts of land occupation and transformation on biodiversity (Curran et al. 2016; Chaudhary et al., 2015). Impacts were initially represented as potential species loss (PSL) per m^2 caused by a unit area of urban land.

This method has been updated to include land-use intensities (minimal, light, and intense use) and to link the affinity or habitat preference of particular species to urban land use (Chaudhary & Brooks, 2018). Other refinements include applying global extinction probabilities to understand species-specific impacts (Kuipers et al. 2019). Alternate measures for biodiversity impacts in LCA include species-specific toxicity fate and effect modelling from pesticides, and ecotoxicity effects on total biomass and individual species (Oginah et al., 2022). As yet there is no globally agreed standard for representing biodiversity in LCAs.

Box 3.4 Life Cycle Assessment: Challenges when Assessing Biodiversity

LCA requires quantitative data on inputs and impacts. In the absence of standardised biodiversity metrics and assessment models, there is no simple way to assess biodiversity loss in LCAs (U.S. General Services Administration, n.d.). Although there are well-established methods to measure land-use impacts on biodiversity (Curran et al. 2016, Chaudhary et al., 2015), land use is still excluded from most LCA studies (Allacker et al., 2014). Moreover, most biodiversity assessment methods can only be implemented at a large spatial scale, and are not reliable for smaller scales such as building construction sites due to the need for fine-scale data on species movements and distributions that are rarely available (Brachet et al., 2019).

LCA generally prioritises impacts pertaining to resources, waste, and energy, and currently do not cover all pressures threatening biodiversity. There are no indicators for invasive species, noise and light pollution, and over-exploitation of resources is only partially accounted for through water consumption (Brachet et al., 2019). LCA is often limited to only the materials with the most impact or found in the largest quantities (e.g. sand, commonly used timber; U.S. General Services Administration, n.d.). Less common materials (e.g. rare tree species for timber) are less likely to be evaluated due to less data being available for them, but these are often the natural materials most vulnerable to overexploitation (due to their rareness and high market value).

The main strength of LCA is to assess impacts along the value chain, i.e., the set of activities that an organisation operating in a specific industry performs in order to deliver a valuable product to the end customer (Brachet et al., 2019). However, standardised LCA methods to calculate effects on biodiversity are not available or generally applied in the context of the construction industry. By coupling LCA modelling with ecological expertise on the specific conditions of the local site, it is possible to get a more complete picture of the impacts of a building on biodiversity (both positive and negative). This hybrid approach is recommended to give results that are indicative of a total impact assessment on biodiversity (Ibid.).

Delivering sustainability for the built environment requires attention to multiple issues at different scales, both spatial and temporal. As discussed above, the built environment has diverse impacts on people and nature, both directly and indirectly. Given the range of impacts as well as the multiple drivers of impacts, responses must be multi-pronged. Sustainable outcomes in the built environment cannot be achieved by addressing a single issue (e.g. climate change) or by using just one tool (e.g. urban planning).

Sustainability in the built environment requires changes in the planning, design, construction and operation of buildings, as well as the surrounding infrastructure. More fundamentally, sustainable living implies change in the culture of organisations, individual lifestyles and community relations. Improved approaches to human settlements should seek to reduce environmental impacts, minimise the unsustainable use of natural resources and restore ecological health both onsite and in supply chains, while also enhancing community wellbeing and equitable economic benefit. In the following Chapter, we explore how sustainability in the built environment can be achieved through various frameworks, standards, and strategies at both urban and building scales, with an evolving focus from resource efficiency to nature-positive outcomes.

Chapter 4 - Improving Sustainability and Biodiversity in the Built Environment

Delivering sustainability in the built environment requires attention to multiple issues at different spatial and temporal scales. Sustainability proposes changes in planning, design, construction and operation of buildings and surrounding infrastructure to reduce environmental impacts, enhance community wellbeing, and provide more equitable economic benefits. At an urban scale, sustainability can be improved in many ways, such as densification, increasing efficiency of water and energy use, providing green spaces and public transport, and encouraging sustainable lifestyles. Various frameworks exist to support more sustainable cities, such as compact cities, circular cities, net zero carbon cities, ecological cities, and biophilic cities.

For individual buildings, sustainability involves consideration of land use, energy sources and efficiency, water use and conservation, indoor as well as outdoor air quality, materials sourcing, waste management, and other impacts on biodiversity. Sustainable (or *'Green'*) building design aims to be more resource efficient and to reduce life cycle environmental impacts. Concepts like biophilic design, ecological design, and *Regenerative Design* go even further, integrating buildings within living systems with the aim of contributing positively to human and ecological health. The mitigation hierarchy of avoid, minimise, remediate, and offset can also be applied to reduce adverse biodiversity impacts at each stage of a building's life cycle.

Most green building initiatives historically focused on energy, water and materials, but attention is increasingly turning to biodiversity or nature. Government regulations and *Voluntary Sustainability Standards* are key tools for educating stakeholders, raising expectations and defining criteria for integrating biodiversity in buildings. Hundreds of voluntary standards, ratings and certifications are already available to assess and demonstrate the sustainability of buildings, building products and materials. Most of these systems aim to reduce adverse impacts relative to conventional practices. However, there are also more ambitious 'nature-positive' approaches available that seek to ensure buildings deliver an overall positive impact on nature.

This chapter reviews sustainability initiatives for the built environment at the urban and landscape scale, including regulatory and voluntary approaches, as well as some policies and tools developed to mitigate adverse impacts and improve outcomes at the level of individual buildings. It examines the application of the mitigation hierarchy, discusses regulatory initiatives in Australia, as well as *Voluntary Sustainability Standards* (VSS) for buildings, construction materials and products. It describes how the mitigation hierarchy can be applied to building projects to reduce biodiversity impacts and, ultimately, to achieve 'nature-positive' outcomes. Finally, it emphasises the importance of adopting integrated approaches, systems thinking, and multi-stakeholder collaboration to realise a more sustainable built environment.

4.1 Sustainable Cities

The concept of sustainable cities implies the creation of liveable built environments that are socially responsible, economically viable, and environmentally sensitive. It is not a new idea. Improving the sustainability of cities can be achieved in many different ways and progress has been observed in different countries and contexts over many years.

Addressing anthropogenic climate change has been a key focus more recently, with commitments by both governments and the private sector to achieve 'net zero' GHG emissions by 2050 (Darby & Gerretsen, 2019; Global Climate Action, n.d.; Intergovernmental Panel on Climate Change [IPCC], 2018).

Rapid decarbonisation and improved climate resilience[18] in the built environment are key steps towards more sustainable cities and essential to deliver the *Paris Climate Accords* and the *UN Sustainable Development Goals*, as agreed by governments in 2015 (UNEP, 2021a).

One opportunity to reduce GHG emissions of cities at an urban scale is through densification or intensification[19]. *Densification* involves increasing the human concentration of urban areas, in terms of floor area ratio, residential density, population density, or density of employment (Designing Buildings, 2022). Urban *intensification*, on the other hand, refers to maximising the use of previously built-up areas, reducing transport needs, and rejuvenating neighbourhoods that are in disrepair or out of favour (Williams, 1999).

There may be synergies (but also tradeoffs) between reducing GHG emissions through urban densification or intensification, and other aspects of sustainability. For example, some propose a '3+30+300 rule' for urban greenery, which states that residents should be able to see at least 3 trees from their home or workplace; neighborhoods should have a minimum 30% tree canopy cover; and no one should be more than 300 meters away from a park (Konijnendijk, 2022). A recent study of eight global cities, including Melbourne, Sydney, New York and Singapore, found that most cities fail to meet these standards, with Singapore performing best and cities like Melbourne showing particularly poor canopy coverage despite having visible trees (Croeser, 2024).

Additional urban sustainability initiatives include reducing air pollution by investing in public transport and cycleways (thus reducing reliance on personal motor vehicles), increasing the efficiency of water and energy use (e.g., through rain water harvesting or LED street lighting), and improving public access to urban green spaces. Green infrastructure, urban farms or commons, and wildlife corridors are other ways to enhance sustainability in the built environment by providing valuable ecosystem services which also enhance community wellbeing.

Encouraging sustainable lifestyles, such as walking and cycling, or promoting healthy diets, can further reduce environmental impacts while also improving social outcomes. Creating more sustainable cities also implies the provision of affordable housing, equitable access to services, and facilitating community engagement in decision-making. Box 4.1 summarises some existing frameworks and approaches to creating more sustainable cities.

In the context of population growth and increasing urbanisation, many cities are expected to grow (UN Habitat, 2022). Cities may grow 'upwards', by increasing the average height of buildings, but all too often cities grow 'outwards', by expanding onto greenfield sites[20]. Typically, low-density infrastructure, and industrial and suburban residential developments displace rural or agricultural land on the fringes of previously developed areas.

[18] Climate resilience refers to the ability of a system (whether it's a community, ecosystem, or infrastructure) to anticipate, prepare for, and adapt to climate-related hazards while maintaining essential functions. This includes both recovering from extreme weather events like floods or hurricanes, and adapting to longer-term changes like rising sea levels or shifting temperature patterns.

[19] Densification and intensification can improve resource and material efficiency, but may adversely impact biodiversity and some ecosystem services (Colding & Barthel, 2013).

[20] 'Greenfield' refers to *'newly developed real estate on what was previously undeveloped open space'* (Loftness, 2020, p. 163). Such sites offer developers an opportunity to build 'from scratch', with complete control over design and layout. However, development on greenfield sites can have serious adverse impacts on the environment, including the loss of natural habitats.

Box 4.1 Creating Sustainable Cities

The New Urban Agenda. Adopted at the *UN Conference on Housing and Sustainable Urban Development* (Habitat III) in October 2016, and later endorsed by the *UN General Assembly*, the *New Urban Agenda* (https://habitat3.org/the-new-urban-agenda/)represents a shared vision for a sustainable urban future. It is aligned with the *2030 Agenda for Sustainable Development*, particularly *Goal 11* on cities and communities (United Nations, 2017). The *New Urban Agenda* offers standards and principles for planning, construction, development, management, and enhancement of urban areas, not only for governments but also for NGOs, the private sector, constituent groups, and urban residents (*The New Urban Agenda*, 2016).

Compact Cities are denser economically (in terms of employment and population) and morphologically (e.g., compact land cover, high floor area ratios, and street connectivity to encourage movement by pedestrians and cyclists). *Compact Cities* promote mixed use, through co-location of residential, commercial, and civic amenities (Newton, 2017).

Circular Cities focus on reducing demand for natural resources by increasing recovery, recycling and reuse of materials, nutrients, stormwater, and other waste. The aim is to reduce a city's overall ecological impacts (ICLEI Circulars, n.d.).

Net Zero Carbon Cities (or '*Net Zero Cities*') aim to decarbonise the urban environment while also delivering other benefits. Key concepts include fostering 'systemic efficiency' across energy use, transport and the built environment. Combining clean electrification and smart digital technology, more efficient buildings and infrastructure, and a *circular economy* approach to water, waste and materials, a *Net Zero City* is also more climate resilient (World Economic Forum, 2021).

Ecological Cities (or '*Eco-Cities*') seek to preserve and restore natural landscape features, while ensuring ecologically sensitive management of water, soil, and vegetation. *Ecological Cities* aim to provide inhabitants with a high quality of life while being resource efficient. This is achieved by relying on local materials and energy supplies; taking advantage of natural processes (e.g., sunlight, wind, and water cycles); integrating ecosystems into the urban landscape; microclimate control through vegetation; creating convivial social environments for communities; and adopting technologies to improve liveability (Urban Ecology Australia, n.d.). Other features of *Ecological Cities* include promoting renewable energy and locally grown food; waste recovery and recycling; reducing long-distance transport; encouraging the use of public transport, bicycles, and walking; avoiding pollution of air, water, and soil; and preserving carbon in vegetation (Shu-Yang et al., 2004).

Biophilic Cities (also Biophilic Urbanism) involves a 'deliberate attempt to translate an understanding of the inherent human affinity to affiliate with natural systems and processes into the design of the built environment' (Wilson 1984, Kellert and Wilson 1993, Kellert et al., 2013). Biophilic Cities conserve biodiversity and enhance connections between people and nature through the use of green spaces, natural lighting, and access to water, as well as by using natural materials and forms in the design of buildings and public spaces (Beatley & Brown, 2019). Biophilic Urbanism similarly seeks to 'improve the connection between urban dwellers and urban nature and nourish the experience of nature on a daily basis as an integral part of urban living' (Cabanek et al., 2020, p2).

Biodiversity Sensitive Urban Design (BSUD) aims to 'create urban areas that deliver on-site benefit to native species and ecosystems through the provision of essential habitat and food resources' (Kirk et al., 2021, p1). BSUD provides a flexible framework to help developers and urban planners consider and improve impacts on biodiversity alongside socio-economic outcomes, early in the development process (Garrard et al., 2018). A related approach is Water Sensitive Urban Design (WSUD), which aims to: 1) minimise the impacts of urban development on the natural water cycle; 2) protect and enhance natural water systems within urban environments; 3) incorporate water management measures into the landscape to maximise the use of alternative water sources (e.g., rainwater, stormwater, and recycled water); and 4) reduce pollution and improve the quality of urban stormwater runoff. Examples of WSUD include permeable pavements, bioretention systems (e.g., rain gardens), swales, wetlands, and rainwater harvesting systems.

Animal-Aided Design (AAD) is a species-centred conservation approach developed in order to integrate wildlife conservation into urban spaces, with animals explicitly included in design and planning processes. AAD aims to establish or maintain populations of 'desired' wildlife species at a project site, or contribute to population growth of wildlife within larger areas (Weisser and Hauck, 2019). The approach involves selecting target species at the beginning of the planning process; identifying the critical needs of target species based on their biology, life cycle and interactions with humans (e.g., food sources, requirements for nesting sites, or protection from predators etc.); and ensuring that these requirements are incorporated into the design of green spaces (Ibid.). Target species may be animals already present at a site, or species that are currently absent but of high conservation concern and well-suited to a site (Ibid.).

Regenerative Cities go beyond the preservation of existing natural environments by encompassing the restoration and regeneration of local ecosystems, while also considering impacts on the wider environment (Fayed et al., 2020). Characteristics of a *Regenerative City* include: maintaining the relationship between a city and natural systems through restorative means; reliance on renewable energy; and encouraging residents to participate in regeneration through their lifestyle choices and adopting new economic opportunities (Girardet, 2014; Thomson & Newman, 2018). *Regenerative Cities* 'give back' to nature not only by being resource-efficient and low carbon, but by actively enhancing the natural environment and improving people's health and wellbeing (Otterpohl et al., 2014).

Sustainable Urban Design aims to create functional and attractive cities, while minimising adverse impacts. Urban design brings together many disciplines, including planning, architecture, engineering, and finance, to create liveable spaces where people interact with each other and with nature. 'Smart urban planning' integrates technology to enhance the quality of life while optimising construction costs (Spiridonov & Shabiev, 2020). The scope of *Sustainable Urban Design* ranges from designing large-scale infrastructure to smaller elements like street furniture.

Managing urban growth is imperative to reduce pressure on ecosystems, biodiversity and other resources. Environmental impacts may be reduced by anticipating or even preventing land use change and construction on greenfield sites, requiring rigorous impact assessment and strictly adhering to the mitigation hierarchy. Where new construction is deemed essential, adverse impacts can often be reduced by locating buildings on previously developed ('brownfield'[21] or 'greyfield'[22]) sites. The following section focuses on policies, tools and initiatives that can help reduce environmental impacts and improve the sustainability of individual buildings.

4.2 Sustainable Buildings

Shifting focus from urban precincts to individual buildings, many of the same principles and approaches apply. Creating a more sustainable building requires consideration of multiple issues: land use change, energy sources and efficiency, water conservation, indoor air quality, material sourcing and waste management. Impacts on nature must be addressed, as well as a building's accessibility, affordability and community impact. Moreover, ensuring the sustainability of individual buildings requires attention

[21] 'Brownfield' refers to 'an unused urban site of derelict or underused land, which requires intervention to bring it back to beneficial use and which may have real or perceived contamination problems' (Loftness, 2020, p. 235).
[22] 'Greyfield' refers to 'ageing, occupied, residential tracts of inner and middle suburbs that are physically, technologically, and environmentally obsolescent, and which represent economically outdated, failing, or under-capitalised real-estate assets' (Newton et al., 2022. para. 2).

to the entire life cycle of the structure, from *Planning, Design* and *Construction* through *Operation and Maintenance*, and eventual *Decommissioning* and *Demolition*.

This section briefly reviews the theory and practice of '*Green Building Design*', with a focus on the integration of biodiversity. It explores how the mitigation hierarchy can be used to reduce the adverse impacts of new buildings, while also highlighting options to improve the sustainability and biodiversity performance of existing buildings.

4.2.1 Designing Greener Buildings

Many factors influence the design of a new building, including the client's brief and budget; the architect or designer's approach to aesthetics and architectural styles; available construction technology, materials and skills; heritage protection requirements and/or symbolic references; local community preferences; mandatory and voluntary building standards, as well as financing. The connections between sustainability and nature in architecture and building design are increasingly important (WGBC, 2013). The concept of *Sustainable* (or *'Green'*) *Design* is not new but has gained traction recently with growing awareness of the adverse effects of the built environment on climate and nature.

From a sustainability perspective, the most important stage of the building life cycle is the initial *Planning and Design* stage. Decisions made at the start of a project (e.g., site planning, definition of the building floor area, height, and enclosure, consideration of structural and building service systems, as well as building materials, finishes and product selections) consequently have a major influence on a building's sustainability performance throughout its life cycle.

A *Green Building* should be 'less resource intensive, have a lower environmental footprint, and reduce the life cycle environmental impacts of the material used' (Loftness, 2020). Following this definition, designers should consider the natural resources and conditions of the project site, as well as the construction materials used (e.g., reducing or eliminating materials that involve energy-intensive or heavily polluting manufacturing processes, or that must be sourced and transported over long distances). Such *Green Building* designs should include dedicated systems to address waste: reducing, recycling, and reusing waste where feasible, as well as efficiently and responsibly managing waste disposal.

While *Green Building* designs may focus on just a few broad environmental issues, such as climate change and energy consumption, increasingly, they address multiple concerns and principles (e.g., the concepts of 'reduce, reuse, recycle', *cradle-to-cradle*,[23] *circular economy*[24]), and emerging concepts that encompass a broad range of ecological and social issues, such as 'climate-responsive' or 'health-conscious' design (Tabb, 2014). In addition, diverse terminology is used today to describe the *Green* design of buildings, with more specific or nuanced approaches described as 'biophilic', 'ecological', 'climate-sensitive', 'bioclimatic', or 'low-carbon'.

Increasingly complex terminology reflects the expanding concerns of built environment stakeholders. Nevertheless, all conceptions of *Green Building Design* share a fundamental purpose to mitigate adverse impacts on the environment (and to improve outcomes for people) by managing land, water, energy,

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[23] The *Cradle-to-Cradle* (C2C) design framework was developed in the 1990s by Prof. Dr. Michael Braungart, William McDonough, and EPEA Hamburg. C2C design principles promote safe and sustainable circulation of materials and nutrients, with all components being non-toxic and recyclable, thereby eliminating traditional waste by only producing useful by-products (EPEA, n.d.)

[24] The *circular economy* model aims to minimise waste by keeping products in use for as long as possible and then recovering and reusing materials at the end of a product's useful life.

waste, and materials more efficiently (Gamage & Hyde, 2012). Several approaches to *Green Building Design* are outlined in Box 4.2, illustrating their varied focus and ambition.

Box 4.2 Energy- and Resource-Efficient Building Design and Construction

Design for Adaptability (DfA) involves planning for the possibility of modifications during a building's lifespan. This may include incorporating flexibility into a building's spatial, structural, and functional capabilities. Enhancing the ability of a building to adapt to changing circumstances and needs can extend its lifespan and reduce waste from premature demolition (Askar et al., 2022). DfA is one of a family of circular design strategies, including *Design for Disassembly* (DfD), as well as *Design for Longevity and Durability*, *Design for Change* (DfC), and *Reversible Building Design* (Ibid.).

Design for Disassembly (or Deconstruction) (DfD) is 'the process of designing products so that they can easily, cost-effectively and rapidly be taken apart at the end of the product's life so that components can be reused and/or recycled' (UN-Habitat, 2017). DfD considers the entire building life cycle, from Design and Construction through Operation to final Decommissioning. DfD often specifies modular components and standardised connections, which make it easier to disassemble and recycle materials, as well as minimising use of hazardous materials that hamper renovation or demolition. DfD principles include: (1) documentation of materials and methods for future disassembly; (2) use of prefabricated or modular structures with joints and connections that are easily accessible and simple to dismantle (e.g., using screws and bolts rather than chemical or welded joints); (3) separating out non-recyclable, non-reusable, and non-disposable items in mechanical, electrical, and plumbing systems; (4) designing structures and forms that use standard components and dimensions; and (5) considering labour practices, productivity, and safety in the design process (Rios et al., 2015; World Business Council for Sustainable Development [WBCSD], n.d.). Despite the extra effort to realise DfD, potential energy and material savings during a building's construction and lifespan can be even greater[25]. In addition, reusing and recycling building components can have additional sustainability benefits, such as minimising consumption of natural resources, reducing loss of species and habitats, minimising waste production and pollution (Crowther, 1999).

Industrial, Flexible, and Demountable (IFD) building systems are methods for achieving high-quality, cost-effective, and more sustainable architecture. *Industrialisation* involves streamlined production processes to deliver high-quality components; *flexibility* enables buildings to accommodate functional changes over time, without requiring destruction of partitions or exterior walls; and *demountability* enables buildings to be reconfigured or relocated without the need for demolition (Richard, 2006). The use of factory-made components allows more precise detailing and adaptability (Ibid.).

Modular Prefabrication (or 'offsite' / 'industrialised' / 'modular construction') involves manufacturing building components in a controlled environment, typically an offsite facility. Prefabricated components are then transported, positioned and assembled on the building site. This approach reduces material waste, energy consumption, and disruption (e.g. noise, vibration, and emissions) at the building site and surrounding community. *Modular Prefabrication* can deliver higher-quality buildings in less time with more predictable costs than conventional 'onsite' construction methods (Jiang et al., 2019). Prefabrication can also reduce a building's carbon footprint, due to less need for material transport and lower energy consumption during its lifetime.

Passive Design is a broad approach to building design that seeks to utilise the inherent environmental attributes of the site and work with natural climate factors to minimise energy use. It seeks to maintain a *'comfortable temperature within the building using the climate and natural elements to get the optimum benefit and to reduce or eliminate the dependence on mechanical systems for heating, cooling and lighting'* (Altan et al., 2016, p.210). *Passive Design* employs various strategies to reduce

[25] DfD for buildings may necessitate additional energy input during the *Construction* stage, while the disassembly process often requires more energy than standard demolition. However, up to one-third of a building's total energy use can be avoided by recovering embodied energy through salvaging and reusing materials and components (Crowther, 1999).

energy consumption for space heating and cooling, including the use of natural daylight and ventilation, thermal mass, and building orientation to take advantage of solar radiation, as well as the use of insulation and shading to reduce heat loss in winter and heat gain in summer.

The Net Zero Carbon Buildings Commitment was launched by the *World Green Building Council* in 2018. It challenges businesses, cities, states, and organisations to achieve net zero carbon in operations for all built assets under their direct control by 2030, and advocates that buildings should have net zero carbon emissions in their operational phase by 2050 (WGBC, n.d.). The Council defines a 'net zero carbon building' as *'a building that is highly energy efficient and fully powered from on-site and/or off-site renewable energy sources'* (WGBC, n.d.).

Implementing *Green Design* for individual buildings involves a variety of initiatives, methods, or technologies. Recent efforts focus on energy efficiency and reducing GHG emissions in order to meet 'net zero' climate targets. Climate-friendly building design may involve using low-carbon materials (e.g., Cross-Laminated Timber (CLT)), rammed earth walls, specifying double glazed windows for insulation, or installing renewable energy sources onsite (e.g., solar panels). The resulting 'high-performance buildings'[26] can deliver better energy-efficiency and/or emit less GHG than buildings which only adhere to minimum building codes and regulations.

While in situ construction methodologies remain the traditional practice, increasingly, consideration of the benefits of offsite prefabrication of building components which allow for faster construction (i.e. shorter programs and duration of construction works) as well as less physical disturbance at the construction site. Use of prefabricated modules can reduce the volume of deliveries to a project site during the *Construction* stage by up to 60%, as well as reducing the number of workers and need for onsite contractors or 'wet trades' (Hashemi et al., 2016).

Modular Prefabrication can also help deliver higher quality and lower cost buildings, due to better control over manufacturing and construction processes, including reducing or recycling waste. This is achieved through close coordination of labour, materials, machinery, and sub-trades under controlled factory conditions, allowing for greater quality control and for remedial work to be carried out before products leave the factory floor (Hashemi et al., 2016). *Modular Prefabrication* also offers a safe and healthy environment for workers, on top of material and financial savings (Ibid.).

4.2.2 Integrating Biodiversity in Building Design

While the primary objectives of *Green Building Design* may not necessarily focus on nature or biodiversity, nevertheless, many existing *Green Building* frameworks can help to reduce direct (onsite) impacts on biodiversity, particularly during construction. Existing *Green Building Design* approaches can also help to reduce indirect (offsite) impacts by minimising raw material requirements, both onsite and in manufacturing, as well as potential adverse impacts on biodiversity from material wastage in the *Construction*, *Occupancy*, and *End-of-Life* stages.

Many approaches to *Green Building Design* have been developed to address the challenge and opportunity to improve biodiversity conservation. Ecologically-oriented approaches may propose using living or green walls and façades, roof gardens, rainwater harvesting, storage, and recycling systems, or

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[26] The US Energy Policy Act of 2005 (Public Law 109-058) defines high-performance buildings as: 'buildings that integrate and optimize all major high-performance building attributes, including energy efficiency, durability, life-cycle performance, and occupant productivity' (42 USC 16194: Building Standards, n.d.).

bio-based materials[27]. More ambitiously, biodiversity-friendly building design may involve changes in the behaviour of building occupants, not just to reduce environmental impacts during the *Occupancy* stage, but to improve the health of people and nature, and strengthen connections between them. Box 4.3 highlights several approaches to biodiversity-friendly building design.

Box 4.3 Designing Biodiversity-Sensitive Buildings

Architects Declare is a statement of intent that acknowledges not only the impacts of buildings on the global climate but also seeks to reduce adverse impacts on biodiversity (builtenvironmentdeclares.com, n.d.; Walsh, 2019). Members pledge to design buildings, cities, and infrastructure with less negative and more positive impacts on the natural environment.

Biophilic Design seeks to strengthen connections between humans and nature, in order to ensure an harmonious relationship between the built and natural environments (Newman, 2014). As with *Biophilic Cities* (Chapter 2, Box 4.2), buildings designed according to biophilic principles typically incorporate features such as plants, water and natural light. Examples include green roofs, living walls, and natural ventilation systems.

Ecological Design (or eco-design) aims to *'minimise environmentally destructive impacts by integrating … with living processes'* (van der Ryn & Cowan, 2007, p. 33). *Ecological Design* encompasses architecture, as well as fields such as planning, engineering, industry and agriculture, through the consideration of ecological concerns at relevant spatial and temporal scales. Arguably, any design that minimises adverse impacts on the environment by integrating and emulating natural ecosystems can be described as a form of 'eco-design' (Shu-Yang et al. 2004). In the case of architecture, *Ecological Design* may be accomplished by minimising land use change, conserving heat during winter and coolness during hot seasons, reducing pollution, and naturalising the landscape. Examples include constructing multi-level buildings to reduce land use; specifying renewable construction materials; using shading and reflective surfaces to reduce energy use for cooling; or by selecting building materials and furniture manufactured from renewable resources and avoiding emission of harmful pollutants (Shu-Yang et al., 2004). Native plants may be used in landscaping to create conditions suitable for local wildlife (Ibid.).

Regenerative Design in architecture has two aims: 1) it emphasises preserving and making buildings more efficient, minimising environmental impacts through material choices, energy efficiency, and intelligent design; and 2) it considers nature as a stakeholder in the process, including how natural and living systems can inform the design of a structure. *Regenerative Design* thus aims not just to minimise adverse impacts but to rejuvenate and improve both natural and human systems (Cole, 2011; du Plessis, 2011; Hes & Bush, 2020; Littman, 2009; Mang & Reed, 2012b). *Regenerative Design* is holistic, integrating social and community aspects with concern for physical and psychological wellbeing, in harmony with ecological health (du Plessis, 2012; Pedersen Zari, 2017). A *Regenerative* building project engages the community from the outset, to create a socially inclusive built environment that contributes to collective wellbeing throughout the building's lifespan. A sense of place is a key aspect of *Regenerative Design*, as built structures express cultural diversity and identity, and seek to nurture emotional and spiritual connections (Mang & Reed, 2012a; 2012b). At the same time, the focus is not simply on creating a socially-inclusive building, but also ensuring the building contributes to the wider community (Cole, 2012; du Plessis, 2012).

[27] Bio-based materials are substances derived from living matter (biomass) that occur naturally or are manufactured. Traditional construction materials such as paper, wood, wool, and leather are all bio-based, although typically the term refers to modern engineered materials (Curran, 2010).

4.2.3 Applying the Mitigation Hierarchy to Buildings and Biodiversity

Whatever design approach is used, whether *Green* or conventional, building owners and designers are often required by law, or by financiers, to balance development aspirations with avoiding adverse impacts on nature. Box 2.5 outlines the role of impact assessment and the mitigation hierarchy in regional development planning, including the priority to avoid harm before compensating (offsetting) environmental damage. The same mitigation hierarchy typically applies at the level of individual building projects.

All too often, impacts on nature are overlooked or addressed in a cursory manner by building designers, developers and regulators. Where nature is considered at all, there is a tendency to rely heavily on offsetting to compensate for impacts that might not have been permitted otherwise (Phalan et al., 2018; Catalano et al., 2021).

The mitigation hierarchy requires that impact avoidance is prioritised. Only when impacts cannot be avoided or minimised does it make sense to consider alternatives, such as on-site biodiversity compensation (ideally integrated into the project design) or, if necessary, support for off-site conservation and restoration (i.e., offsets).

Before determining the feasibility of and need for offsetting, potential impacts on nature at each stage of a building's life cycle should be assessed rigorously. Where there is an existing building on the site, options for renovation and reuse should be explored before the demolition and construction of a new building (see Box 4.5). In such cases, it may also be possible to remediate the landscape and restore degraded ecosystems, or to reintroduce native species that previously occurred on the site.

Table 4.1 illustrates how potential impacts on biodiversity can be factored into project planning and design, focusing on the *Construction* stage of the building life cycle. The table shows several examples of potential adverse environmental impacts that can arise during the period of construction, and how they relate to the drivers of biodiversity loss, namely: ecosystem disturbance and conversion; climate change; pollution; over-exploitation; and invasive species. The table also provides examples of the actions that could be taken to reduce adverse impacts on biodiversity, following the mitigation hierarchy (avoid, minimise, remediate, offset).

Similar tables of impacts and responses can be developed for other stages of the building life cycle (e.g. *Occupation, End-of-Life*). In practice, all building projects are different and biodiversity impacts and responses will vary accordingly. What is constant across all projects are the *drivers* of biodiversity loss, the steps in the mitigation hierarchy, and the stages of the building life cycle.

Table 4.1 Applying the Biodiversity Mitigation Hierarchy in Building Construction

Driver of Biodiversity Loss	Mitigation Hierarchy step	Biodiversity Impact example	Potential Responses / Actions
1. Habitat disturbance & conversion	avoid	potable water use	Use non-potable water where feasible. Reclaimed water can be used for cooling system make-up water, process water (e.g., concrete batching plant), fire protection (in sprinkler systems), as wash-down water, or for dust suppression at construction sites.
	minimise	deforestation	Wood products to be from certified sustainably managed forests, salvaged from existing buildings, or harvested on site (e.g., from areas cleared for construction or to restore / enhance site ecology).
	minimise	use of virgin materials	Prioritise durability of products and materials; use salvaged or recycled materials (e.g. recycled steel, salvaged timber and bricks, concrete made from recycled aggregate); reduce material offcuts on site.
	minimise	wasted materials due to damage	Store materials securely to protect from theft, vandalism and weather damage; distribute commonly used materials (e.g. bricks) around the site to reduce damage during transport; schedule materials delivery as close to the day of installation as possible to minimise the risk of damage.
	minimise	wasted materials due to surplus	Calculate required quantities in advance and create cutting lists for carpenters; avoid over-ordering; use suppliers who will take back surplus material. Where there are excess materials, retain for other projects (e.g. pour surplus paint back into the tin, save excess insulation or plasterboard).
	minimise	noise / pollution	Use prefabricated components for construction, wherever feasible, to minimise severity and duration of impacts at the construction site (e.g. noise, leaching, emissions).
	minimise	freshwater use	Install efficient irrigation; use a broom rather than a hose or water jets to clean paths and gutters; retain vegetation to reduce evaporation; use buckets of water to clean tools instead of running water.
	minimise	water pollution	Minimise disturbance of waterways and adjacent vegetation; control erosion and sediment in runoff; cover or filter stormwater inlets and drains; store building materials away from drains or roads.
	minimise	habitat loss	Plan construction to retain existing vegetation and avoid disturbing aquatic ecosystems.
	compensate	habitat loss	Restore and rehabilitate habitat lost or damaged during construction, either on-site or at comparable off-site locations (note this may be an obligation borne by the developer, rather than the builder).
2. Climate Change	minimise	opaque supply chains	Require contractors to disclose supply chain data, including embodied carbon in materials, to enable selection of low-carbon options. This may require enhanced Environmental Product Declarations by manufacturers.
	minimise	embodied carbon	Source materials locally if feasible, to reduce transport emissions. Seek out and source building materials with low embodied carbon.

	minimise	fossil energy use	Specify plant and equipment that use renewable energy or carbon-neutral, biodiversity-friendly biofuels.
	compensate	GHG emissions	Purchase high-integrity, nature-based, certified carbon offsets for unavoidable, residual GHG emissions.
3. Pollution	avoid	toxic pollutants	Avoid the use of toxic building materials, such as asbestos or PVC, that pollute soils and/or groundwater.
	minimise	construction waste / pollution	Use prefabricated components for construction, wherever feasible, to minimise waste and pollution impacts at the construction site (e.g. noise, materials surplus waste, leaching, emissions).
	minimise	construction & demolition (C&D) waste	Divert C&D waste from landfill by salvaging and/or recycling materials (e.g., bricks, steel, concrete rubble). Provide separate bins for landfill and recyclables for waste generated on site.
	minimise	waste going to landfill	Engage waste disposal service providers to sort and treat C&D waste in order to maximise recycling, while also ensuring that non-recyclable waste is disposed of safely and responsibly.
4. Overexploitation / Unsustainable Use	avoid	illegal extraction	Avoid using timber or other construction materials coming from unknown, threatened or vulnerable ecosystems. Wood products in particular should be certified under a credible sustainability standard.
5. Invasive Species	avoid	use of untreated construction materials	Avoid untreated, imported construction materials, where feasible. Source materials that are available locally, within 1,000km (or closer) of the construction site, if possible.

4.2.4 Making Existing Buildings More Sustainable

While the construction industry is adopting low- or zero-carbon strategies and other environmental measures for new building projects, the existing stock of buildings continue to consume enormous quantities of energy and water, generating both GHG emissions and solid waste (see Chapter 3). Studies suggest that 80% of the buildings that will exist in 2050 have already been constructed, highlighting the importance of making existing buildings more sustainable (Dadzie et al., 2018).

Reusing existing buildings can minimise environmental impacts by increasing energy efficiency, reducing GHG emissions, preserving natural resources, reducing waste, and to sequester carbon in the retained building structure. This may involve converting existing buildings and structures for new uses, and/or recycling materials or other structural components. Examples of design approaches that maintain and/or reuse existing buildings are provided in Box 4.4.

In some cases, retrofitting and reuse of existing buildings can offer greater potential to reduce GHG emissions, or to reduce construction and demolition (C&D) waste, than constructing new buildings (Herrmann et al., 2022). Such approaches may also help slow biodiversity decline by utilising existing buildings and materials, thereby avoiding additional habitat loss, pollution and waste from resource extraction.

Box 4.4 Green Design for Existing Buildings

Conservation Design involves protecting and preserving historical and heritage buildings from damage and preserving their original features. Heritage conservation can occur on both an urban and architectural scale, and includes preserving historical cities, heritage areas, housing centres, and individual buildings of significant historical, cultural, or architectural importance (Farhan et al., 2021). This also includes replacing defective parts with exact copies, introducing new configurations that align with the original design but are updated for contemporary use, and renewing areas affected by deterioration or change in use (Ibid.).

Historical buildings may be more sustainable to the extent they are adapted to the climate of the region (Shetabi, 2015). In Australia, the traditional *Queenslander*[28] home is an example of a dwelling design that allows air to circulate beneath it to maintain cooler temperatures (Wilkinson & Remøy, 2017). Other regions utilised high thermal mass to maintain comfortable temperatures during summer and winter seasons. Heritage buildings also typically contain a substantial amount of embodied energy as pre-industrial buildings were usually constructed with natural, chemical-free materials. They are often constructed using locally sourced materials that are well-suited to the local climate and require minimal transportation when repairs are needed. They are also often designed in a way that makes it easy to repair or replace individual components (Shetabi, 2015). While such buildings may have higher energy and water consumption when in use, compared with modern construction, there may be opportunities to reduce energy and water usage through retrofitting (Wilkinson & Remøy, 2017).

Adaptive Reuse is the process of modifying an old building or site for present use. This practice recycles existing material and land, aiding in historical and environmental conservation and reducing urban sprawl (Kallipoliti, 2018). By retaining all or most of the building (structure, shell and interior components), *Adaptive Reuse* can extend a building's lifespan. The process involves adapting an existing building or structure to comply with current regulations and laws, or altering it so it can serve different purposes, while retaining historic features. Reusing buildings – even with retrofitting – is often more energy efficient than demolishing an old structure and building a new one, as the energy and materials used in the original building are not wasted (Herrmann et al., 2022; Shetabi, 2015).

Design for building conservation and *Adaptive Reuse* are also important design strategies for preserving historical and cultural resources. *Adaptive Reuse*, for example, can preserve culturally significant and important physical connections with the past, while enhancing diversity through a combination of old and new building elements. Such projects offer opportunities to value historical context and to address contemporary social concerns, such as fairness and equity, while enhancing community pride, memory, and participation (Office for Design and Architecture SA [ODASA], 2014).

4.3 Regulating for Green Buildings

With so many tools available, there would seem to be limitless options to design greener buildings. However, in the absence of strong motivations, incentives, regulations, legal and institutional frameworks, as well as limited industry education and training, the development of green buildings may be slow (Liu et al., 2022). Well-crafted environmental law, policy, building codes and regulations can define guidelines and parameters for development, prioritising sustainability and the protection of nature, while minimising adverse impacts (Gamage & Hyde, 2012).

[28] A '*Queenslander*' refers to a detached timber house with a corrugated iron roof situated on its own plot of land. Such houses are typically elevated, single-level homes with a distinctive veranda that stretches around the property to varying degrees but never fully encircles it (Osborne, 2014).

The overarching government policy goal for sustainability in Australia is known as *Ecologically Sustainable Development* (ESD). The term was introduced into legislation through the *National Strategy for Ecologically Sustainable Development* (1992), where ESD was defined as: *'Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'* (Australian Government Department of Environment and Energy, 1992, p.1)[29].

The term 'ESD' is cited in over 60 pieces of Australian legislation, notably at a federal level in the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*). The *EPBC Act* sets out key principles for integrating ESD in decision-making, including that *'the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision -making'* (Federal Register of Legislation, Environment Protection and Biodiversity Conservation Act 1999, Section 3A)[30]. The *EPBC Act* is the main legal instrument at a federal level for regulating the environmental impacts of development.

Similar legislation has emerged at state level. For example, in New South Wales (NSW), the *Environmental Planning and Assessment (EPA) Act 1979*, and the P*rotection of the Environment Operations (POEO) Act 1997* aim to ensure that development activities in NSW are conducted in an environmentally sustainable manner[31]. In addition, many other policies have been developed by Federal, State and Territory, and also local governments across Australia, in order to promote sustainability in the built environment. They include frameworks, regulations, codes, standards and rating tools that guide development planning and approvals. Many of these policies include explicit provision for environmental protection, such as energy efficiency standards, renewable energy requirements or water conservation guidelines. Box 4.5 provides selected examples of Australian government initiatives for sustainability in the built environment.

Notwithstanding a suite of laws and frameworks intended to protect the environment, and the development of sustainability initiatives specifically targeting the construction industry, biodiversity loss in Australia has continued at a rapid pace. Recent reports, notably the independent review of the *EPBC Act* (the *Samuel Review*) (2020), and the *2021 State of Environment Report*, both concluded that the *EPBC Act* was not fit for purpose. The *Samuel Review,* in particular, stated that governments are not effectively protecting significant environmental matters and that Australia lacks an adequate policy framework to ensure good environmental management (Samuel, 2020) (https://soe.dcceew.gov.au/overview/key-findings).

[29] Confusingly, the same acronym 'ESD' is used by architects to refer to *Environmentally Sustainable Design*, which is the process of designing environmentally friendly and energy efficient buildings.

[30] Other ESD principles cited in the *EPBC Act* are as follows:

- 'decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations
- if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
- the principle of intergenerational equity—that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations
- improved valuation, pricing and incentive mechanisms should be promoted'

[31] The *NSW EPA Act* sets out legal requirements and procedures for the management of land use and development, while the *POEO Act* regulates environmental pollution and waste management.

Box 4.5 Regulatory Initiatives for more Sustainable Buildings in Australia

National Construction Code (NCC). Maintained and published by the Australian Building Codes Board (ABCB), the NCC details the minimum mandatory requirements for safety, health, amenity and sustainability in the design and construction of new buildings in Australia. NCC requirements for energy efficiency in residences include the level of thermal comfort and a 'whole-of-house' energy use budget, as well as measures to reduce the cost of installing onsite renewables and electric vehicle charging in the future (*National Construction Code,* n.d.). (https://ncc.abcb.gov.au/)

Nationwide House Energy Rating Scheme (NatHERS) is administered by state and territory governments to regulate the energy efficiency of residential buildings (houses and units). NatHERS software rates the energy efficiency of a home, based on its design, to ensure compliance with mandated performance requirements (*About NatHERS*, n.d.). Most Australian homes aim for a minimum of 7 stars, as required under the *National Construction Code* (NCC). (https://www.nathers.gov.au/)

National Australian Built Environment Rating System (NABERS) is a national building rating scheme that evaluates the operational performance of Australian commercial offices, shopping centres, hotels and residential buildings. It is managed by the *New South Wales Office of Environment* on behalf of Commonwealth, state and territory governments. NABERS awards up to 6 stars based on one or more of the following criteria: energy efficiency, water efficiency, waste efficiency, or indoor environmental quality. NABERS assessors use operational information (e.g., utility bills) to determine a building's sustainability performance. Unlike NatHERS and other predictive tools, NABERS can only be used only for existing buildings and is intended to measure actual performance (*NABERS*, n.d.). (https://www.nabers.gov.au/)

Commercial Building Disclosure (CBD) Program was mandated federally in Australia by the *Building Energy Efficiency Disclosure Act 2010*. Before an office building is listed for sale, lease or sublease, the CBD requires most sellers or lessors of buildings with more than 1,000m^2 floor space to obtain a *Building Energy Efficiency Certificate* (BEEC). The certificate shows the building's NABERS energy rating and a tenancy lighting assessment (Parliament of Australia website, n.d.). The BEEC must be accessible on the public *Building Energy Efficiency Register*, provided to potential buyers or lessees, and must also be included in any advertising material for the sale or lease of the building (*Commercial Building Disclosure Program,* n.d.). (https://www.cbd.gov.au/)

Building Sustainability Index (BASIX) sets minimum standards for all new dwellings in New South Wales (NSW), as well as alterations and additions to existing homes. It measures the energy and water efficiency of households in NSW based on a building's envelope and the energy used by fixed appliances (e.g., heating and cooling, lighting, hot water). A BASIX assessment involves using an open access web-based tool and entering data about the new dwelling or renovation (e.g., size, building materials, location). The assessment results are then scored against energy and water targets, and if the targets are achieved, a BASIX certificate is issued. Local councils in NSW require a BASIX certificate in order to approve plans for construction (*Sustainability Standards for Residential Development (BASIX)*, n.d.). (https://www.planning.nsw.gov.au/policy-and-legislation/buildings/sustainable-buildings-sepp/sustainability-standards-residential-development-basix)

4.4 Voluntary Initiatives for Green Buildings

In addition to stronger government regulations and greater public spending on the environment, and on biodiversity conservation specifically, there is also a need for voluntary initiatives that can fully integrate biodiversity and help deliver nature-positive outcomes.

Governments cannot achieve sustainability without the cooperation of businesses and other non-governmental stakeholders. Even if governments impose minimum standards as legal requirements, they may also rely on voluntary initiatives or incentives to promote 'beyond compliance' sustainability performance. Similarly, where government policy and enforcement are deemed inadequate, voluntary sustainability initiatives developed and led by non-governmental actors may help to fill the gap.

Fortunately, many businesses are willing to go beyond compliance with minimum legal standards. This is true in the construction industry, as in other sectors. Thus, we see leading companies implementing sustainable design and construction practices that go beyond the minimum requirements (e.g., energy efficiency measures, water conservation, etc.). This kind of initiative not only helps reduce adverse environmental impacts but may also lower business operating costs while improving companies' market competitiveness.

A range of voluntary tools and initiatives have been developed to assist the construction industry in the transition to sustainable practices. They include *Voluntary Sustainability Standards* (VSS), rating systems and certification programs (e.g., for buildings, products, materials), as well as frameworks and benchmarks for investors and managers (e.g. *Sustainability-Linked Loans*, *Green Bonds*). These voluntary mechanisms are widely used to assess the environmental, economic and social characteristics of buildings, neighbourhoods, cities, and infrastructure. This section focuses on standards and certification systems for buildings, as well as for building materials and products.

4.4.1 Voluntary Sustainability Standards (VSS) for Green Buildings

Several *Green Building VSS* have been developed by governments, professional associations, and non-profit organisations. They include prescriptive certification schemes, design review processes, life cycle assessment methods, and educational tools. Some of these VSS offer certification as a means to demonstrate to financiers, owners, occupants, regulators, and other stakeholders that a building meets specified 'performance criteria'. Box 4.6 describes some *Green Building VSS* and rating schemes used in Australia and abroad.

VSS schemes devised for green buildings ('*Green Building VSS*') typically function as guidelines for design and construction and can be effective tools to reduce long-term operating costs (Ade & Rehm, 2020; Lee, 2013; Reeder, 2011; Darko et al., 2017). VSS can support systematic assessments of design and construction across a range of sustainability parameters. Hence, meeting VSS requirements (with or without certification) can help developers and designers establish priorities for their buildings, while also providing financiers and owners with a consistent metric to evaluate their investments.

Box 4.6 Voluntary Standards for Green Buildings

Building Research Establishment Environmental Assessment Method (BREEAM) is one of the first green building rating systems, launched in the UK in 1990 (Ade & Rehm, 2020; Doan et al., 2017). BREEAM is a comprehensive rating system for new and existing buildings, refurbishments, and large developments where projects are evaluated on a scale ranging from 'Pass' to 'Outstanding'. In addition to energy use and GHG emissions, BREEAM assessments cover a range of other sustainability issues, including water consumption, health and wellbeing, pollution, transportation, materials, waste, ecology, and management. Over 500,000 buildings have received BREEAM certification, mainly in the UK but also in other countries. (https://bregroup.com/products/breeam/).

Leadership in Energy and Environmental Design (LEED) was launched by the *United States Green Building Council* (USGBC) in 1998 to evaluate the environmental performance of buildings (and later, communities), and to promote more sustainable design and construction practices. Projects applying for LEED certification earn points in several categories, such as energy efficiency, water conservation, indoor air quality, and materials selection. More points translate to higher levels of certification (i.e. *Certified*, *Silver*, *Gold*, or *Platinum*). LEED offers different standards depending on the type of project and location (i.e. *Building Design and Construction*; *Operations and Maintenance*; *Interior Design and Construction*; *Neighborhood Development*; *Residential Design and Construction*; and *Cities and Communities*). As of 2023, over 105,000 buildings in nearly 190 countries were LEED certified (*U.S. Green Building Council (USGBC),* n.d.). (https://www.usgbc.org/about/mission-vision)

Green Star was established in 2003 by the *Green Building Council of Australia* (GBCA). *Green Star* is a sustainability rating and certification system similar to LEED, with project impacts categorised into 'credits'. Each credit earns a certain number of points and corresponds to initiatives that can improve a project's sustainability performance. Every credit specifies a particular result that a project must achieve. If it does so successfully, the project receives the allotted points. After evaluating all credits, the total number of points earned is compared to the available points in the *Green Star* rating system, resulting in an overall rating for the project. Different *Green Star* rating tools offer standards and certifications for various built assets, including new and existing buildings, residential homes, interior fitout, and whole communities. As of 30 June 2022, the GBCA had issued over 3,700 *Green Star* certifications, mainly for office, retail and industrial uses (GBCA, 2022a). More recently, GBCA has published discussion papers and undertaken stakeholder consultation on how to regenerate nature and biodiversity in the built environment. (https://new.gbca.org.au/green-star/green-star-strategy/building-nature/)

The Living Building Challenge was launched by the *International Living Future Institute* (ILFI) in 2006 as a performance standard and certification system for buildings. The *Living Building Challenge* (LBC) is described as a '*regenerative design framework to create spaces that, like a flower, give more than they take'* (ILFI, n.d-a). The LBC assessment criteria ('Imperatives') are grouped in categories ('Petals') that include *Place*, *Water*, *Energy*, *Health and Happiness*, *Materials*, *Equity*, and *Beauty*. The LBC aims to enhance provision of ecosystem services for the wellbeing of both people and nature. For example, the LBC *Ecology of Place* imperative requires that projects *demonstrate a positive contribution to the site ecology through the restoration or enhancement of ecological performance,' measured* against the site's baseline (i.e., pre-project) ecological condition (ILFI, 2022, p22). The LBC also requires the preservation of land in high conservation areas to offset areas used by the buildings it certifies (ILFI, 2022). (https://living-future.org/lbc/)

Passive House (or 'PassivHaus') is a performance standard focused on the energy efficiency, health and interior thermal comfort of buildings that was developed in Germany. By employing *Passive House* design principles and practices, including insulation, airtightness, high performance windows and doors, mechanical ventilation with heat recovery, and elimination of thermal bridges, a building can be comfortable year-round with only minimal energy needed for heating and cooling. The *Passive House Institute* administers a certification scheme to enable buildings to be deemed *Certified Passive House* if they meet the specified performance criteria, notably airtightness (*Passive House Institute / About Us,* n.d.)
(https://passivehouse.com/01_passivehouseinstitute/01_passivehouseinstitute.htm and https://passivehouseaustralia.org/APHA/APHA/What_is_Passive_House/FAQs.aspx)

WELL Building Standard is a performance standard that focuses on human health and wellness. WELL assesses air quality, natural light, and water supply in buildings, while also promoting healthy eating choices, active lifestyles, and good mental health for occupants. Projects earn points toward certification based on policy, design, and operational strategies. WELL certification has four levels: *Bronze*, *Silver*, *Gold* or *Platinum* (*International WELL Building Institute, n.d.*). (https://www.wellcertified.com/en/explore-standard)

GRESB, formerly the *Global Real Estate Sustainability Benchmark*, is an internationally recognised benchmark for the *Environmental, Social and Governance* (ESG) performance of real estate assets. GRESB provides financial markets with standardised and validated ESG data to inform decision-making by institutional and financial investors (GRESB, 2021). GRESB covers a range of sustainability issues, including energy and water efficiency, waste management, social impact, governance, and resilience. The performance and development components of a GRESB assessment consider GHG emissions, water and waste reduction, and materials (including product selection and embodied carbon). Assessment results are used to develop sustainability benchmarks for different categories of real estate portfolios, such as office buildings, retail centres, and residential buildings. (https://www.gresb.com/nl-en/)

Certification using *Green Building VSS* is increasingly sought by developers to demonstrate a commitment to sustainability and be recognised for good practice. While an owner or developer can claim that their building is 'sustainable' without relying on VSS, such claims may be discounted if they are not based on widely accepted standards (Ade & Rhem, 2020). Credible certifications usually involve verification by a third-party auditor, who is independently accredited to assess buildings against a particular VSS. Note that most *Green Building VSS* also require recertification on a regular basis, to ensure that a property continues to meet the standard over time.

VSS can be valuable marketing tools: helping to raise awareness of the possibilities of green buildings; making it easier to compare the performance of different buildings; and strengthening the business case for investment (WGBC, 2013; GBCA, 2019). For property developers and building owners, the potential benefits of using VSS may include increased market value of the property or higher rental rates,[32] greater employee satisfaction and retention, brand and reputation, and lower operating costs, due to greater energy and water efficiency (Vierra, 2022; Eichholtz et al., 2010; Steering Committee of the State-of-Knowledge Assessment of Standards and Certification, 2012).

VSS-certified buildings may also be more comfortable for occupants, offering increased natural light, fresh air or greenery, which makes them more attractive to buyers and tenants. This in turn helps to enhance *Green Building* marketability, reduce turnover, and ultimately leads to higher sale or leasing prices (Ade & Rehm, 2020). Accordingly, VSS have become a key enabler of green buildings both in Australia and abroad (Illankoon et al., 2019; Agyekum et al., 2019).

Despite their many benefits, the uptake of *Green Building VSS* and related practices has been slow (van der Heijden, 2014; Ade & Rehm, 2020), including in Australia (Illankoon et al., 2019; Martek et al., 2019). Barriers to the uptake of VSS include: stakeholders' lack of awareness or resistance to change; the perceived higher costs of green building technologies; arduous VSS assessment methodologies; complex performance modelling processes; and time-consuming requirements for project review and certification, which may involve additional consultant fees (Chan et al., 2017; Ade & Rehm, 2020; Yudelson, 2016).

[32] Based on data collected from LEED-certified office buildings in the US.

The potential for buildings to contribute to biodiversity and supply ecosystem services in built up areas (e.g., by providing wildlife habitat through green roofs and biodiverse green infrastructure), is increasingly recognised by *Green Building VSS*. Considering biodiversity in building design and construction can provide additional benefits to occupants, in the form of improved air quality, natural cooling, and improved resilience to climate change.

Incorporating biodiversity considerations into *Green Building VSS* presents both challenges and opportunities. While energy efficiency and GHG emissions are well-integrated into many VSS, biodiversity is a newer and more complex aspect to incorporate. Specific challenges include the difficulty of measuring biodiversity impacts and benefits on and off-site, the lack of standardised metrics for assessing biodiversity in buildings and/or the urban context, and limited awareness among stakeholders about the importance of biodiversity in urban settings.

4.4.2 Green Building Product Standards and Eco-labels

Alongside *Green Building VSS* that rate or certify the sustainability of a building as a whole, or even an urban precinct, additional VSS are available for building products and/or materials. Many of the latter were developed in response to concerns about product toxicity, human health impacts, and indoor environmental quality (IEQ) (Vierra, 2022).

Product standards, ratings, and certification schemes are important tools for building designers and the construction industry to deliver better buildings, and to demonstrate their sustainability credentials. Moreover, many *Green Building VSS* encourage or even require building products and materials to meet specified third-party certifications, as part of the assessment of the sustainability of a building project. Using certified *Green* products is thus a key step towards the certification of a building as ‘green’. As with *Green Building VSS*, depending on which *Green Products* are used, it may be possible to advance beyond negative environmental impact mitigation to contribute positively to nature and help regenerate it.

4.5 From Mitigating Impacts to Nature Positive

Government regulations as well as voluntary initiatives can help the construction industry make progress towards sustainability. They can reduce energy and water consumption, lower GHG emissions, promote increased use of recyclable and renewable materials, and reduce waste in all stages of the building life cycle. Benefits for the environment can be considerable, compared to conventional practices, not to mention the potential for lower occupancy costs, enhanced corporate reputations, and to improve the wellbeing of residents.

At the same time, the limits of regulation and voluntary initiatives must also be recognised. In general, green design theories and practices aim to mitigate unsustainable consumption, destruction, and depletion of natural resources (du Plessis & Brandon, 2015). Similarly, most contemporary *Green Building* policies, standards and designs aim to reduce adverse impacts (i.e. to be ‘less bad’) relative to conventional/historical buildings. Such initiatives are admirable but arguably cannot lead to truly sustainable outcomes, as adverse impacts still occur. As development proceeds, the environment will continue to decline, even if at a lower rate or to a lesser extent. Moreover, depending on the stringency of regulations and VSS, and the integrity of enforcement and verification processes, the reduction in adverse impacts may be less than expected or what is necessary. More ambitious approaches are required to ensure that buildings deliver a net positive impact on nature and people. This will involve going beyond minimising and offsetting current damages to ensure that nature is better off as the result of a project. It may also include addressing historical losses and injustices associated with existing buildings.

In response to these concerns, assessment tools like LENSES (*Living Environments in Natural, Social, and Economic Systems*) and the *STARfish* app have been developed to help organisations differentiate between relative improvements and whole system gains. The LENSES framework, for example, guides communities through the creation of places where natural, social, and economic systems can flourish together (Plaut et al., 2012). The *STARfish* app enables real-time assessment during the design process, evaluating projects against fixed sustainability benchmarks based on pre-urban ecological conditions (Birkeland, 2022). Both tools aim to encourage fundamental rethinking of design approaches rather than just incremental improvements to standard practices.

The phrase 'nature positive' has emerged as a shorthand term to describe this ambition more generally, attracting widespread interest across countries and industries (see Chapter 2). The implications of nature positive in the design of *Green Buildings* are not well developed, although some organisations are exploring how to assess and incentivise nature-positive outcomes in the built environment (Global GreenTag, n.d.; GBCA, 2024a; WBCSD, 2023b). The concept of *Nature Positive Buildings* is discussed further in Chapter 6.

4.6 The Need for More Integrated Approaches

The process of constructing a building is a complex undertaking, requiring input from multiple authorities, professionals, and trades. Even relatively simple renovations can require extensive planning and approvals, adherence to mandatory building standards, and assurance that products and materials meet specified sustainability criteria and/or standards. The challenge is to manage this complexity in an agile and efficient manner.

When the system works as intended, the result can be a beautiful, truly liveable building that minimises adverse impacts on the environment and biodiversity. In the best cases, a *Green Building* will enhance the wellbeing of its occupants while also generating positive impacts for the wider community, as well as helping to mitigate and adapt to climate change, and regenerate nature.

A *systems thinking*[33] approach can help to manage the complexity of the design and construction of *Green Buildings*. For example, GRESB *Real Estate Assessments* (Box 4.6) consistently find that buildings perform better in relation to several sustainability criteria (i.e. energy consumption, GHG emissions, water consumption and waste) when voluntary initiatives are integrated with mandatory compliance (GRESB, 2021). Similarly, by combining building energy efficiency certification under NABERS with mandatory disclosure under the *CBD Program* (Box 4.5), Australian governments have been able to drive improvements in the energy efficiency of commercial buildings (NABERS, 2022).

GRESB performance assessments, however, do not consider biodiversity. The CBD and NABERS schemes likewise focus predominantly on energy efficiency. Nevertheless, these schemes illustrate how both mandatory and voluntary sustainability initiatives can be combined to drive industry improvement.

To address the biodiversity challenge, the construction industry will need to adopt more holistic approaches. These may combine biodiversity-sensitive urban planning with greening of urban spaces, integrating food production into settlements, combining water efficiency with waste reduction and recycling, conserving native wildlife habitat while also controlling the spread of invasive species, and restoring ecosystems both within and beyond urban boundaries, among other initiatives.

[33] *Systems thinking* involves considering the stocks and flows of materials, energy, and ideas, along with their interconnections (Meadows, 2008).

More integrated approaches to urban development require a shift in mindsets. For example, Stephenson and Damerell (2022) propose a way of conceptualising the bioeconomy[34] within a *circular economy* framework, operating within blue and green economies. Their nested approach offers a pathway for construction industry stakeholders to align practices with broader sustainability goals. However, Stephenson and Damerell's approach also requires a fundamental shift from conventional thinking towards more inclusive, biodiversity-sensitive design.

Government regulations typically set the baseline for performance while incentives and voluntary schemes can encourage excellence and innovation beyond minimum requirements. In this way, different initiatives can complement and support each other to promote more sustainable practices. This, in turn, requires processes that can foster collaboration between private entities and government agencies for the greater public interest.

Industry plays an important role in advancing sustainability by developing and testing green building technologies, materials, and practices to reduce environmental impact. Moreover, shifting the built environment towards sustainability requires investment at a scale that governments alone cannot easily fund or subsidise.

Public information and support is also crucial, as people are asked to embrace *Green Building* policies and practices (e.g., densification of housing, mandatory separation of waste to avoid landfill, reduced car parks and increased public transportation, cycling, and/or walking). In short, alongside *systems thinking*, there is a need for better communication and collaboration between governments, the private sector, designers, professionals, and other stakeholders, in order to achieve biodiversity-friendly, nature-positive built environments.

A key requirement in the quest to achieve a nature-positive building is to engage and listen carefully to the project's stakeholders. The following Chapter describes the findings of interviews conducted with various Australian construction industry representatives to better understand the barriers to, and enablers of, wider uptake of *Green Building VSS* and other biodiversity-friendly initiatives for the built environment.

[34] The bioeconomy encompasses all economic activities and sectors that produce, utilise, or transform biological resources (plants, animals, microorganisms, and biomass) to create products, processes, and services for sustainable economic growth.

Chapter 5 – Stakeholder Perspectives on Sustainability in the Built Environment and the Role of Voluntary Standards

We conducted semi-structured interviews with 26 stakeholders from Australia's construction industry and related sectors to better understand the perceived barriers and enablers to uptake of *Voluntary Sustainability Standards* (VSS) and to the consideration and integration of biodiversity within the built environment generally. The interviews covered all aspects of building project design and construction, including general context (governance), stakeholders' involvement in the industry, their knowledge of biodiversity and environmental issues, and project decision-making processes.

Most interviewees acknowledged growing interest in sustainability within their organisations and from clients, but they also noted that interest in biodiversity was only beginning to emerge and that implementing biodiversity-related initiatives in the construction industry was not currently seen as a priority. Many stated that more rapid uptake of VSS could occur if markets and financiers leveraged these standards when assessing whether to invest or lend to real estate development projects.

Interviewees identified several barriers to the uptake of VSS and deeper consideration of biodiversity in the design and construction of buildings. Lack of strong government / environmental regulation, high VSS certification costs and limited accessibility (especially for smaller businesses and/or projects), opacity of material supply chains, and a lack of clear guidance on how to conserve or restore biodiversity in building projects were identified as the biggest challenges.

Other impediments highlighted by interviewees included low industry awareness of the impacts of buildings on biodiversity, the difficulty of measuring biodiversity impacts, and a lack of agreed standards for corporate reporting on biodiversity-related issues. Solutions suggested by interviewees commonly focused on how governments could support market transformation and innovation, and the need to improve policy and regulatory processes. as well as various *Green Financing* options. For VSS schemes themselves, more flexible cost and access structures would enable smaller businesses to participate. Many interviewees stated that more information is needed to improve industry understanding of the biodiversity impacts of conventional and alternative building practices, processes, and investments, and, specifically, how these could be applied in an Australian context.

Importantly, the gap between ecological expertise and on-the-ground implementation highlights the need for a nuanced approach to biodiversity integration; one that balances the desire for streamlined practices with the recognition that truly effective solutions require site-specific creativity, engaged stakeholders, and substantial *design thinking*.

5.1 Introduction

Industry stakeholders and external observers have long known that improving the social and environmental performance (or 'sustainability') of buildings is necessary and feasible. As described in the previous Chapter, a range of policies, regulations and building codes have been established to promote the adoption of more sustainable (*Green*) building products and practices, complemented by *Voluntary Sustainability Standards* (VSS). These initiatives help ensure that the industry designs, constructs, markets and operates buildings that use raw materials, energy, and water more efficiently, generate less waste, support the health and wellbeing of occupants, and meet other social or environmental objectives.

Although biodiversity has historically not been a major focus of most *Green Building VSS*, some schemes are now incorporating language and addressing issues relating to ecology and biodiversity. Nevertheless, a large gap remains between acknowledging the importance of biodiversity for buildings and how to design, construct and operate buildings that are biodiversity sensitive or even 'nature positive'.

When compared to conventional buildings that are designed to satisfy minimum mandatory building codes and regulations, *Green Buildings* typically perform better on a range of sustainability criteria, such as energy efficiency, water consumption, and GHG emissions (Ade & Rehm, 2020; Olubunmi et al. 2016; Loftness, 2020). As public interest in sustainability has grown in recent years, so too has the market demand for certified *Green Buildings* increased (Darko et al., 2017; Agyekum et al., 2019).

Modern buildings combine various systems, components and materials, making them some of the most complex elements in the built environment. *Green Building VSS* cannot easily address all of these different elements in detail, but often endorse or rely on other certification schemes for building products and materials to ensure that high standards for environmental and/or human health criteria are upheld. It is therefore encouraging that sustainable (*eco* or *Green*) certified building products, materials, and furnishings, which have lower adverse impacts associated with their production and consumption, have also gained market share in the construction industry (Vierra, 2022).

Despite the development of more efficient and sustainable building technologies, products and processes, supported by more stringent building regulations and VSS, uptake of best practices by the construction industry has been slow (Chan et al. 2017). So, what stands in the way of more rapid progress? What factors facilitate the uptake of sustainable building practices, including the use of credible VSS? This Chapter focuses on stakeholder perspectives on sustainability in the built environment, with a particular focus on biodiversity and the barriers and enablers to adopting VSS.

In order to gain a better understanding of stakeholder perspectives, we undertook a series of semi-structured interviews with people involved in various aspects of the construction industry in Australia. We recognised that some stakeholders had limited familiarity or understanding of biodiversity-related issues and therefore used the term 'sustainability' as a broader and more familiar entry point for the interviews. This allowed us to engage stakeholders on topics they were comfortable with, while gradually steering the conversation towards biodiversity-specific aspects. As a result, some responses were more applicable to sustainability issues in general, rather than being biodiversity-specific. However, we found that many of these broader sustainability insights often also applied to biodiversity considerations. Our approach allowed for productive discussions while also highlighting the interconnections between various aspects of sustainability, including biodiversity, within the construction industry.

5.2 Barriers and Enablers to VSS

As discussed in the preceding Chapter, VSS typically define a set of principles, criteria and indicators that can help organisations and individual stakeholders to choose processes, technologies, and/or practices that improve the social and/or environmental performance of a building, product, or related service. VSS also enable financiers and consumers to differentiate among suppliers and choose more sustainable products and services. This may involve devices such as certifications, star ratings or ecolabels that make it easier to identify products (including buildings) that meet the specific performance criteria of a particular VSS.

Across a range of industries, the barriers to adoption of VSS include: limited awareness or concern among stakeholders about the adverse environmental and social impacts of conventional products and services; the perceived costs of adopting VSS or choosing certified products, including auditing, certification and on-going monitoring costs; low consideration of the potential benefits of meeting certified standard; and mistrust or uncertainty about which VSS are credible and add value (Massoud et al. 2010; Brandi et al. 2015; Carlsen et al. 2012; Kuei et al. 2013; Iraldo et al., 2020).

Similarly, the enablers of VSS adoption across industries include: stakeholder awareness and appreciation of sustainability; credible governance systems; reliable metrics; affordable costs; and transparent processes (e.g., Kuei et al. 2013). Numerous benefits of VSS have been cited across different industries, for example, enabling product price premiums in some cases, improved market access, or improved efficiency or productivity (Raynolds et al. 2007).

To understand how different barriers and enablers affect VSS uptake in the Australian construction industry, and the consideration of biodiversity in particular, the remainder of this chapter describes the findings from interviews conducted in mid-2021, including several leaders of green building and related product VSS schemes. Our aim was to explore stakeholder perspectives on sustainability in the built environment, with a particular focus on how biodiversity is considered within sustainable building design and how VSS could help to improve this consideration through existing and/or future rating schemes.

5.3 Assessing Stakeholder Perspectives on Biodiversity Initiatives for the Built Environment

To understand the relationship between biodiversity and the built environment in practice, we conducted semi-structured interviews with 26 stakeholders from across Australia's construction industry, academia, and related sectors to understand their perspectives on integrating biodiversity in the built environment, as well as their views on the role of VSS within that context. Recognising that VSS can be an effective means to promote and facilitate the design and construction of green buildings, we were particularly keen to understand what may help or hinder the uptake of VSS in Australia. By analysing the responses of interviewees to our questions, we hoped to identify ways to overcome the barriers and enhance the enablers to aid the uptake of *Green Building VSS*.

5.3.1 Methodology

Stakeholder interviews followed an open framework of questions that were conversational and flexible (Mason, 2002; Bottrill et al., 2011). Topics discussed covered various aspects of building project design and delivery, including general context (governance), stakeholders' involvement in the industry, knowledge of sustainability issues including biodiversity, and how this influenced their decision-making. A generic version of the interview questions guide is provided in Appendix 2.

We purposely interviewed stakeholders representing a range of professional services, knowledge and experience, who were based in Australia and worked on building projects, located in the eastern states (where most people in Australia live and work); who were involved in different aspects of the construction industry or relevant academic disciplines; and who had varying levels of responsibility in their organisations.

We used a 'snowballing' approach to recruit interviewees. This involved contacting a core group of stakeholders and seeking their recommendations for additional interview subjects. Ten out of the 36 individuals contacted in this way declined to participate[35]. The 26 participating stakeholders came from several different perspectives:

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[35] Ethics approval for the interviews was obtained in advance from the University of Sydney Human Research Ethics Committee (reference number 2021/246).

- 4 from planning and design (e.g., architects, urban planners)
- 5 from research and academia (in the built environment)
- 2 from *Green Building VSS* (CEOs of VSS schemes)
- 1 from ecolabel / sustainability and product environmental certification
- 7 from property development companies (including 3 sustainability managers)
- 3 from furniture / product procurement and/or manufacturing
- 2 from the building construction industry
- 2 from the real estate finance / investment sector

Prospective interviewees were either contacted directly or recruited via a colleague at their organisation. The 26 interviewees who agreed to participate were interviewed once, separately, between May and August 2021. All participants were interviewed by the same member of the research team, joined in some cases by one other researcher.

Interviewees were asked to share their general perceptions of green buildings and VSS, including: if and/or how they interacted with and responded to VSS in their work; what features of VSS helped or hindered their participation; what aspects of the organisation, industry or broader community enabled or hindered uptake of VSS; and what they thought needed to happen or change for VSS to be more widely adopted in their industry or organisation. Interviewees were also asked about their awareness and opinion of the effectiveness of VSS for addressing the impacts of the built environment on biodiversity, specifically. All interviews were recorded and transcribed for analysis. Notes were also taken during the interviews for backup.

5.3.2 Analytical framework

Interview transcripts were assessed using thematic analysis (Liamputtong & Ezzy, 2006), which allowed for the exploration of both explicit and more subtle aspects of interviewees' perceptions and knowledge of biodiversity impacts and VSS in the construction industry. Responses by each interviewee to questions about whether their organisation participated in VSS, why they did (or did not) participate, and what additional issues might need to be resolved before wider uptake of VSS could occur, were primarily coded for descriptive themes. Secondary coding then identified cross-cutting themes.

More generally, we drew on various theoretical frameworks to interpret our findings. The Multi-Level Perspective (MLP) on sustainability transitions (Geels, 2011) is helpful to understand how innovations like VSS interact with existing regulatory regimes and other drivers. Institutional theory (DiMaggio & Powell, 1983) provides insight into how innovations practices become legitimised and adopted across an industry. Additionally, concepts from organisational learning theory (Argyris & Schön, 1978) informed our analysis of how firms adapt to new sustainability expectations demands.

Limitations of our study design may affect the validity of the findings provided below, notably:

- **Sample size and composition:** we interviewed 26 informants from various sectors, who cannot fully represent the entire Australian construction industry
- **Geographic focus:** we focused primarily on eastern Australian states, hence our findings may not be generalisable to other regions
- **Timing:** the interviews were conducted in mid-2021. Industry perspectives may have evolved since then in light of ongoing environmental challenges and policy developments
- **Self-reporting bias:** as with all interview-based research, there is potential for social desirability bias in participants' responses

Future research could address these limitations by expanding the sample size, including a broader geographic range, and employing mixed-method approaches to triangulate findings.

5.4 Findings from the Stakeholder Interviews

Based on the interviews we identified seven broad themes related to VSS and sustainability in the construction industry, including barriers and enablers to VSS uptake and the integration of biodiversity in building projects. The themes were:

- **General knowledge and consideration of biodiversity –** The knowledge and understanding that people and organisations have about what biodiversity is, how their decisions can affect biodiversity, and the level of consideration or importance given to biodiversity, relative to other concerns.
- **Agency, attitude and motivation to change** – The capacity and willingness of people and organisations to adopt and support new behaviours.
- **Social context of decision-making –** The various settings in which people are involved and make choices about building design, construction, and use, including the groups with whom they interact and what they value.
- **Economic aspects of VSS and sustainability** – The costs, benefits and relative economic efficiency of different options to conserve biodiversity and, more generally, to adopt environmentally and socially sustainable practices, including uptake of VSS.
- **Inspiration and innovation** – Innovative design, manufacturing and construction processes, policies and initiatives that integrate sustainable approaches and consider biodiversity explicitly, as well as work cultures that enable and encourage innovation in relation to sustainability.
- **Governance, regulation and best practices** – The institutions and policies that support, or hinder, progress in adoption of more sustainable practices and biodiversity conservation.
- **Characteristics of VSS schemes and certification** – Specific aspects of VSS (e.g., criteria, accessibility) and related processes (e.g., certification, then ongoing maintenance with auditing, monitoring and reporting) which may be necessary but can hinder broad uptake.

General findings from the interviews are summarised in Table 5.1, and discussed in more detail in the following pages.

Table 5.1 Barriers and Enablers to Integrating Biodiversity and VSS in the Construction Industry

Themes	Enablers	Barriers	Both enablers and barriers
1. Knowledge and consideration of biodiversity	Internal organisational communication about biodiversity-specific issues and potential solutions.	Differing perceptions of *'nature'* and *'biodiversity'* across the industry and wider community.	Knowledge of how different VSS address biodiversity, and their benefits to industry.
	Relevant data and guidance on how to integrate biodiversity in building projects.	Lack of metrics, insufficient data, or difficulty to measure and report on impacts and dependencies on nature.	Access to data on biodiversity impacts throughout the building life cycle and supply chain.
	Clear opportunities to integrate nature into the built environment.	Lack of, or low, capacity to implement biodiversity initiatives or practices. Low awareness or difficulty obtaining information about sustainable materials and products.	Education through universities, TAFEs, industry bodies.
	Growing awareness of the biodiversity crisis in the construction industry and supply chain.	Low organisational priority for biodiversity (or for sustainability generally).	Suppliers' and manufacturer's knowledge of and engagement with biodiversity issues.
	Increasing knowledge of and interest in biodiversity (or 'nature') from investors, clients and the general public.	Limited knowledge of, or interest in, biodiversity issues from investors, clients or the public.	Measuring biodiversity outcomes and benefits; awareness of potential to conserve biodiversity on a construction site.
	Communication about real industry progress in conserving biodiversity to stakeholders and the public.	*'Greenwashing'* or token reference to sustainability and/or nature in corporate marketing, leading to public disengagement.	
2. Attitude and motivation to change	Environmental disasters that raise awareness of risks to buildings or supply chains (e.g., floods, wildfire) create a sense of urgency.	Lengthy time required for certification of designs, procurement of green products / materials, construction and/or length of occupancy.	

Themes	Enablers	Barriers	Both enablers and barriers
	Incentives to adopt a systems thinking approach and/or to establish multi-disciplinary project teams	Siloed approach to sustainability (e.g., limited collaboration among stakeholders, piecemeal or uncoordinated initiatives)	Systems approach or integrated design involving multi- disciplinary project teams (a barrier if not well-supported).
	Projects driven by broad-based values and goals (social, economic and ecological). Shifting focus from mitigating adverse impact (*'less harm'*) towards regenerative outcomes (*'more good'*), including relationship- and capacity-building, with explicit targets for biodiversity enhancement.	Projects driven by narrow market-based values and purely project-specific goals, which may be more convenient or familiar ways to mitigate risk and achieve financial targets.	
3. Social aspects	Corporate social responsibility, ESG and other sustainability policies and targets.	Resistance to change and persistence of conventional practices due to financial, regulatory or client and investor pressures.	External drivers (e.g., Covid-19 stimulated demand for *'healthier'* buildings).
	Community-driven initiatives (e.g., biophilic design, tree planting, Indigenous education) that connect and unite project teams, clients and other stakeholders to drive investment in biodiversity.	Community inertia, confusion, conflicts, or frustration by bureaucracy, and difficulty in transferring information about how to make best use of the sustainable attributes of a building to owners and tenants.	
	Development / rehabilitation of brownfield sites through ecological restoration.	Competing demand for space (e.g., urban planning restrictions may constrain green design).	
	Engagement with clients and project teams to identify shared sustainability goals and plans, especially during the design stage.	Extended project timelines can result in key personnel changes (e.g. loss of sustainability champions or in-house experts).	
4. Economic aspects	Support from experts to evaluate biodiversity impacts and cost-effective	High costs (real or perceived) of sustainable / biodiversity-sensitive design and	Client willingness to pay for sustainability initiatives / green features / eco-labelled materials.

Themes	Enablers	Barriers	Both enablers and barriers
	solutions (e.g., how to increase tree canopy cover in urban areas).	implementation (e.g., VSS certification, ongoing maintenance).	
	Larger organisations may be better able to afford VSS certification or other costs of sustainability interventions.	Small / medium sized enterprises may lack capital and/or capacity to invest in biodiversity.	
	Green finance (e.g., green bonds, reduced lending rates and/or insurance premiums for green buildings).	Lack of financing or incentives to support sustainable / biodiversity-sensitive design.	
	New tools to measure and disclose industry impacts and dependencies on nature.	Limited awareness or uptake of environmental / natural capital accounting by the construction industry.	
5. Inspiration and innovation	Green project design champions who can raise awareness of the value and importance of sustainability / biodiversity and drive practical solutions.	Slow diffusion of innovations in supply chains, procurement or manufacturing / construction practices.	
	Industry and government focus on market transformation and design innovation for sustainability.	Innovation perceived to add cost, time and risk by developers, designers, builders, clients, etc.	
6. Governance and regulation	Government acknowledgement of the biodiversity crisis and support for biodiversity-sensitive initiatives.	Lack of strategic approach (e.g., piecemeal planning and assessment of development applications).	Environmental mitigation hierarchy – more effective if mandated at every stage of the project.
	Strong regulations (e.g., regional plans, building performance standards, codes, procurement processes, etc.) that encourage designers, builders, manufacturers to specify biodiversity-sensitive practices and products.	Ineffective monitoring or enforcement of building regulations by governments.	

Themes	Enablers	Barriers	Both enablers and barriers
7. VSS scheme characteristics	Flexibility to respond to differing project needs and opportunities.	Rigidity of VSS scheme processes and requirements.	Access to VSS – multiple entry points for different users.
	Holistic approach going beyond environmental impact mitigation to include adaptation, regeneration.	Lack of guidance on biodiversity (particularly in the operational stage of the building life cycle).	Some requirements of VSS criteria are easier to achieve than others (flexible VSS that allow users to choose which criteria to focus on to make up the points needed for certification can facilitate access but make comparison difficult for clients).
	Communication with end-users and responsiveness to feedback from manufacturing and/or construction.	Lack of clear guidance on biodiversity impacts and/or protection for auditors (e.g., product-level certification).	Support to institutionalise sustainability action.
	Incentives / rewards for innovation and leadership on biodiversity conservation.	Opacity and complexity of product supply chains.	Independent (third party) validation of performance.

5.4.1 Stakeholder Knowledge and Consideration of Biodiversity

A recurring theme when discussing the enablers of and barriers to VSS uptake, consideration of biodiversity specifically, and sustainability initiatives more generally, was people's knowledge and perceptions of the impacts and/or dependencies of buildings on nature. While interviewees reported a general understanding of sustainability issues in the construction industry, knowledge of biodiversity was described as limited or absent, especially in relation to indirect impacts. As one person said:

> *"[...] There's sustainability in general and biodiversity, and those two are quite different. And I think the thing that holds back a lot of these advances is [a lack of] clear and concise, understandable information."*

Another interviewee observed that, *"[...] generally speaking, the majority of the building sector, globally, pays very little attention to its environmental impact and there's still a long way to go."*

Interviewees from the building product and materials manufacturing industry noted that awareness and consideration of impacts on biodiversity are rare, even for certified green/eco products:

> *"There are some companies who use [nature/biodiversity references] in their marketing material, but it's not necessarily the topic that is most prevalent, I would say. [Biodiversity is] definitely still an emerging topic."*

The importance of supply chain information for understanding indirect impacts was also discussed. Limited access to, and availability of, supply chain data was mentioned as a key barrier. Lack of data or communication of impacts at each stage of the product life cycle makes it difficult to assess impacts, while also making it hard for VSS schemes to provide guidance on best practices for supply chain management.

The complexity of product supply chains is another barrier to greater consideration of biodiversity by eco-labels/product certification schemes, as one interviewee explained:

> *"One major aspect is that it's really difficult to keep an eye on the whole supply chain, and to really understand everything to the bottom of the supply chain. [As in,] what's actually happening, and supply chains can be either quite long, or bigger companies just have quite broad [supply chains]."*

Several interviewees noted that the government plays a key role in collecting information about the environment, highlighting the importance of 'nature valuation' for engaging industry with sustainability schemes. They also noted the government's role in communication, such as informing the public about the outcomes of biodiversity-related initiatives.

Regardless of whether sustainability practices are mandated or voluntary, the need for industry-wide education to ensure that stakeholders have accurate knowledge of impacts and dependencies on biodiversity was also raised. As one interviewee explained:

> *"Step 1 is awareness, getting people just aware of this [issue]. Step 2 is actually more detailed education, which is something that needs to be done through universities, through TAFEs, through the Building Trade Unions, who are well aware of these issues [....], and some of the other unions involved in the [construction] industry, the professional associations – architects, engineers, and so on – and also the commercial bodies, the Property Council, Master Builders, etc. So, they all need to be on board."*

Awareness and appreciation of biodiversity (including understanding project-level or organisational impacts and dependencies on nature) can be an enabler of VSS uptake, especially when that knowledge is linked to actions or incentives to encourage sustainable practices. One interviewee noted that increasing uptake of VSS in the construction industry often relies on *"increasing desirability, which is about consumer campaigns or finance campaigns, or reducing friction"*.

Several interviewees perceived communication and exchange of information – either within their organisation, or between the organisation and the general public – as valuable enablers to increase the appeal of VSS and action on biodiversity. For example, one interviewee highlighted the need for internal communication within organisations to increase staff engagement, raise awareness of nature-related issues, and consider what they can do to address them:

> *"We need to be having conversations. And I think every [architectural] practice should sit down with their staff and go, 'Let's talk about this', and I reckon you will find a level of interest and enthusiasm, particularly from some of the younger [designers] to be engaged in positively addressing this. And from that you will get much better outcomes than you will from just saying, 'We're only going to do what's legally required'."*

The role of narratives and storytelling to showcase successful sustainability initiatives was also mentioned. One interviewee described how marketing and branding that includes a strong environmental narrative can increase motivation. These narratives can inspire both individuals and organisations to adopt more sustainable practices, as people may be more willing to make decisions that support biodiversity:

> *"It's [about] creating that irresistible narrative of the future brand of [belonging to that place], and that sense of attachment and belonging [you get] because you're working for the good of the system and understanding that narrative... If [the motivation is] because of that sense of really wanting to move because you have that [regenerative] view of what thriving looks like and being a part of that, then it doesn't become hard to do."*

5.4.2 Agency, Attitude and Motivation to Change

The theme of agency and attitudes to change emerged from the interviews as another important enabler of participation in VSS and the adoption of biodiversity-sensitive practices. In some cases, an organisation may be impelled to adopt more sustainable practices based on knowledge of a single event which brings environmental or biodiversity issues to the fore. For example, the extreme Australian wildfire events of 2019-2020 (Ward et al. 2020) were flagged by one interviewee from the green product certification sector. More generally, interviewees highlighted the environmental crisis as an enabler, by heightening public awareness of the economy's dependence on nature and showing the impacts of environmental change on both people and wildlife. While regrettable, natural disasters can engage and motivate people to behave in ways that reduce the risk of similar events occurring in the future:

> *"...Since the [2019-20] bushfires, definitely the topic of biodiversity is getting more traction. Of course, it's not as prominent as [the] reduction of carbon emissions. But [...] at least now everyone knows that [biodiversity is] an important topic."*

While natural disasters can draw attention to the impacts of climate change and other environmental trends, change in the construction industry often proceeds slowly. The industry is heavily regulated by Government Acts, Council and Authority regulations, mandatory building codes, Australian Standards, work health and safety (WHS) and quality assurance practices, and other requirements that can take years to evolve and often lag both technology and stakeholder expectations. Industry conservatism is also a factor, resulting in a preference for conventional building methodologies, systems, and technologies, or building materials that are readily available, low cost, and well-known for performance. As one interviewee noted, *"[...] at the moment, the focus is on a finished building not falling down."*

> *Adherence to traditional industry practices was seen as a common barrier. As one interviewee explained, "[...] there are challenges in terms of the way [the construction industry] work[s], the way that contracts are led, the way that procurement processes are run, that inherently work against the ability to deliver the outcomes that the [VSS] Tool sets out."*

Another interviewee stated:

> *"...There are a lot of old practices that just have momentum and people understand them so they're easier, and cheaper. [Contractors might say,] 'We've been doing these for 20 years, the guys know what to do. It's just cheaper that way'. It's that mindset. And I think that's a limiting factor... The [contractor] that's been doing the same thing for 25 years might also be a nice person, [so] you don't want to bring in somebody else."*

One interviewee from the building product manufacturing industry highlighted the particular challenge of marketing new, more sustainable building products:

> *"...Usually one of the hardest situations that [manufacturers and suppliers] have is convincing the people doing the design and the procurement to use them. In [relation to the built environment] especially, while there's some innovation, there's also a lot of [...] momentum towards traditional practices."*

Despite such barriers, the potential benefits for people's health and wellbeing from integrating nature in the built environment are increasingly recognised. Local-scale action was perceived as a foundation for large-scale behavioural change, beyond 'sustainable' and towards more nature-positive, regenerative actions. As one interviewee explained:

> *"...There are psychological benefits and health benefits: you start there. But once you start valuing nature, you start looking at nature as a model, [and incorporating] biomimicry. [That leads to] permaculture, then positive development, and then you get to regenerative [design]."*

A specific enabler of uptake of VSS, cited by some interviewees, was the demonstration of 'proof on the ground', where the requirements of the VSS standards are shown to be both achievable and commercially viable. Such projects can raise awareness of what best practice within the construction industry looks like and reduce psychological barriers. As one VSS leader explained, as more projects are certified the more it encourages other people to consider certification of their projects:

> *"...Once there is a [building] that you can point to, and people can walk around, you can prove that it can be done – that's really helpful. ...The more [certified buildings] we have, the easier it becomes for the next project [to take on certification]."*

5.4.3 Social Context of Decision-making

The theme of community and social responsibility for sustainability decisions arose in multiple interviews. Consideration of both environmental and social factors across all aspects of a project were seen as important to achieving sustainability goals and outcomes. As one interviewee from the property development sector noted:

> *"...[It's about asking,] 'how do we create a better environment for our customers?' And it's more than just providing car parking spaces and wellbeing spaces; it's now using environmentally friendly*

materials when creating that [development], and looking at some of those social factors, [...] and trying to create more than just four walls."

Meeting client and/or market demand was cited as a key enabler. On the flipside, a lack of client demand for sustainable products and materials, or low corporate commitment to sustainability within the organisation, were seen as barriers to VSS certification or adopting biodiversity-sensitive approaches in building projects.

Corporate Social Responsibility (CSR), when supported by decision makers in the Project Team, was seen as an enabler, with VSS certification helping companies to market themselves as 'greener' or meet their sustainability goals. Multiple interviewees highlighted the value of VSS tools to help assess social and economic wellbeing and livelihoods, as well as for verifying positive environmental outcomes.

Strong leadership was seen as a key driver of environmentally conscious behaviour and actions within the construction industry. Several interviewees noted that it often comes down to a particular individual in an organisation or Project Team to provide inspiration, to 'champion' a sustainability ethos or a particular sustainability initiative. As one interviewee noted, progress on sustainability often relies on:

"...Finding the right person in the organisation to champion a project. And that might be [an] individual or family owners, [etc.]. For example, we had one person [on the Project Team] that was incredibly tenacious and was inspired by the fact that it was hard and a challenge. And that person was a key person to get it over the line, because whenever it was hard, he just threw himself at it more, rather than going, 'oh, it's too hard'."

5.4.4 Economic Aspects of VSS and Green Building Initiatives

The economics of VSS and sustainability initiatives was a recurring theme across the interviews, both in terms of the costs to implement such initiatives, and from the perspective of consumer demand and clients' willingness to pay for more sustainable products and project outcomes.

The cost of developing green building designs, VSS application, membership, and certification fees, ongoing participation and recertification, as well as the costs of audits, monitoring and reporting, were all cited as barriers to uptake of *Green Building VSS*, as well as for the purchase of certified building products and materials. Some interviewees noted that a major barrier to adoption of VSS was the resulting increase in up-front design and project costs:

"The biggest challenge you have in that step is convincing the Client, because sustainability comes at a dollar value, and convincing the Client that in order to feel warm and fuzzy about doing 'the right thing', they need to spend a bit more money. In a commercial [architectural] practice, that's where our challenge is."

Another person noted that:

"It's ease and cost reduction over ecological [intent], so [biodiversity] is not a priority, it's a 'nice to have'. It's a good 'nice to have', but if it's going to cost more, or it's hard to do, or it's going to take more time, it still becomes a limitation".

The issue of cost is exacerbated by a lack of consistent pricing and established standards in emerging green technologies. As one interviewee said:

"[At the time when] the green roof industry in Australia [was] still relatively new, [the developer] was going out to get quotes from installers and was getting order of magnitude difference in those quotes.

[...] [D]evelopers are really nervous about that. They don't feel like they know what they're getting for their money, they're not confident."

Uncertainty about pricing and quality creates a significant hurdle for developers considering biodiversity-sensitive features like green roofs. The same interviewee elaborated: *"industry immaturity, or, you know the newness of industry and the lack of skills and standards [...] can be a barrier for developers' willingness to actually integrate those measures into their designs."*

Some interviewees noted that when sustainable materials and/or products are proposed as design initiatives early in a project, these were often the first items to be removed as a value-managed and cost-control measure, as they were deemed to be unaffordable or unnecessary 'features'. As one interviewee elaborated:

"[There] is also a cost associated with having a building certified, and the majority of the additional professional cost comes from the upfront costs: the design costs. You've got the cost for design, cost for certification, which is all front-loaded. And then, if you're a speculative property developer, [...] you're bearing that additional risk that you won't find the returns. And so that is possibly a little bit off putting."

Several interviewees stated that VSS are perceived as being associated with high-end commercial products. For example, developers may be motivated to put up 'green' commercial buildings and have them certified in an effort to increase the project's marketability and the investor's profits, on the assumption that VSS-rated buildings will generate higher lease revenues than conventional, uncertified buildings. One interviewee stated:

"[...] Property developers and real estate investors derive benefit from projects which have been certified with voluntary standards, because they tend to be considered as a higher-end product, and therefore, there is an opportunity to get high quality tenants, and get higher rents, lower vacancy rates. And there's a reputational value as well."

However, not all developers are adept at marketing green buildings, which may require a different approach than traditional real-estate sales. Moreover, some interviewees maintained that a purely profit-driven approach would have limited success in delivering long-term industry sustainability. Others argued that potential increased up-front costs should be considered relative to the growing consumer demand for, and the potential long-term increased financial returns from, a greener building / product:

"If you have the right Client [...] big corporations will invest that money because it's part of their corporate social responsibility, or it's part of their branding to be headquartered in green buildings. ...People who have the disposable incomes who want a really high end [product], or [a] really high-performance home or building, will pay [for] it because it speaks to their value system."

Even at a large scale, seeking VSS certification may be perceived as risky, as there is no guarantee of increased profitability (Ade & Rehm, 2020). Moreover, relying on high-income clients or high-profile organisations to adopt VSS or related initiatives could limit their reach. Rising costs of building design and construction mean that sustainable options may not be affordable or desirable for all clients, particularly in a housing market that is already prohibitively expensive for many people in Australia. As one interviewee noted, *"if you want to make a real impact, then move away from [VSS] being simply high-end people doing it."*

Time lags were identified as another potential barrier. Delays in construction due to the limited availability of green building materials, insufficient environmental data, or lack of local building contractors with the knowledge and skills to apply green practices / technologies were cited as deterrents to the uptake of VSS in both the building design and product / manufacturing sectors. For example, some building projects undergoing more stringent VSS certification processes were described as taking as long as ten years to meet the requirements to become fully certified.

Several interviewees highlighted the pivotal role of the finance sector in supporting green initiatives. For example, green financing schemes have the potential to influence system-wide change and encourage broader VSS uptake. Such schemes may require organisations to demonstrate that their project complies with a particular VSS to be eligible for financing or insurance. As one person explained:

> *"If you look at the 'food chain' of the property industry, and you try and control access to money based on green credentials (sustainable credentials) then you can have potentially a systems[-wide] impact. …There are frameworks around that provide criteria for investment, criteria for giving loans, [etc.] …"*

The same interviewee discussed VSS in relation to market transformation, stating that stronger environmental performance standards are already being implemented in some countries, and that rapid uptake of VSS could occur if markets and industry financiers used these standards to assess whether to invest in large development projects:

> *"If you apply environmental performance standards to finance, you can achieve a rapid or accelerated uptake in environmental performance in the [building construction] industry, and there's evidence to demonstrate that link […] That takes time, but there are indications of a market transformation […] where [financiers] pay attention to the kind of environmental performance criteria that they require when considering whether or not to provide finance for large projects: large housing projects, for example."*

The benefits of a more holistic approach to climate risk management, including the use of Nature-based Solutions (NbS), was highlighted as a key enabler to integrating biodiversity within VSS schemes. As one interviewee explained:

> *"The discourse on climate change is dominated by, and for good reason, mitigation. But when you look at the adaptation activities, then you see a lot more discussion about biodiversity and ecosystem services and Nature-based Solutions because they tend to be the most cost-effective ways of reducing climate risk."*

The emerging interest in biodiversity among property investors aligns with global trends towards nature-positive development, although the Australian market may be lagging somewhat. One interviewee explained:

> *"…When we ran [a] materiality process to understand across our stakeholder groups, what were the most important issues that our stakeholders expected [our organisation] to act on, […] climate change came across in every interview [and] has been the most important thing. Biodiversity was one of the lowest ranking issues within those interviews".*

5.4.5 Inspiration and Innovation

Support for innovation at multiple levels – from governments, industry, and VSS schemes – was seen by many interviewees as an important driver of participation in green design initiatives. This support may include government or industry incentives, or preferred procurement specifications, to encourage innovation in green building design, as well as clients interested in embracing and pioneering new ideas. One interviewee commented:

"...Policies can also focus on provision of incentives and awards, grants, recognition [etc.]. And when policy mechanisms are framed effectively, then incentives can push best practice and push innovation."

Multiple interviewees cited the importance of materials selection for avoiding or minimising the impacts of buildings on the natural environment. One person added that innovations in the use and application of building materials may achieve more sustainable outcomes than simply sourcing what are purported to be 'green' materials or products:

"I [don't think it] necessarily always [comes down to] using natural materials. It's [also about] coming up with ways of creating new materials, [such as] using recycled materials to create a new material".

For projects seeking VSS certification, meeting the assessment criteria pertaining to materials selection can be challenging. One VSS leader noted, for example, that one requirement of their global standard is to source a certain percentage of the overall project spend within 500km of the building site. This can present a significant challenge for projects in Australia, since many building products and materials are manufactured overseas and Australia doesn't have *"that manufacturing capability that the US does"*.

In response to this constraint, prospective projects may use recycled and reclaimed materials in innovative ways to satisfy the VSS requirements. However, this strategy presents its own challenges, particularly relating to the availability of reclaimed materials[36]. As one VSS leader explained:

"Currently, ... someone [from the Project Team] needs to know that another project is dismantling, or that there's this piece of wood [that is available to be reclaimed as a building material], [...] And then the timing has to be right because there's nowhere to store these [salvaged materials]. There's no mass[ive] warehouse where all of this reclaimed building material lives, that has an inventory that projects all over Australia [can select] from. [The reclaimed materials market is] really opportunistic, and it depends [on whether] you've heard [about what materials are available at the time, via] the grapevine."

Reuse of building products and materials also presents challenges for producers and suppliers. One interviewee from the manufacturing industry explained that, from a sustainability perspective, it makes sense to reuse products or materials as *"...the life cycle advantages of using something that's already gone through most of the steps of production should be a lot lower. [Such as] bricks that are already made, rather than destroying them and making new bricks"*. However, the sustainability benefits of buying back or reclaiming and reusing products / materials are often outweighed by inconveniences, lack of economic incentives, low recognition within the industry, or clients' / customers' apathy:

"...[A] lot of times, it's not necessarily worth the time to think through all the individual steps [of buying back or reusing products / materials]; or [producers] are not rewarded for it; or [customers] will still go with [what they know], or [the argument that] housing is so expensive already."

Moreover, it is not always possible to satisfy the public's expectations to improve the sustainability of certain products. For example, manufacturers / producers are often criticised for not using recycled materials. However, they may be unable to do this consistently, due to fluctuating and unreliable supply of recycled materials, which are often sourced overseas. As one interviewee from the manufacturing industry put it:

[36] The period since these interviews were conducted has seen the emergence of several *circular economy* material exchanges in Australia, which facilitate the collection, storage and distribution of salvaged materials for reuse.

"You're trying to standardise something that the markets are constantly fluctuating on, and that will affect your ability to use recycled content. And that moves much quicker than standards, procurement, recycling. So if [manufacturers] say, 'We'll try and use as much recycled content as we can', that may be seen as wishy-washy, but it's actually a more accurate reflection [because] sometimes you're not going to get the material. [...] Something can happen halfway around the world that means you can't source [that recycled material when you need it]."

Innovative green building design can be more costly and time consuming. A lack of publicly accessible data on the cost and time implications of deconstruction and material reuse, versus traditional demolition and rebuilding, makes it challenging for project teams to implement *circular economy* principles while adhering to tight budgets and schedules. As one interviewee highlighted, from the property developer perspective:

"The biggest challenges that we saw through construction [was] trying to deliver things that were physically impossible. So, we had to go back and forward at our cost, as well as time, to procure materials, and to rethink resourcing strategy, well before Australia was, at the time, [...] able to support something like that. So, you're defining a new way of building in the Australian construction industry, but [...] when you're a pioneer it can be very costly to the organisation..."

5.4.6 Governance, Regulation and Best Practice

Another common theme from the interviews was the role of governance, regulation, and best practice in green building initiatives generally, and the construction industry specifically. Several interviewees state that building standards set by governments needed to be reformed. If legislation was strengthened to reflect the best practice and standards currently defined by VSS schemes, then VSS organisations could move forward and drive the next generation of best practices for the built environment, continually raising the bar for sustainability. As one interviewee put it:

"Mandatory [building standards] need to set the minimum standards and define what everyone needs to achieve, and then the voluntary rating schemes need to push the best practices. So that reinforces the necessity for both minimum standards and rating schemes to continue to be reviewed and re-calibrated, to keep pushing better practice."

Some interviewees highlighted what they described as the fragmented process of development and planning assessments by governments and local councils, which do not allow holistic assessment of development impacts on the broader landscape at the urban / precinct scale. As one interviewee commented:

"The way that developments are managed with a landowner, or someone like a council or a state planning group, is that each pocket of land is very much viewed on its own. And so, improving the way that we, as an industry, and with all the stakeholders (both up and downstream) do it, is by viewing these pockets more as a whole, as opposed to individual lots, so that we're not isolating biodiversity, and so that we are creating larger areas that are linked."

Another interviewee stated that one reason why biodiversity-sensitive practices are still uncommon in the industry may be because there are not the same mandatory building standards or tools for biodiversity as there are for energy efficiency:

"You haven't got a situation [for biodiversity] where it's mandatory in the sense of the Building Code of Australia[37], or BASIX[38], or NatHERS[39], and some of these other mandatory tools which are used, for example, for improving energy performance [of buildings].".

One interviewee suggested that stronger environmental regulations can help to normalise sustainable behaviours and actions across the whole construction industry:

"You need to get that level, at the basic level, where it becomes that if you want to get a certificate of occupancy for your building, whether it's a home, or whether it's an office, or retail, or industrial, [etc.], you need to achieve certain things in terms of sustainability, which includes [...] reducing impacts on biodiversity."

In Australia, as in many other countries, there are some compulsory requirements regarding biodiversity in the development application process. For example, NSW has a long-standing policy requiring ecological assessment of development projects and avoidance of environmental harm, in line with the Mitigation Hierarchy, including mandatory compensation (offsets) for unavoidable residual impacts. However, the effectiveness of such policies for ensuring the protection of biodiversity has been roundly and repeatedly criticised as inadequate (Samuel, 2020; NSW Auditor General, 2022; Henry et al., 2023).

Other government actions flagged by interviewees that could encourage VSS uptake and improve biodiversity outcomes include mandatory compliance monitoring, as well as incentives and grants for green initiatives in the construction industry. One interviewee distinguished between regulatory 'sticks' and 'carrots', and voluntary 'tambourines', as enablers that can drive adoption of best practice in the construction industry:

"Market transformation requires a combination of mandatory building codes and standards, what we call 'the sticks'. Then 'the carrots' are subsidies, fiscal policy, tax breaks, grants, investment incentives, possibly carbon pricing (these sorts of things which provide that financial incentive) or, from a non-financial point of view, looking at things like accelerated approvals for [green] developments, changes in plot ratio allowances, etc., to make it more attractive to developers. And then you've got the [VSS] rating schemes which could be picked up and applied voluntarily. They're very good for [...] helping to define things like low carbon bonds, green bonds, [etc.]; they are what we call 'the tambourines'."

The organisations that own and manage VSS often act as a conduit between industry and government for driving sustainability in the built environment. For example, ongoing dialogue between a VSS organisation and stakeholders in the construction industry, as part of the development of VSS tools, can help to inform government policy. As one VSS leader put it:

"One of the reasons why [it was hard to] get to net zero for 2050 as a political commitment [from the Australian Government] is because the materials area has been so complex. So [our VSS] was hired by the Commonwealth to [prepare a] policy paper [...] about the fate of embodied carbon from now

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[37] The Building Code of Australia (BCA), contained in volumes I and II of the National Construction Code (NCC), is a performance-based code that sets the minimum requirements for a building in relation to its structure, fire safety, access and egress, energy efficiency, and health and amenity. It is referenced and given effect in NSW through the *Environmental Planning and Assessment Act 1979*.

[38] The Building Sustainability Index (BASIX), is an online planning tool devised by the NSW Government to reduce residential energy and water use by setting minimum sustainability targets for new and renovated homes. BASIX applies to all NSW residential dwellings as a way to ensure they meet the BCA's energy efficiency requirements.

[39] Nationwide House Energy Rating Scheme (NatHERS) provides a standardised approach to rating the thermal performance of Australian homes, and is administered by the Australian Government on behalf of state and territory governments. NatHERS works closely with the Australian Building Codes Board (ABCB) and is one method of demonstrating compliance with the minimum energy efficiency standards for new residential buildings outlined in the NCC.

until 2050. But the important reason that we were engaged is because we already, through our other work, have relationships with all the different materials sectors."

This kind of collaborative approach between VSS organisations, governments and industry stakeholders exemplifies the multi-stakeholder engagement flagged by many interviewees as necessary to drive systemic change towards nature-positive built environments.

5.4.7 Characteristics of VSS Schemes and Certification

Several interviewees highlighted the characteristics of VSS schemes and their certification processes as both enablers and/or barriers to the uptake of sustainable practices. The preventive or proactive approach of some VSS was viewed as an enabler, including (as one person put it) a *"holistic approach to tackling environmental issues that goes beyond mitigation to adaptation and resilience"*.

Different VSS schemes were highlighted for supporting different objectives. Reducing adverse environmental impacts on the building site (e.g., by avoiding or minimising harmful construction processes) is a fundamental characteristic of most of VSS that interviewees were familiar with.

On the other hand, VSS that require proactive strategies to maximise nature-positive outcomes for the environment, rather than simply reducing known adverse impacts, are often more difficult to achieve. One interviewee described the differences between VSS schemes using the example of The Living Building Challenge as a benchmark[40]:

> *"[T]he Living Building Challenge-type framework sits within the paradigm of say 'positive design', where we're looking at designing and operating buildings to actually improve ecosystem services and increase biodiversity, repair degraded environments, and improve the basic conditions for public health and wellbeing. Whereas, the ... 'efficiency' paradigm talks about minimising environmental impacts, and that means that you may well still be having an overall impact, but it's less than it would have been if you hadn't taken any action at all."*

While differences in VSS schemes offer the possibility of context-specific certifications to meet the varying needs of different building projects, there is also an argument for greater standardisation and more ambitious biodiversity targets across all VSS schemes. This would enable VSS to play a more substantial role in promoting urban biodiversity conservation, based on comprehensive and consistent integration of biodiversity criteria.

On the other hand, as highlighted by one VSS leader, *"most great biodiversity solutions, apart from not doing terrible things, can't actually be streamlined into procurement guidelines."* This underscores a fundamental barrier, namely the inherently bespoke and site-specific nature of effective biodiversity integration into building projects. As the same person further explained, effective solutions are *"usually individual opportunities taken (that are bespoke to sites) with engaged designers who are working with their clients and partners,"* and *"actually take a lot of design thinking*." This reality clashes with the drive for standardised, easily replicable approaches.

Several interviewees recognised this tension, suggesting that both flexibility within a scheme and greater consistency between the requirements and objectives of different VSS schemes, as well as the availability of multiple entry points to achieve certification, were potential enablers of participation. On the other hand, the absence of such features can be a deterrent to the certification process. This was

[40] While various VSS schemes address biodiversity to some extent, there is wide variation. The Living Building Challenge, for example, takes a holistic and regenerative approach, aiming to improve ecosystem services and increase biodiversity. Others, such as LEED and Green Star, tend to focus more on reducing negative impacts rather than actively enhancing biodiversity.

also discussed in relation to the green product certification and auditing processes, as one interviewee from the furniture manufacturing sector noted:

> *"A lot of times it might not be clear which sort of certification program is best. Or if you have multiple customers and they have different preferences for different certification programs. Then, to take advantage of those opportunities you might be paying multiple schemes to be certified and go through audits and you're repeating the information or presenting it slightly differently to different [schemes], and that slows things down. I think we would see more uptake if there was some greater consistency [among] different certification programs."*

Some interviewees highlighted the need for targets that are accessible to all stakeholders, not just large corporations, with *"easy targets that people can adopt; not just developers, but other companies as well, [...] and then some steps on how to get there."*

One barrier cited was a relative lack of attention by certain VSS to sustainability in the building occupation (or in-use) stage. Supporting the ongoing sustainability behaviours of building occupants was highlighted as a topic that deserves greater attention:

> *"The building is the thing that gets the certification at the end of the day; and then the operating of the building – that's sort of another step, where some rating schemes continue on to look at them as-built and then in-operation, and some rating schemes don't. [...] There need[s] to be [operation] manuals for building occupants [and] education; there needs to be some format [or] platform for data collection, monitoring, and reporting. And then there's an infrastructure around checking that the building is actually performing the way [it's] designed to, which is really important. But that's also an area where there is a lack of attention paid. It's quite easy to design and certify a design. It's a lot harder to get that design built. And then to actually have the building operate [as intended] is [even more] difficult."*

The requirement for independent (third party) verification of performance to secure VSS certification was perceived as both a barrier and enabler. On the negative side, particularly with regards to green product certification, independent benchmarking and validation takes more time, effort, and investment. As one interviewee from the furniture manufacturing industry remarked:

> *"It ends up just costing [us] a lot of money, which I think kind of makes it prohibitive, frankly. It makes less people take up these [voluntary] standards. I think a lot of manufacturers already do [make an effort to be sustainable], but they just can't get the [certification] because they can't pay the price. The admin cost is having someone in-house, having to set up all these documents to show that we're doing the right thing, even though we've been doing the right thing all along."*

On the positive side, organisations that rely on third-party accredited verifiers can attest to clients that their building's (or asset's) performance has been independently validated. This was seen as a strong enabler to justify the cost of certification in some cases:

> *"We rely on third-party independent benchmarking and validation of performance. That's important for us to be able to set out improvement plans across a variety of metrics for each of our properties, and then rolled up into our ESG strategy and targets that we've set for 2025. We're accountable for [the] performance of our properties, both in minimising the impact of our properties, and [...] understanding from a cost perspective how we can make sure our buildings run as efficiently as possible. So we look to those [VSS] tools, particularly that third-party independent validation. And investors also like that it's not just us saying, 'Trust us, we've done a great job', but we've actually got the rubber stamp from that independent authority that confirms that."*

One barrier for organisations seeking third-party certification of new green products / materials was that some certification criteria might not be comprehensive or recognise innovation. For example, products that use well-established technology or well-known and previously assessed materials are often more easily certified than initiatives or products that use novel materials, or which reuse or recycle existing materials in their products[41]. As one interviewee from the green product certification sector noted:

> *"A lot of times people might find their niche in an aspect of sustainability, and then they'll say that the certification programs don't reflect the full extent [of a product's sustainability features]... I've seen some improvement on things like reuse, but I still think that's got a long way to go. So many things are about new products (new procurement and everything) whereas, in theory, reuse [of existing products and materials] should be better".*

Several interviewees highlighted that sustainability outcomes are more likely to be achieved if the certification process begins as early as possible in the project life cycle. One VSS leader stressed the importance of engaging the entire Project Team at the start of the design process, and how collaboration between professional disciplines should be taught through training and education programs:

> *"[A certified green] building [...] requires an Interdisciplinary Design Process [IDP]. I think a lot of those [construction industry] disciplines would benefit from learning how to do that. And also being part of the design process right at the beginning. So the most cost effective way to [approach the certification process for a project] is to bring as many stakeholders as you possibly can right from the beginning, and get them to be on the same page. But also [to] talk about it together before they even start [the project]. So that when the builder is on the ground, or when the electrician is installing things, they understand why it's really important not [to] substitute [the sustainable] building products, for example, [as] that would jeopardise the entire [sustainability] intent of the project. And I don't think that that process is necessarily taught that well [to construction professionals], [n]or is that common in an education setting."*

Collaboration between VSS organisations and industry stakeholders was highlighted as both an enabler and a pre-condition for continual improvement. Industry partners, including property developers as well as material suppliers and product manufacturers, are in constant dialogue with VSS organisations about the application of their tools. The VSS schemes take this feedback on board, which helps to shape updates to the standards.

One VSS leader noted that as new benchmarks for sustainable building materials are defined by advanced manufacturers, those practices can be integrated within VSS tools to encourage other producers, as well as those in the wider construction industry, to follow suit. For example:

> *"A lot of the sustainability activities that [the concrete industry] have been doing is biodiversity rehabilitation: [for example], the best of them have been doing biodiversity rehabilitation of old quarries and returning them to nature. And so, it was actually incredibly helpful [for the Green Building VSS scheme] to receive that feedback [...] that actually gave [our VSS scheme] the mandate to help drive [biodiversity] as an additional criterion through all our standards".*

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[41] Some certification programs address the challenge of novel or recycled products by implementing more comprehensive evaluation methods. For instance, certain certifications use comparative life cycle analysis (LCA) to measure a product's sustainability against a baseline 'business as usual' alternative. These approaches are designed to overcome the limitations of traditional certification criteria, allowing for a more accurate assessment of innovative products. Some certifications have also expanded their scope to include *circular economy* principles and biodiversity impacts, demonstrating a shift towards more holistic sustainability evaluations. These methods aim to showcase the benefits of novel products and have been successfully used in the market for many years.

5.5 Conclusion

The interviews highlighted both barriers and enablers related to the consideration of biodiversity in the design and construction of buildings and related products, as well as the uptake of VSS and certification within the construction industry. A fundamental barrier, highlighted by many interviewees, was the limited knowledge and consideration of biodiversity within the construction industry, especially regarding the adverse effects of construction activities on threatened species and ecosystems. Several interviewees noted that the complexity of measuring biodiversity, as well as the novelty and relative lack of awareness and uptake of new tools for reporting on biodiversity performance[42], create barriers to industry-wide consideration of biodiversity.

Some interviewees note that, while frameworks may exist for integrating biodiversity into building designs, knowledge of how to use them is often confined to specialists, making it difficult for the industry as a whole to implement these frameworks effectively. Bridging the gap between ecological experts and the construction industry was therefore seen as essential. Some went further to suggest that construction industry stakeholders and VSS owners should work together to develop more practical, user-friendly guidelines and toolkits that could be adapted to different project scales and contexts.

Another frequently cited challenge was data gaps, which are exacerbated by the complexity of building material supply chains. Some interviewees noted that a lack of data and/or inconsistent reporting by product suppliers make it difficult to measure biodiversity impacts, deterring companies from reporting on this issue. At the same time, potential synergies can facilitate sustainability reporting. For example, one interviewee said that organisations which have conducted supply chain analyses for issues like ‘modern slavery’ may be able to leverage these data systems to assess biodiversity impacts and dependencies.

The local planning and regulatory landscape was often described as hindering rather than helping the integration of biodiversity in building projects. Interviewees noted that development approvals at the time were often handled in a piecemeal manner, with little coordination at the broader geographic level. One person suggested that improvements could be achieved if new developments were regulated in a way that links up green and blue infrastructure spaces, ensuring that biodiversity is an integral part of urban design at all levels. This interviewee cited the Greater Sydney Green Grid as an example of how urban development can improve ecological diversity and quality of life by connecting green spaces.

While most interviewees identified a need for stronger regulatory and policy support to integrate biodiversity in building projects, many also highlighted that effective integration requires site-specific approaches and careful design thinking. Some noted the challenge of how to balance the need for locally relevant biodiversity solutions with industry’s desire for standardised processes and reliable pricing. One VSS leader explained how the construction industry struggles with standardisation in emerging green technologies, stating that biodiversity-sensitive (or nature-based) solutions often need to be tailored to the unique characteristics of a site, making standardisation difficult.

[42] The recent emergence of frameworks and tools, including the Global Reporting Initiative’s (GRI) *‘GRI 101: Biodiversity 2024’* standard, the LEAP framework of the Taskforce on Nature-related Financial Disclosures (TNFD), the WBCSD’s *‘Roadmap to Nature Positive: Foundations for the built environment system’*, and the *‘Biodiversity Indicators for Site-based Impacts Methodology’* developed by a group of governmental and non-governmental organisations, has made it far easier for companies and facilities to measure and report on their biodiversity impacts and dependencies. See Center for Environmental Education and Communications (CEEC, 2022; Global Reporting Initiative [GRI], 2024; Proteus & UNEP-WCMC, n.d.; UNEP-WCMC et al., 2020; TFND, 2024; WBCSD, 2023b).

The financial feasibility of adopting VSS was flagged as a major concern, particularly for small-scale and medium-sized enterprises. The costs of the certification process and perceived limited return on investment in sustainability initiatives can discourage participation. However, some interviewees pointed to potential solutions. For property developers and their financiers, there was a suggestion to expand and improve green financing tools, tax incentives, and subsidies.

Interviewees also emphasised the role of real estate markets and financiers in accelerating VSS uptake, by including biodiversity criteria in their investment decision-making. Similarly, one person suggested that policies such as *Australia's Nature Repair Act 2023*, which establishes a voluntary national framework for biodiversity projects and certificates (Australian Government, 2023), could create new opportunities for more biodiversity-sensitive development, by incentivising projects that enhance ecological outcomes.

Interviewees also offered solutions for improving VSS schemes based on their experience, such as adjusting fees and accessibility to enable small organisations to participate. In relation to integrating emerging green technologies in buildings, some interviewees noted how innovations in green design, such as the use of recycled and salvaged materials or infrastructure like green roofs, demonstrate that sustainability and biodiversity can be integrated into building developments in creative and effective ways, even without implementing or seeking VSS certification.

The social context of decision-making emerged as both a barrier and enabler to VSS uptake. Decisions about VSS are often influenced by the values and goals of project teams and clients. As client awareness of sustainability grows, so too does the potential for biodiversity-sensitive initiatives to evolve. Inspiration and leadership within organisations were also identified as powerful enablers of VSS uptake. Several interviewees noted that sustainability champions—whether individuals or teams—play a critical role in driving the adoption of VSS and biodiversity-sensitive initiatives.

Despite these and other challenges, interviewees reported growing interest in sustainable and biodiversity-sensitive or biodiversity-inclusive practices from both internal organisational leaders and clients, driven in part by increasing public awareness of environmental issues. Interviewees also agreed there is potential for biodiversity-sensitive initiatives and practices to evolve within their industries, but that uptake would be faster if the real estate market and industry financiers consistently referred to relevant VSS standards when considering whether to invest in building projects.

While significant barriers remain, growing interest in sustainability and biodiversity, coupled with emerging biodiversity-related frameworks and tools for the construction industry, offer a pathway for change in the construction industry. Moreover, while there are many challenges to widespread adoption of VSS and biodiversity-sensitive practices, the industry is increasingly aware of their importance.

Concerted efforts are needed to enhance stakeholder knowledge, financial incentives, and regulatory frameworks, as well as the adoption of site-specific solutions, while also fostering innovation and collaboration across sectors. The future of the built environment will likely depend on the extent to which these factors can be aligned to ensure that biodiversity becomes a core consideration in the construction industry, delivering long-term benefits for developers, investors, occupants, and ecosystems.

Chapter 6 - Overcoming Barriers to Nature Positive Buildings

The construction industry will need to move beyond conventional sustainability approaches if it is committed to creating nature-positive outcomes. While significant progress has been made through *Green Building* standards and sustainable design practices, achieving nature-positive buildings requires addressing multiple interconnected challenges. This Chapter examines these challenges and explores pathways toward creating built environments that enhance and regenerate natural systems, rather than simply mitigating damage to them.

We begin by examining the evolution of sustainability in the built environment and the limitations of current approaches, particularly the tendency to address environmental impacts in isolation. The Chapter then explores how *systems thinking* principles can be applied to better understand and manage the complex relationships between buildings, communities, and ecosystems. This is followed by an examination of nature's diverse values in the built environment, from ecological and cultural to economic and aesthetic, and how these can be better integrated into decision-making processes.

The Chapter revisits the key barriers to implementing nature-positive approaches in the built environment, identified in Chapter 5, including knowledge gaps, economic constraints, cultural resistance, and regulatory fragmentation, and offers practical strategies to overcome these challenges. Case studies of pioneering projects across Australia show how *Regenerative Design* principles and systems thinking can be successfully applied at different scales to create buildings that contribute to environmental regeneration. Throughout the Chapter, we highlight the importance of transdisciplinary collaboration and holistic approaches to deliver truly nature-positive outcomes.

6.1 Challenges of Nature Positive in the Built Environment

The construction industry faces a pivotal challenge in transitioning from current approaches to achieving more sustainable, nature-positive outcomes. While substantial progress has been made in areas like energy efficiency and green building standards, the industry still grapples with fragmented approaches and limited understanding of how buildings can contribute to the regeneration of nature. This section reviews the evolution of sustainability in the built environment, highlighting the advances made through V*oluntary Sustainability Standards* (VSS) and the persistent barriers that impede more transformative change. It also explores how holistic, systems-based solutions can help to address the biodiversity challenge in the built environment in a more integrated way.

6.1.1 Sustainability in the Built Environment: Progress and Gaps

The concept of sustainability in the built environment has evolved from a focus on efficiency and functionality to a more holistic approach that considers the interactions between buildings and their occupants, the urban environment and rural hinterland, and the natural world as a whole. Today, sustainability in the built environment embraces concepts and ambitions such as *net-zero energy*, *circular economy*, and *resilience*, which seek to minimise environmental footprints and risks, while promoting the wellbeing of both building occupants and the wider community (Liu et al., 2022; Ruokamo et al., 2023). Some have gone further to advance the concept of *Regenerative Design*, which aims to create buildings and communities that actively contribute to the restoration of degraded natural systems (Fayed et al., 2020; Hes & Bush, 2020; Pedersen Zari & Hecht, 2020).

Many design principles and initiatives now labelled 'regenerative' or 'nature positive' have deep historical roots, including the practice of *systems thinking*, ethical considerations, and support for natural processes (Kallipoliti, 2018). While such approaches may sometimes be presented as 'emerging', they were already well-established in earlier ecological design movements (Reed, 2007; Kallipoliti, 2018; Tabb, 2014). The term *'Green Building'* originally encompassed holistic sustainability principles but has arguably been re-interpreted to focus primarily on energy and resource efficiency (Rees, 2009; du Plessis & Brandon, 2015). This has prompted calls for more holistic definitions of *Green design* that go beyond mere technical solutions to address underlying structural and political challenges (Rees, 2009; Reed, 2007; du Plessis & Brandon, 2015).

To guide the transformation toward regenerative buildings, researchers have identified several core principles and practical strategies that can be incorporated into design and construction. *Regenerative Design* principles focus on creating buildings that enhance ecosystems through net-positive energy production, sustainable water systems, healthy materials, and biodiversity support, and which are implemented via site-specific features like green roofs and modular construction (Box 6.1).

Voluntary Sustainability Standards (VSS) for the design of *Green Buildings* have also made major strides in recent years. However, as leading VSS still mainly focus on reducing negative environmental impacts, rather than achieving net positive environmental outcomes (Birkeland, 2022; Liu et al., 2022), this can discourage the transformative approaches promised by *Regenerative Design*. For example, a building that reduces its energy consumption or carbon footprint might receive a high rating from a VSS, even if it makes no positive contribution to the natural environment (such as by providing more habitat for wildlife or increasing urban green space).

Furthermore, VSS that tend to emphasise more easily measured dimensions of sustainability, such as energy efficiency or water conservation, often overlook other impacts that are complex or difficult to quantify, such as biodiversity enhancement or community and social wellbeing (Cole, 2012; Chandratilake & Dias, 2013; Illankoon et al., 2017; Liu et al., 2022). Bias in favour of easy measurability can lead to a 'checkbox' approach, where proponents aim to meet only the minimum requirements for rapid certification under leading VSS, rather than pursue more comprehensive or innovative sustainability solutions for the long term.

Another methodological challenge facing *Green Building VSS* is an apparent gap between assessment metrics and ecological outcomes (Doan et al., 2017; Holz & Sigler, 2016). Analysis of design review processes reveals both progress and ongoing challenges in evaluation methods (Cole, 2012a; du Plessis & Brandon, 2015). Studies show that while VSS and other rating systems have driven improvements in building performance metrics, they are less effective at addressing environmental impacts beyond the project boundary (Chandratilake & Dias, 2013; Illankoon et al., 2019). Recent research highlights opportunities to develop assessment approaches that better integrate site-level interventions with broader ecological considerations (Hernandez-Santin et al., 2022; Kirk et al., 2024).

In response to these limitations, *Green Building VSS* could evolve to encompass more holistic approaches and nature-related metrics. For example, recent updates to prominent VSS such as LEED, BREEAM, and *Green Star* align with some *Regenerative Design* principles, including increased consideration of social equity and more attention to biodiversity and ecosystem services. By broadening their focus, these and other *Green Building* standards encourage developers and designers to go beyond mere impact reduction, towards improving both environmental and community wellbeing.

Box 6.1 Regenerative Design Principles and Implementation Strategies

General principles and strategies for the design and construction of *Regenerative Buildings* are outlined by Dumitrescu et al., (2021):

Key Principles

- Holistic integration with ecosystems (emphasising a co-creative partnership with nature)
- Healthy indoor environment and wellbeing
- Zero consumption of non-renewable energy and promotion of renewable energy sources
- Minimising carbon footprint through considered material use and waste management throughout the building life cycle
- Connection to place and local context

Implementation Strategies

- **Architectural integration:** Designing for natural light and passive solar gains with features like atriums, green roofs, and community spaces that connect with nature
- **Flexible construction:** Use of adaptable, modular systems that enable easy assembly/disassembly and future adaptability
- **Material selection:** Prioritising benign, healthy materials with low embodied energy that support and adhere to *circular economy* principles
- **Integrated performance systems:** Focusing on exceeding renewable energy needs, water reuse, biophilic features, and urban agriculture

In spite of recent progress and opportunities, the implementation of sustainable practices in the construction industry continues to face numerous challenges. The stakeholder interviews described in Chapter 5 revealed both barriers and enablers to implementing sustainability initiatives and the uptake of *Green Building VSS*.

Key barriers include:

- **Knowledge Gaps:** Limited knowledge and consideration of biodiversity within the wider construction industry, with many stakeholders describing a general lack of understanding of direct and indirect biodiversity impacts, and the connection and dependence of the built environment on nature.
- **Resistance to change:** The persistence of traditional building materials, methods, and practices, combined with a reluctance to test or implement new sustainable approaches.
- **Narrow decision-making:** Decisions are largely driven by market and economic criteria that do not consider or prioritise biodiversity, particularly when owners/clients and project teams lack a strong sustainability or nature-positive mindset.
- **Financial constraints:** The costs of implementing VSS and sustainable practices are seen as prohibitive, particularly for small and medium sized businesses. The upfront costs of sustainable practices can deter adoption, despite potentially significant long-term benefits. A desire to innovate may give way to 'value engineering' or 'practical' arguments that ultimately undermine sustainability goals.
- **Inadequate regulations:** Mandatory building standards and *Green Incentives* may be weak, disjointed or poorly enforced, while VSS may be ineffective due to low uptake, complexity, and/or high costs of implementation.

Addressing these challenges requires change in policy and practice, as well as more interdisciplinary collaboration, but also a shift in how the construction industry values its interactions with the natural environment. *Systems thinking* can help us to better understand these challenges and develop effective strategies to address them.

6.1.2 Siloed Approaches Slow Adoption of Integrated Solutions

Green Design Approaches for the construction industry have tended to emerge in a piecemeal fashion, in response to specific environmental issues (e.g. water pollution, solid waste, greenhouse gas emissions, material and resource efficiency; Cole, 2012). This approach has delivered real improvements in environmental outcomes, albeit in an unbalanced way. Thus, we see rapid advances in energy efficiency and low-carbon construction, but less progress on other environmental and social issues (du Plessis & Brandon, 2015; Reed, 2007). Government policies and international voluntary initiatives, such as the *2015 Paris Climate Agreement* and the *Task force on Climate-related Financial Disclosures* (TCFD), have played a major role in shaping these priorities, focusing attention and resources on GHG emissions reductions and energy efficiency, potentially at the expense of other sustainability concerns (Rees, 2009; Cole, 2011; Shi et al., 2016).

Despite well-intentioned international agreements, and real progress in developing policy, sustainable building practices, and tools for sustainability such as *Green Building VSS*, the evidence suggests that current approaches to sustainability in the built environment are insufficient. The building industry continues to contribute significantly to ecosystem degradation both through its direct onsite impacts and indirect effects across supply chains (IPBES, 2019).

Simply following a checklist and making buildings 'less bad' through improved resource efficiency cannot deliver nature-positive outcomes at large, especially when we consider cumulative impacts across spatial and temporal scales. Addressing impacts in isolation, without considering wider ecological, social and economic contexts, leads to an incomplete understanding of sustainability issues and their root causes. The result is fragmented implementation of partial or short-term solutions that fail to address underlying systemic issues, as well as potentially perverse, unintended consequences (Rees, 2009; Cole, 2011).

6.2 Systems Thinking for Nature-Positive Buildings

Achieving nature-positive buildings requires reconfiguring the systems that shape our built environment. Planners and designers must engage in wider efforts to reshape governance structures, transform decision-making processes, manage cumulative impacts, and develop holistic performance standards. Success ultimately depends on addressing the root causes of unsustainable development, through strategic interventions in systems of economic power and social control.

The built environment constitutes a complex web of interactions that extends beyond individual structures and their immediate surroundings. Buildings are linked to broader systems encompassing material flows, energy exchanges, human relationships, economic exchange and ecological processes. Understanding this complexity requires moving beyond approaches that treat buildings as isolated units, and embracing *systems thinking* – a perspective that deliberately considers the interconnections, feedback loops, and emergent properties within the built environment. Below, we explore how *systems thinking* can be applied to create nature-positive buildings, including for both new construction and retrofitting existing structures.

6.2.1 Principles of Systems Thinking

Systems thinking and *whole systems thinking* are distinct but complementary approaches to analysing complex systems. *Systems thinking* focuses on understanding the interconnections and dynamics within a particular system (Meadows, 2008; Checkland, 1999), while *whole systems thinking* takes a more comprehensive view. For example, *whole systems thinking* considers the built environment as part of an even larger, interconnected system shaped by multiple factors and perspectives (Blizzard & Klotz, 2012; du Plessis, 2012).

The principles of *systems thinking* include:

- **Interconnectedness:** Recognising that all parts of the system are connected and influence each other (Meadows, 2008).
- **Feedback loops:** Understanding how actions can reinforce or balance changes within the system (Senge, 2006).
- **Emergence:** Acknowledging that the system as a whole exhibits properties that its individual parts do not possess (Holland, 2014).
- **Non-linearity:** Recognising that cause and effect relationships are often not proportional or straightforward (Sterman, 2000).
- **Adaptation:** Understanding how systems change over time in response to internal and external pressures (Walker & Salt, 2006).

Whole systems thinking builds on these principles and further emphasises:

- **Holistic perspective:** Considering the entire system, rather than focusing on isolated parts (Checkland, 1999).
- **Long-term view:** Assessing the long-term consequences of decisions and actions (Bossel, 2007).
- **Stakeholder engagement:** Involving diverse perspectives in decision-making (Stasinopoulos et al., 2009).
- **Integration of multiple domains:** Considering ecological, social, and economic factors simultaneously (Capra & Luisi, 2014).

By applying the principles of *whole systems thinking* to buildings and the built environment, we can begin to address the challenges outlined above, such as limited knowledge of biodiversity, economic barriers, and siloed approaches to sustainability.

6.2.2 Interconnections Between Social, Economic and Ecological Systems

Decisions in the construction industry are heavily influenced by their social context, including the values of project clients and their teams. For example, a conducive corporate culture and supportive leadership can drive pro-biodiversity decisions for designing and constructing buildings, demonstrating the impact of social factors on ecological outcomes.

Economic considerations also play a key role. The stakeholder interviews described in Chapter 5 revealed that the upfront costs of adopting *Green Building VSS* and implementing sustainable practices are often seen as prohibitive. However, a *systems thinking* approach reveals that perceived economic constraints are deeply entwined with broader social and ecological factors. For instance, the undervaluation of nature by markets can lead to decisions that prioritise short-term financial gains over long-term ecological health and resilience (Chan et al., 2016; Pascual et al., 2017; Pascual et al., 2023). This undervaluation can manifest as limited consideration of ecosystem services and biodiversity in building design and planning processes (Gibbons & Lindenmayer, 2007).

A *systems* approach should be able to recognise and manage the diverse values of nature, while also enabling inclusive organisational cultures. The IPBES highlights the importance of adopting valuation methods that reflect the market and non-market benefits of nature, including ecosystem services, biodiversity, and cultural or spiritual values. By incorporating these broader values into cost-benefit analyses and decision-making processes, stakeholders can better justify investments in sustainable practices (IPBES, 2022b; Pascual et al., 2023).

6.2.3 Applying Systems Thinking to Biodiversity and Buildings

Applying *systems thinking* throughout a building's design and construction can help deliver more efficient, functional, resilient, regenerative, and nature-positive buildings. This requires an *Integrated Design Process* (IDP)[43] that brings together architects, ecologists, engineers, and community representatives from the start (or earliest project stages) to consider ecological, social, and economic factors, holistically. Key elements of IDP for nature-positive buildings could include long-term biodiversity monitoring, ecosystem service valuation, and economic incentives that align market interests with ecological benefits.

A *whole systems* approach to nature-positive buildings requires a comprehensive framework for analysis and decision-making, including meaningful, measurable performance indicators and reliable reporting on progress. For example, Thomson et al. (2022) propose that frameworks for restorative buildings should be rooted in ecological evidence, include quantitative indicators, and help build strong business cases; whilst Makram (2019) introduces a framework combining *Nature-Inspired Design*, focusing on eco-efficiency and biomimicry, with *Nature-Integration*, which incorporates nature into architectural spaces.

Hernandez-Santin et al. (2023) explore biodiversity's role in urban design and identify three potential roles for nature as a non-human stakeholder: passive, incidental, and active. They describe five design approaches that can position biodiversity as a stakeholder: *Adaptive Design* (emphasising scientific evaluation), *Regenerative Design* (applying living systems concepts), *Water-Sensitive Design* (utilising green infrastructure), *Placemaking* (emphasising emotional attachment), and *Ecosystem Service Design* (incorporating nature-based solutions) (Hernandez-Santin et al., 2023). The authors' proposed approach, *Biodiversity Inclusive Design* (BID), positions local biodiversity as non-human users of place, aiming to protect existing habitats while creating new wildlife spaces in urban environments. There is a growing number of different design frameworks aligned with BID practices (Hernandez-Santin et al., 2022). To enable the most effective nature-positive outcomes, it is not necessary to choose a single framework, but to find one or more that best suit the project. Some key concepts for integrating *systems thinking* into *Green Building Design* approaches are provided in Box 6.2.

Some *Green Building VSS*, such as the *Living Building Challenge* (LBC) and *Green Star*, incorporate elements of *Regenerative Design* and offer practical tools for realising nature-positive buildings, while also providing the market recognition and independent verification that are hallmarks of sustainability certification. These VSS LBC and other *Regenerative* frameworks and tools (e.g., LENSES or the *STARfish* app) encourage systems-based processes, consider the intricate relationships between the built environment and nature, and aim to create buildings that harmonise with local ecologies.

The design approaches outlined above emphasise the importance of interdisciplinary collaboration (e.g., between ecologists, First Nations representatives, and architects) to incorporate *systems thinking* into project design, whether at the urban or building scale. By engaging diverse stakeholders, including a spokesperson for biodiversity in the planning and design process, we can begin to take tangible steps towards creating nature-positive outcomes for the built environment while acknowledging the diverse values of nature in decision-making processes.

[43] *Integrated Design Process* (IDP) is a method that involves close collaboration between different disciplines to meet stakeholder requirements in a sustainable way and helps design teams avoid sub-optimal solutions by intervening early in the design process.

Box 6.2 Whole Systems Thinking for Regenerative Buildings

Regenerative Design aims to create buildings that actively contribute to regeneration of ecological, economic and social systems (Mang & Reed, 2012a). While definitions vary, key principles of *Regenerative Design* include:

- **Whole systems thinking:** Considering the interconnectedness of all elements within a system (Reed, 2007).
- **Place-based approach:** Aligning with local ecological and cultural contexts (Mang & Reed, 2012a).
- **Biomimicry:** Emulating nature's time-tested patterns and strategies to solve human challenges (Benyus, 1997).
- **Biophilic design:** Incorporating natural elements and processes into the built environment to enhance human wellbeing (Kellert et al., 2008).
- **Circular economy:** Designing out waste and pollution, keeping products and materials in use, and regenerating natural (eco)systems (Ellen MacArthur Foundation, 2013).
- **Coevolution:** Fostering mutually beneficial relationships between human and natural (eco)systems (Lyle, 1996).
- **Continuous improvement:** Embracing adaptive management and ongoing learning to enhance system performance over time (du Plessis & Brandon, 2015).

Implementing *Regenerative Design* requires planners, developers and architects to:

- **Set clear goals**: Establish ambitious, place-based goals grounded in local context and community needs (Mang & Reed, 2012b).
- **Engage stakeholders:** Involve diverse perspectives, including traditional and First Nations communities, in a collaborative design process (du Plessis & Brandon, 2015).
- **Consider multiple capacities**: Address operational, organisational, and aspirational capacities when setting project goals (Mang & Reed, 2012b).
- **Integrate living systems:** Incorporate elements such as green roofs, living walls, and constructed wetlands to provide habitat and improve environmental quality (Pedersen Zari & Hecht, 2020).
- **Design for Adaptability:** Use modular and flexible building systems that can be easily modified over time (Birkeland, 2022).
- **Prioritise sustainable resources:** Use renewable, locally-sourced materials and design for closed-loop resource cycles (Mang & Reed, 2012b).
- **Foster community connection:** Create spaces that celebrate local and indigenous culture and promote social interaction (du Plessis, 2011).

6.2.4 Embracing Indigenous Knowledge as a Foundational Concept

Engaging and empowering local communities, particularly traditional landowners and First Nations Peoples, is fundamental to creating nature-positive built environments that are socially just, culturally sensitive, and ecologically regenerative. Many traditional communities possess deep knowledge, values, and stewardship practices developed over generations of living in harmony with nature (Gammage, 2011; Pascual et al., 2023).

Indigenous Knowledge offers valuable insights for creating more sustainable and environmentally regenerative built environments, developed through millennia of observation and stewardship. In Australia alone, this knowledge spans more than 250 nations speaking over 800 dialects, unified by a cultural system with '*Country*' at its centre. The concept of *Country* extends beyond physical geography to encompass a belief system, worldview, and living knowledge repository, based on 65,000-plus years of continuous history. Central to this understanding are *Songlines*, which serve as knowledge systems and libraries, connecting sites of knowledge embodied in features of the land (Regenerative Songlines Australia, 2023).

The integration of *Indigenous Knowledge* into the built environment may be facilitated through the practice of 'Country-centred design', which follows three key principles: *Country* (land, waters, flora, fauna), *Culture* (language, identity), and *Community* (kinship, cultural practices) (AECOM, 2024). Meaningful integration demands more than mere aesthetic considerations, or sporadic or late-stage consultation. As emphasised by First Nations design specialists, engagement must begin early in the development process, with conversations starting well before development applications are submitted (GBCA, 2024c).

The first step for the building and construction industry is to develop cross-cultural competency and increase First Nations participation in the workforce (AECOM, 2024). Recent initiatives such as the NSW Government's *Connecting with Country framework* (NSW Government, 2024), together with Indigenous-led initiatives like *Regenerative Songlines Australia*, are working to create continent-wide connections that enable people to *Care for Country* while building regenerative economies and societies (Regenerative Songlines Australia, 2023). This multidisciplinary approach recognises that in *Indigenous Knowledge* systems, 'there is no separation between the animate and inanimate. Everything is living – people, animals, plants, earth, water and air' (Regenerative Songlines Australia, 2023). Such holistic understanding can help to create buildings and surrounding environments that actively contribute to the flourishing of both human and non-human life.

Going further, the building and construction industry can treat *Indigenous Knowledge* as valid technical expertise, incorporating cultural heritage as a vital element in building projects, and focusing on 'bicultural design' that recognises ancestral relationships with the environment (GBCA, 2024c). Such approaches not only support environmental sustainability but also contribute to healing historical injustices and navigating the path towards reconciliation (Hassell & GBCA, 2024).

6.2.5 The Challenge and Opportunity of Existing Buildings

While new construction offers significant potential to implement *Regenerative Design* principles, millions of buildings already exist and will be in use for years to come. One crucial challenge is to consider strategies, such as retrofitting, that will sustain and extend the useful life and occupancy of existing buildings and to incorporate features that increase climate resilience for communities as the effects of climate change and ecosystem degradation become more acute. This implies that individual or small-scale regenerative developments not only need to reduce their own negative impacts, but also help address on-going adverse impacts of existing buildings in the vicinity (Pedersen Zari, 2012; 2014).

As with new construction, the search for sustainable solutions to existing buildings may benefit from adopting a *systems thinking* approach, which considers the interconnections between buildings, supporting infrastructure, and the surrounding urban ecosystems (Webb et al., 2018). One example is *Greyfield Precinct Regeneration* (GPR), which focuses on redeveloping existing low-density suburban areas at a precinct scale, rather than only focusing on individual buildings (Newton et al., 2022). GPR can be implemented through one of two strategies: *place-activated GPR* which focuses on neighborhood regeneration, or *transit-activated GPR* which concentrates on development along transport corridors.

Central to the GPR approach is the concept of 'additionality', which means going beyond the mitigation of adverse effects. Additionality in the context of GPR implies delivering more housing with community benefits that go beyond just increasing housing density, for example by improving sustainability and livability (Newton et al., 2022). Moreover, this approach necessitates transdisciplinary collaboration among architects, engineers, ecologists, and community stakeholders to develop holistic solutions that enhance the diverse values of nature in urban environments (Croeser et al., 2021).

When it comes to the individual building scale, a key question is how to retrofit or adapt existing buildings in both a climate-resilient and nature-positive manner. Strategies for retrofitting and upgrading existing buildings to align with these objectives using *Regenerative Design* principles may include:

- **Incorporating biophilic elements**, such as green walls and roofs, to provide habitats for local flora and fauna and improve occupant wellbeing, thus enhancing both ecological and health values of nature (Kellert et al., 2008).
- **Implementing energy-efficient upgrades,** such as improved insulation, high-performance windows, and renewable energy systems, to reduce the building's carbon footprint and contribute to climate regulation (Gómez-Baggethun & Barton, 2013).
- **Adopting water conservation measures**, like rainwater harvesting and greywater recycling, to minimise water consumption and support local water cycles (Ferguson et al., 2013).
- **Integrating sustainable materials and construction techniques** during renovations and repairs to reduce waste and embodied carbon, aligning with *circular economy* principles (Pomponi & Moncaster, 2016).
- **Incorporating micro-utilities and distributed systems** for energy, water, and waste management to enhance the sustainability and resilience of existing urban areas (Newton et al., 2022).

Retrofitting existing buildings for climate resilience is increasingly important. This involves assessing vulnerabilities to climate change impacts such as extreme heat, flooding, and severe weather events, and implementing adaptive measures. These could include improving thermal performance, enhancing structural integrity, and incorporating green infrastructure and vegetation for stormwater management (Wilkinson et al., 2014).

To facilitate regenerative approaches in existing urban areas, changes in planning and governance structures may be necessary. This could include district 'greenlining', a strategic planning process for identifying priority areas for regeneration, and developing new zoning and planning overlays to enable more comprehensive urban renewal (Newton et al., 2022). Furthermore, new (or enhanced) assessment tools may be needed to quantify the benefits of regenerative projects in existing urban areas, ensuring that the additionality of these projects can be measured and validated.

Community engagement is a critical component of successful *Regenerative Design* projects, whether for new or existing buildings. The GPR approach is one example that emphasises the importance of community and stakeholder partnerships in remediating and regenerating existing urban areas, ensuring that the *Regenerative* benefits are shared equitably and that projects align with specific community needs and values (Newton et al., 2022).

6.3 Valuing Nature in the Built Environment

Creating nature-positive outcomes in (and for) the built environment requires a major shift in how we understand and value nature's contributions to humanity. In addition to economic inputs, nature provides an array of benefits spanning ecological functions, human health and wellbeing, cultural and aesthetic value. These diverse values are often overlooked or underweighted in conventional decision-making, leading to development choices that fail to protect or enhance biodiversity (IPBES, 2022b; Pascual et al., 2023). This section examines approaches to recognise, measure, and integrate nature's multiple values into construction industry practices, from economic valuation techniques to *Voluntary*

Sustainability Standards, while acknowledging the challenges and opportunities to implement more comprehensive valuation frameworks.

6.3.1 The Diverse Values of Nature in the Built Environment

Systems thinking emphasises the interconnections between components that make up the whole. This approach can inform a fuller appreciation of nature's benefits to society ('dependencies'), as well as the many ways human activities affect nature ('impacts'). These impacts and dependencies can be evaluated using both quantitative and qualitative approaches, using monetary as well as non-monetary measures.

Understanding nature's diverse values is crucial for urban biodiversity conservation, and a key goal of the CBD's *Global Biodiversity Framework* (GBF). When stakeholders recognise nature's full spectrum of benefits – from ecosystem resilience to human wellbeing – they are more likely to support meaningful conservation and restoration efforts. In the context of the built environment, this value-based approach can help justify design choices that protect and enhance biodiversity, such as preserving existing habitat or incorporating native species into landscaping.

The Nature Positive concept aims to *'halt and reverse nature loss by 2030 on a 2020 baseline, and achieve full recovery by 2050'* (Nature Positive Initiative, 2023). This target challenges the construction industry to reimagine its role and responsibility, beyond traditional *Green Building* practices toward environmentally regenerative ones. Creating nature-positive buildings requires that we recognise both the intrinsic and instrumental benefits nature provides, as well as buildings' impacts on ecosystem services (Chan et al., 2016).

Nature has diverse values (see Chapter 2). In the context of the built environment, nature's values can manifest through ecological functions supporting ecosystem resilience (Aronson et al., 2017), positive impacts on human health (Kellert et al., 2008), cultural and spiritual importance (Pascual et al., 2017), educational opportunities (Krasny & Tidball, 2015), aesthetic benefits (Gobster et al., 2007), and financial advantages like reduced energy costs and increased property values (Gómez-Baggethun & Barton, 2013). To incorporate these diverse values into the creation of nature-positive buildings, we need to:

- **Educate stakeholders** about the importance of considering the non-monetary values of nature in building design and construction;
- **Develop practical valuation methods** for buildings and/or urban developments that capture the range of impacts and dependencies on nature, including non-market values;
- **Integrate the diverse values** revealed by these methods into government and industry decision-making processes and frameworks; and
- **Establish effective policies and incentives** that recognise and meaningfully reward projects that address the full spectrum of nature's values in the built environment.

Transdisciplinary frameworks and approaches already described in this report, such as *Nature-Inspired Design, Animal-Aided Design* and *Biodiversity Inclusive Design*, can be used to help construction industry stakeholders to recognise, assess and incorporate nature's values in their decisions (Makram, 2019; Hernandez-Santin et al., 2023; Weisser & Hauck, 2017; Apfelbeck et al., 2020). Some of these are already being applied across Australia. For example, an 'action research' approach to urban planning that aims to integrate nature regeneration into development using a multi-scale design framework (for the region/city, precinct, and individual garden/building scales) is being used to preserve and expand Black Cockatoo habitat in Perth, Australia (Thomson et al., 2022).

Despite the availability of holistic frameworks and practical tools for the design of *Regenerative* buildings, uptake is limited and implementation remains challenging. Many decision-makers continue to prioritise short-term tangible and financial gains over long-term ecological health and community wellbeing (Pascual et al., 2017). To achieve meaningful progress toward nature-positive buildings, we must move beyond simply acknowledging nature's diverse values to actively embedding them in decision-making processes, financial models, and regulatory frameworks that drive on-the-ground outcomes.

6.3.2 Integrating Monetary and Non-monetary Values in Decision-Making

Many of the benefits provided by natural systems (e.g., air purification, stormwater management, mental health benefits) are ignored or underweighted in financial analysis and decision-making (Gómez-Baggethun & Barton, 2013). Part of the problem is the inherent complexity of nature's values, which include not only marketed benefits but also ecological, cultural, and intrinsic values that are not easily measured in monetary terms. As noted by Pascual et al. (2023), the diverse values of nature include:

- **Ideal values:** Abstract concepts like justice or beauty (e.g., the aesthetic value of a scenic landscape)
- **Real or objective values:** Inherent characteristics of natural objects (e.g., the carbon sequestration capacity of a forest)
- **Subjective values:** Based on human preferences (e.g., the historical or cultural significance of an ancient battlefield or sacred grove)
- **Intrinsic values:** The inherent worth of nature, independent of human valuation (e.g., the claim that all species have a right to exist)

While economic valuation techniques can reliably measure certain values, they have limitations when applied to ecosystems and biodiversity. Economic methods primarily capture exchange values but often fail to account accurately for non-market use values, option values, or the intrinsic values of nature. Additionally, economic valuation tends to focus on average or marginal changes and often fails to account for long-term impacts or nonlinear change (e.g., ecological thresholds).

A comprehensive approach to nature-positive building design and urban planning should ideally build on both monetary and non-monetary valuation methods. This may include:

- **Ecosystem service valuation techniques** that translate the benefits of nature into monetary terms that are readily understood by industry stakeholders (TEEB, 2012; United Nations, 2014; Natural Capital Coalition, 2016; NCAVES & MAIA, 2022).
- **Multi-criteria analysis (MCA)** to accommodate various types of values without relying solely on monetary metrics (Bryan et al., 2011).
- **Deliberative valuation methods** that allow stakeholders to discuss and reflect on the multiple dimensions of ecosystem values (Raymond et al., 2014).
- **Interpretive methods** to understand the cultural and symbolic meanings associated with natural elements in the built environment (Gee & Burkhard, 2010).

6.3.3 Valuing Nature in Voluntary Sustainability Standards

Voluntary Sustainability Standards (VSS) offer a practical approach to integrating nature in decision-making without necessarily relying on complex valuation techniques. While historically *Green Building VSS* prioritised categories like energy efficiency over nature (Chandratilake & Dias, 2013), many have evolved to emphasise the importance of biodiversity and ecosystem services (Doan et al., 2017; Medineckiene et al., 2015). Moreover, new certification schemes specifically focused on biodiversity have emerged, such as the *Sustainable SITES Initiative* administered by *Green Business Certification Inc.* (GBCI), which guides and certifies sustainability in landscape design and outdoor spaces (Green Business Certification Inc. [GBCI], n.d.).

In Australia, the *Green Building Council of Australia* (GBCA) has been at the forefront of efforts to promote sustainable building practices through its *Green Star* rating system. In recent years, *Green Star* has made significant strides in integrating nature-related criteria into its certification schemes, with the latest version of the rating system at the time of writing, *Green Star Buildings (v1)* (GBCA, n.d.), incorporating a dedicated *Nature* category that assesses a project's impact on biodiversity and ecosystem services (GBCA, 2021).

The *Green Star Future Focus* program introduced a dedicated *Nature* category across several rating tools, including *Green Star Buildings, Green Star Communities*, and *Green Star Performance*. The *Nature* category aims to encourage active connection between people and nature and create opportunities to deliver new natural corridors and green spaces in cities. It includes certification 'credits' that address ecological value conservation, biodiversity enhancement, nature connectivity, and nature stewardship (GBCA, 2023).

The GBCA is also developing a *Nature Roadmap for the Built Environment* that will establish goals for nature in construction, considering regional and local nature values, enhancement targets focused on demonstrated improvements rather than offsets, and the integration of traditional *Indigenous Knowledge* in ecological assessments (GBCA, 2023). In early 2024, GBCA published a discussion paper on *'a nature roadmap for the built environment'*. It responds to nature's critical role in Australia's economy by proposing a comprehensive framework built on key international standards, national regulations, and First Nations principles (GBCA, 2024a). The framework outlines five core principles (protect, connect, use low-impact materials, renew, and engage communities) applied across three areas (sites, surroundings, and supply chains), with specific roles for stakeholders from developers to First Nations communities, while emphasising biodiversity net gain and adaptation to changing expectations (Ibid.).

Additionally, the *Green Star Buildings v1.1* update represents an important evolution of the rating tool, designed to influence building design and construction through 2035 and beyond. While the update encompasses several changes, including mandatory all-electric buildings and enhanced grid interaction requirements, there is also an increased emphasis on nature and biodiversity. Nature-focused changes include rebalancing the *Nature* category with new metrics and the introduction of a *Nature Positive Pathway* that requires nature-related reporting metrics by 2026 and biodiversity net gain targets, beginning with 6-star buildings (GBCA, 2024b). The update also addresses circularity in building design and construction, clarifies the recognition of project achievements, and aligns with the NABERS Embodied Carbon methodology (Ibid.).

New nature-inclusive standards and frameworks offer promising directions for nature-positive building design. However, ensuring the rapid and wide uptake of these approaches will require addressing key knowledge gaps, increasing industry awareness of nature's multifaceted values, and developing more practical methods for integrating natural values in decision-making.

6.4 Addressing Barriers to Nature-Positive Buildings

Creating nature-positive buildings requires overcoming barriers that have historically limited progress in the adoption of *Green Building* practices. These barriers span knowledge gaps, economic constraints, cultural resistance, regulatory fragmentation, and siloed expertise. While the challenges are real, they are not insurmountable. This section examines key obstacles to implementing nature-positive approaches in the built environment and explores practical strategies to address them – from education and training programs to innovative financing solutions, leadership initiatives, regulatory reforms, and the integration of diverse expertise in project teams. By understanding and systematically addressing these barriers, the construction industry can accelerate its transition toward more regenerative and nature-positive practices.

6.4.1 Education and training for a nature-positive culture

Industry stakeholders' understanding of the impacts of the built environment on biodiversity (and vice versa) is limited, as revealed by the interviews summarised in Chapter 5. This knowledge gap can lead to persistent neglect or undervaluation of biodiversity, resulting in missed opportunities to create nature-positive buildings.

One reason for limited stakeholder understanding is the complexity of the links between the built environment and ecological systems (Pickett et al., 2013). Industry professionals may be proficient in their areas of expertise but lack even a basic understanding of ecological systems and their interactions with the built environment. As a result, standard practice tends to favour analysis and decisions that prioritise client preferences and financial considerations over ecological sustainability.

The rapid pace of change in sustainability science and technology exacerbates the knowledge challenge. Keeping up with the latest research, innovations, and emerging best practices requires continuous education and training, which may not be readily available or prioritised in professional settings (Robichaud & Anantatmula, 2011).

Education and training programs can help fill the biodiversity knowledge and awareness gap (Chan et al., 2017). Such programs should aim to increase understanding of biodiversity and foster a nature-positive culture. Key topics may include the ecology of buildings and the built environment, nature's place in sustainability, and the advantages of *systems thinking* and, where appropriate, training on monetary and non-monetary valuation methods and how they can be integrated into decision-making. On-going professional development should include continuous training on the latest sustainable technologies, best practices, and how to interpret green building standards and VSS. Education programs should highlight the interconnections between built environments, ecosystems, and human communities, and should incorporate instruction in holistic frameworks such as *Regenerative Design*, *Biodiversity Inclusive Design* (BID), and/or others such as *Animal-Aided Design* (AAD).

6.4.2 Strengthening Incentives and Sustainable Financing Solutions

The perceived high costs of implementing *Green Building* practices can lead to the prioritisation of short-term financial gains over long-term sustainability (Darko et al., 2017). This is particularly challenging when applying *systems thinking* and holistic frameworks, like *Regenerative Design*, which may require higher upfront investments but could deliver long-term benefits that are not captured by conventional market metrics.

Green Building certifications can increase property values and attract environmentally conscious buyers or tenants, but the financial return is not always apparent or guaranteed. Again, this can make it difficult for decision-makers to justify the upfront investment, especially in markets where premiums for *Green Buildings* are not well-established (Fuerst & McAllister, 2011).

Using social cost-benefit analysis (SCBA) to inform sustainable design can reveal the relative magnitude of public and long-term benefits, and help to justify the upfront investment of adopting *Green Building* practices. However, undertaking a comprehensive SCBA is complex, especially when attempting to account for the diverse, non-monetary values of nature and their distribution among different stakeholders. Such complexities may deter some industry stakeholders from considering more sustainable (or nature-positive) options (Zhang et al., 2018).

A transdisciplinary approach to building design and construction can help to overcome these barriers. Experts from different fields - including ecology, economics, architecture, and public policy - should be enabled to develop collaborative and qualitative valuations of building projects that capture the full spectrum of impacts, costs and benefits, both monetary and non-monetary, and that show how these costs and benefits are distributed among different stakeholders. Such an approach would also help educate decision-makers on the financial and non-financial benefits of sustainable practices, such as lower operating costs, higher property values, potential tax incentives, improved ecosystem services, and community wellbeing.

Innovative financing solutions that incentivise *Green Building* construction can help bridge the gap between short-term costs and long-term gains. These may include green bonds, impact investing, sustainability-linked loans and other financing instruments that align with the principles of *Regenerative Design*. By making the adoption of *Green Building* practices financially viable, we can accelerate the transition towards a nature-positive built environment.

In Australia, the *Brisbane 2032 Olympic and Paralympic Games* present a significant opportunity to demonstrate nature-positive financing at scale. According to Aurecon (2024), designing for nature positivity offers a solution to potential biodiversity degradation resulting from major sporting events. The idea is that the Games can be made nature-positive through various design initiatives, such as engaging ecologists early, considering biodiversity in regional contexts, incorporating built features for native fauna, and designing in harmony with natural features. This approach aligns with wider sustainability goals, as the Government has committed to the *Brisbane 2032* Games being *climate positive* (Queensland Government, n.d.), through the protection of unique ecosystems and investments in climate resilience.

The commitment to target 6-star *Green Star* ratings for both new and substantially upgraded venues demonstrates how public-private investment can drive higher environmental performance standards (Queensland Government, n.d.), creating a model for future large infrastructure projects not just in Australia but potentially globally. The Brisbane 2032 Olympics will be delivered through a mixed financing model combining private funding for operational costs with coordinated public investment from federal, state and local governments for infrastructure development (Australian Government, n.d.). The approach leverages existing buildings and facilities where possible, with new infrastructure projects funded through partnerships between different levels of government, private sector contributions, and local philanthropy (The Urban Developer, 2021).

6.4.3 Leadership and Cultural Change Strategies

The construction industry, like other sectors, can be resistant to change, especially when it comes to approaches that challenge traditional concepts and practices (Hoffman & Henn, 2008). The more disruptive the change, the stronger the resistance.

Cultural barriers to *Green Buildings* may include limited environmental awareness, high risk aversion, and a focus on short-term direct costs and benefits over long-term or indirect impacts (Hoffman & Henn, 2008). Additionally, the siloed nature of building design, procurement, and construction can hinder the transdisciplinary collaboration that is needed to implement more holistic frameworks (Cole, 2012).

Leadership is vital to overcome these and other cultural barriers. Leaders who understand and champion the diverse values of nature can drive cultural change within their organisations and across the industry.

This means not just promoting awareness of nature-positive approaches but also demonstrating their value through tangible examples and pilot projects (Robichaud & Anantatmula, 2011).

Strategies for cultural change include:

- Fostering a learning culture that encourages continuous education and adaptation to new sustainability concepts and practices (Senge et al., 2008).
- Promoting transdisciplinary collaboration by encouraging dialogue between stakeholders, including architects, engineers, ecologists, and community representatives (Reed, 2007).
- Implementing change management processes that address concerns and resistance at all levels of the organisation (Kotter, 1995).
- Aligning organisational values and reward systems with nature-positive principles, thereby incentivising behaviour change (Hoffman & Henn, 2008).
- Showcasing successful case studies that demonstrate the benefits of holistic approaches in terms that resonate with different stakeholders (Yudelson, 2009).

6.4.4 Integrated Governance to Address Regulatory Fragmentation

The regulatory landscape is often fragmented and provides limited support for the adoption of sustainable practices (Martek et al., 2019). Building codes, zoning laws, and environmental regulations may not be well-aligned or may even conflict, making it difficult to implement integrated, systems-based solutions that account for the diverse values of nature (Cole, 2012).

Poor coordination of voluntary and mandatory sustainability standards across jurisdictions can lead to inconsistent expectations, resulting in confusion and increased compliance costs for developers and builders operating across multiple regions. Regulatory variability is particularly challenging for multinational companies seeking to implement consistent sustainability policies and practices (Darnall & Aragón-Correa, 2014). Moreover, regulatory fragmentation can hinder *systems thinking* and the adoption of holistic *Regenerative Design* frameworks, which often require consistent and supportive regulatory environments (Reed, 2007).

Policy reform can help to align building codes, zoning laws, and environmental regulations with *Regenerative* sustainability goals and methods. This includes updating standards to mandate stronger sustainability requirements and practices that reflect a broader understanding of nature's values (du Plessis & Brandon, 2015). Regulatory policies should encourage and incentivise a *systems thinking* approach that considers the interconnections between different aspects of sustainability, including biodiversity, energy efficiency, and human wellbeing (Gibberd, 2015).

Policy incentives or requirements for nature-positive outcomes in building projects can include:

- Incorporating biodiversity and ecosystem services valuation into building approval processes (Gómez-Baggethun & Barton, 2013).
- Mandating biodiversity net gain for all new developments (Bull & Brownlie, 2017).
- Encouraging transdisciplinary collaboration in the design and planning stages of building projects (Reed, 2007).
- Developing standardised metrics for assessing the diverse values of nature in built environments (Pascual et al., 2017).

6.4.5 Integrating Diverse Expertise in Project Teams

Creating nature-positive built environments requires a collaborative effort across multiple sectors and disciplines (Reed, 2007). Urban systems and the buildings within them are complex, involving actors with competing interests and diverse perspectives. Success depends on transdisciplinary collaboration that can bring together experts from ecology, architecture, engineering, and the social sciences to co-create solutions grounded in both scientific evidence and local knowledge (Raymond et al., 2010).

To effectively integrate diverse expertise, project teams should:

- Implement Regenerative Design or Biodiversity Inclusive Design approaches that require interdisciplinary collaboration (Cole, 2012; Hernandez-Santin et al., 2023).
- Use Integrative Design Processes (IDP) that foster systems thinking and consider interconnections between project elements and their broader ecological context (Meadows, 2008; 7group & Reed, 2009).
- Ensure representation from ecology, architecture, engineering, and social sciences to advocate for ecological, cultural, social, and economic values of nature (Chan et al., 2016).
- Maintain ecological expertise throughout all project stages, including design, construction, and post-occupancy evaluation (Reed & Lister, 2014).
- Incorporate Indigenous Knowledge and local community perspectives, recognising their unique insights into ecosystem valuation (Tengö et al., 2014).
- Create opportunities for meaningful public participation in shaping built environments (van Heezik & Brymer, 2018).
- Develop shared language and goals to facilitate cross-disciplinary communication (Lang et al., 2012).
- Utilise boundary objects like ecosystem services maps, biodiversity potential (Kirk et al. 2024, in press) and biodiversity impact assessments as common reference points.
- Create platforms for knowledge exchange and lessons learned across disciplines (Lang et al., 2012).
- Implement knowledge co-production processes that integrate scientific and local (including Indigenous) expertise (Norström et al., 2020).
- Use adaptive management approaches that allow for learning and adjustment throughout the project life cycle (Allen et al., 2011).

Successful implementation requires that designers serve as integrators of diverse information and perspectives. When combined with academic research, this approach enables rapid feedback and innovation. Tools such as simulations, models, and ecological indices can provide valuable insights for implementation (Hernandez-Santin et al., 2022; 2023).

6.5 Progress Towards Nature-Positive Buildings

While the challenges of creating nature-positive buildings are substantial, several projects across Australia demonstrate that transformative change is not only possible but already underway. From individual buildings to large-scale urban developments, innovative projects are showing how *Regenerative Design* and *systems thinking* can be successfully implemented to enhance both human and ecological wellbeing.

This section describes four case studies that exemplify different approaches to nature-positive building practices – the *Sustainable Buildings Research Centre* (SBRC), *Barangaroo South*, the *Exchange Precinct* at Curtin University, and *The Paddock* Eco Village. Each project illustrates how principles like *whole systems thinking*, biomimicry, and biophilic design can be applied at different scales to create built environments that actively contribute to ecological regeneration and community wellbeing.

6.5.1 Case Study: Sustainable Buildings Research Centre (SBRC)

The *Sustainable Buildings Research Centre* (SBRC) at the University of Wollongong is a multi-disciplinary facility designed to address the challenges of making buildings sustainable and effective. Completed in 2013, the 2,491 square meter building serves as a living laboratory for sustainable building technologies

(ILFI, n.d.-b). It was the first, and is still, at the time of writing, the only, fully *'Living Building'* certified building in Australia (COX, n.d.).

Sustainability Rating Tools

The SBRC achieved *Living Certified* status under the *Living Building Challenge* (LBC) version 2.1, which guided the design and implementation of sustainable features throughout the project (COX, n.d.). In April 2024, the SBRC celebrated 10 years of enduring performance in maintaining *Living Certification* (recertification is required every three years).

Key Regenerative Features

- Net-zero energy and water consumption
- On-site renewable energy generation through a 160 kW solar PV array
- Rainwater harvesting and blackwater treatment systems
- Use of recycled and locally sourced materials
- Extensive native landscaping and urban agriculture
- Biophilic design elements integrated throughout the building (ILFI, n.d.-b).

Alignment with Regenerative Design Principles

The SBRC demonstrates *whole systems thinking* by integrating various systems (energy, water, waste) to create a sustainable environment. It adopts a place-based approach by acknowledging the local climate and incorporating indigenous vegetation. The building's systems mimic natural processes, such as water filtration through constructed wetlands, exemplifying biomimicry. The project emphasises material reuse and recycling, aligning with *circular economy* principles. Biophilic design is evident in the incorporation of natural daylight, views, and green spaces. The SBRC acts as a living laboratory, fostering co-evolution of research and innovation in *Green Building* practices, while its design accommodates ongoing research and adaptation of new technologies, supporting continuous improvement (ILFI, n.d.-b).

6.5.2 Case Study: Barangaroo South

Barangaroo South is a large-scale urban renewal project in Sydney, encompassing 7.5 hectares of mixed-use development, including commercial, residential, and retail spaces. The project aims to be Australia's first large-scale carbon neutral precinct (GBCA, 2022b).

Sustainability Rating Tools

Barangaroo South achieved a 6 Star *Green Star - Communities* rating, scoring an unprecedented 104.98 out of 110 points. The *Green Star* certification process guided the implementation of sustainable practices across the precinct (GBCA, 2022b).

Key Regenerative Features

- Carbon neutral operations through energy efficiency and offsets;
- District cooling plant using harbour water for heat rejection (instead of releasing waste heat into the air, like traditional cooling towers);
- On-site renewable energy generation;
- Centralised waste management system with 19 distinct waste categories;
- Water recycling and reuse systems;
- Extensive public spaces and green areas (GBCA, 2022b; Barangaroo South, n.d.).

Alignment with Regenerative Design Principles

Barangaroo South demonstrates whole systems thinking by integrating various urban systems to create a sustainable community. It adopts a place-based approach by acknowledging the site's harbour location and incorporating it into the cooling system. The waste management system aims for zero waste emissions and high recycling rates, aligning with *circular economy* principles. The project incorporates extensive green spaces and connections to the harbour, exemplifying biophilic design. It fosters co-evolution through a relationship between urban development and natural systems, and includes ongoing monitoring and adaptation of sustainability practices, supporting continuous improvement (GBCA, 2022b; Barangaroo South, n.d.).

6.5.3 Case Study: Exchange Precinct at Curtin University

The *Exchange Precinct* at Curtin University in Perth is a mixed-use development that features student accommodation, a boutique hotel, 30 apartments, alongside 3,000 square meters of educational space and 800 square meters of retail areas (*Curtin University Exchange Precinct*, n.d.). The project aims to create a sustainable hub for residents, students, and visitors (cefc, n.d.).

Sustainability Rating Tools

The precinct received a 6 Star *Green Star - Communities* certification, demonstrating leadership in sustainable community development (Realm Studios, 2022).

Key Regenerative Features

- Retention of key stands of iconic pines, supporting the endangered Carnaby's Black Cockatoo
- Water-sensitive urban design including a 700 kL rainwater harvesting system
- Extensive use of native and bush tucker plant species in landscaping
- Biophilic design elements integrated throughout the precinct
- Enhanced end-of-trip facilities to encourage low-emissions travel (Realm Studios, 2022; cefc, n.d.)

Alignment with Regenerative Design Principles

The *Exchange Precinct* demonstrates *whole systems thinking* by integrating various functions (education, living, retail) in a holistic environment. It adopts a place-based approach by respecting and enhancing local ecology, particularly through plant selection. The landscaping mimics local ecosystems to support biodiversity, exemplifying biomimicry. The project incorporates natural elements throughout, and connects people with nature through biophilic design. It fosters co-evolution through a mutually beneficial relationship between the university community and the local ecosystem, and includes ongoing monitoring of environmental performance, supporting continuous improvement (Realm Studios, 2022; cefc, n.d.).

6.5.4 Case Study: The Paddock Eco Village

The Paddock is a cluster housing development in Castlemaine, Victoria, designed to challenge conventional development practices while enhancing social connection and biodiversity. The project includes 27 dwellings arranged around stepped productive gardens (The Paddock, n.d.; Crosby Architects, n.d.).

Sustainability Rating Tools

The project was registered with the *Living Building Challenge*, which guided many of its sustainable and *Regenerative* features (Crosby Architects, n.d.).

Key Regenerative Features

- High-density, low-impact housing design
- Food production systems integrated into residential development
- Native landscaping to enhance local biodiversity
- Community-driven governance and management systems
- Water-sensitive urban design and rainwater harvesting
- All-electric homes with solar PV systems (The Paddock, n.d.; Contributive Practice, 2021)

Alignment with Regenerative Design Principles

The Paddock demonstrates *whole systems thinking* by integrating housing, food production, and community systems. It adopts a place-based approach by respecting and enhancing the local ecology and community context. The landscape design emulates natural ecosystems to support biodiversity, exemplifying biomimicry. *The Paddock* emphasises local food production and resource recycling, aligning with *circular economy* principles. It incorporates extensive green spaces and connections to nature, demonstrating biophilic design. The project fosters co-evolution through a symbiotic relationship between residents and the local ecosystem, while the community governance system allows for ongoing adaptation and learning, supporting continuous improvement (The Paddock, n.d.; Contributive Practice, 2021; Crosby Architects, n.d.).

6.6 Paving the Way for Nature-Positive Buildings

A transition to nature-positive buildings requires a shift in how we conceive, design, construct, and operate built environments. This Chapter explored the challenges and opportunities in achieving this transition, emphasising the need for systemic approaches that recognise the complexities and interdependencies between buildings, communities, and ecosystems.

While the *Green Building* movement has made significant strides in recent years, multiple barriers continue to impede the construction industry's ability to achieve truly sustainable or nature-positive outcomes. These barriers span individual, organisational, industry, and societal levels, ranging from insufficient knowledge and understanding of biodiversity to misaligned economic incentives and inadequate regulatory frameworks.

To overcome these challenges, we highlight the importance of adopting *systems thinking* and *whole systems* approaches. These perspectives allow us to better understand and manage the intricate relationships between various aspects of sustainability, including biodiversity, energy efficiency, and human wellbeing. Frameworks such as *Regenerative Design*, *Biodiversity Inclusive Design*, and *Animal-Aided Design* offer promising pathways for integrating ecological considerations into building practices.

We also highlight the critical need to recognise and incorporate the diverse values of nature into decision-making processes. This involves not only considering the financial benefits of ecosystems but also acknowledging the cultural, spiritual, and intrinsic values of biodiversity. By adopting more comprehensive valuation methods and metrics, we can make more informed decisions that balance human needs with ecological health.

The case studies presented above demonstrate that nature-positive buildings are not just theoretical concepts but achievable realities. Projects like the *Sustainable Buildings Research Centre, Barangaroo South*, the *Exchange Precinct* at Curtin University, and *The Paddock* Eco Village showcase innovative approaches to integrating biodiversity considerations into building design and urban planning at various scales.

Addressing the challenges of creating nature-positive buildings will require sustained collaboration and commitment from all stakeholders in the construction industry. This includes governments, civil society organisations, knowledge institutions, financial institutions, and industry itself. It will necessitate continued innovation in materials and technologies, reform of policies and regulations, and a cultural shift towards valuing nature in all its forms.

The following and final Chapter sets out a checklist of recommendations for construction industry stakeholders, as well as an agenda for future research and development, and a plea for collective action to advance nature-positive buildings.

Chapter 7 - Conclusion & Recommendations: Towards Nature Positive Buildings

Chapter 7 synthesises the findings of this report and presents recommendations for creating biodiversity-friendly (or 'nature-positive') buildings. It reviews the various environmental challenges facing the construction industry and emphasises the need for a *whole systems* approach to biodiversity. We present 27 specific recommendations for action, organised under five themes:

- Reduce Threats to Nature
- Conserve and Restore Biodiversity
- Innovate and Share Knowledge
- Govern with Nature in Mind, and
- Foster a Nature-Positive Culture

The Chapter also identifies priorities for future research and development, including the creation of better tools to integrate biodiversity conservation in building processes, assessment of nature-based solutions, development of innovative financing mechanisms, and revision of educational programs. The Chapter concludes by emphasising the need for collective action across all sectors of society to accelerate the shift towards more sustainable, regenerative, and ecologically-minded planning, design, and construction.

7.1 Conclusion: Towards a Nature-Positive Built Environment

The urban built environment is a complex system – socially, economically and technologically. It is a constructed system, comprising cities and their constituent neighbourhoods, individual buildings, and vast infrastructure networks for transport, water distribution and sewerage, supply of energy, food and other products, and waste management (Batty, 2008). Built environments are not only massive in scale, they are also multi-layered with complex government, economic, technological, environmental, societal, and behavioural relationships.

When the built environment and its interactions are considered in relation to the living systems of the natural world, an even more complex picture emerges. This complexity is accentuated by a rapidly evolving and increasingly unpredictable world, due to climate change, pandemics and other risks (Alberti et al., 2008).

Consideration of biodiversity adds more complexity. As discussed in Chapter 2, biodiversity is crucial for maintaining essential ecosystem services and has intrinsic value (Dudley, 2024). Unfortunately, human activity has resulted in significant declines in biodiversity, while also altering the global climate. While we all rely on nature for survival (Steffen et al., 2015), decisions that affect nature are often based on narrow economic reasoning or financial considerations, neglecting the many other ways in which people connect with each other and with nature (Pascual et al., 2023; Chan et al., 2016; Ives et al., 2018).

Turning to the built environment, Chapter 3 described how conventional practices have led to unrestricted urban sprawl, use of carbon-intensive and water-intensive building materials and construction methods, minimal effort to reduce, recover, reuse or recycle resources, limited concern for energy efficiency or renewable energy sources, and careless introduction of invasive, non-native plant species in landscaping. The building design and construction industry tends to focus on complying with minimum building regulations, and are influenced more by private profitability than community amenity or environmental stewardship (Hallegatte et al., 2019; Nilon et al., 2017; Zari, 2018). The outcome is ongoing and widespread habitat conversion, waste and pollution, natural resource depletion, and the disconnection of the built environment and its occupants from local ecologies.

Chapter 4 reviewed efforts to improve sustainability in the built environment, through regulatory reforms and voluntary sustainability initiatives. As a result of these efforts, planning and development decisions for the built environment are increasingly influenced by economic, social, and environmental considerations. The *Green Building* design movement has made major strides, including the development of *Voluntary Sustainability Standards* (VSS) - encompassing various frameworks, rating systems and tools - as well as new technologies and materials that can reduce the environmental impact of buildings (Kibert, 2016).

Nevertheless, many barriers continue to hinder the industry's ability to achieve sustainable or nature-positive outcomes in the built environment. Interviews with industry stakeholders, described in Chapter 5, reveal a complex interplay of barriers and enablers across individual, organisational, industry, and societal levels. Insufficient knowledge and understanding of biodiversity, absence of motivating factors, misaligned economic incentives, disciplinary silos, financial constraints, limited market interest and demand, and inadequate regulatory frameworks and building codes for sustainable construction are just some of the hurdles facing green building design and construction (Hoffman & Henn, 2008; Darko & Chan, 2017; Olubunmi et al., 2016; Zhang et al., 2018). Other themes that emerged from interviews with industry stakeholders include the need for innovation on sustainability and the limits of VSS.

As we strive to mitigate the effects of climate change and address environmental degradation more broadly, it is clear that the construction industry is moving in the right direction but needs to move much further and faster. Overcoming barriers requires a shift in how we conceive, design, construct, and operate our built environments. As discussed in Chapter 6, reductionist and linear thinking must give way to circular, whole-systems approaches that recognise the complex interdependencies between buildings, communities, and ecosystems (du Plessis, 2012). *Regenerative Design* principles can support this transition, by focusing on improving the health and resilience of socio-ecological systems (Hes & du Plessis, 2014). However, translating *Regenerative* principles into mainstream practice requires concerted effort on multiple fronts. We can take inspiration from the growing number of buildings where *systems thinking*, *Regenerative* principles and nature-positive approaches are put into practice.

7.2 Recommendations for Nature-Positive Buildings

Efforts to create nature-positive buildings must be informed by the CBD's *Global Biodiversity Framework* (GBF) and the principles of *Regenerative Design*. Both can serve as practical frameworks and share a common goal of creating a sustainable and resilient future by working with nature, conserving biodiversity, engaging stakeholders, and promoting sustainable resource use. Both the GBF and *Regenerative Design* emphasise the importance of respecting traditional ecological knowledge, building capacity, sharing knowledge and continuous improvement. By applying principles such as eliminating waste, creating positive impact, and fostering a nature-positive culture, buildings can contribute to the health and resilience of both ecological and human communities, aligning with the overall vision set forth in the GBF.

Creating nature-positive buildings is not the responsibility of one group of stakeholders in the construction industry. It requires sustained collaboration and commitment from all stakeholder groups, including governments, civil society organisations, First Nations peoples, knowledge institutions, financial institutions, and the construction industry itself (Table 7.1).

Table 7.1 Who Should Deliver Nature Positive Buildings?

Sector / Industry	Actors / Stakeholders
Government	National, regional and local government, regulators and other authorities (e.g., building codes and standards), state-owned companies, international organisations and agreements (e.g., CBD), public training institutions, political parties.
Civil Society	NGOs, private foundations, First Nations and community groups, labour unions, faith-based organisations, advocacy and awareness-raising campaigns, *Voluntary Sustainability Standards*, citizens.
Knowledge development and dissemination	Science, academia and industry innovation; data, measurement and information providers; materials and technology R&D experts; specialised and general media.
Finance	Banks, asset managers, brokers and traders, financial analysts, insurance and reinsurance companies, investors, data providers and other financial services.
Building and Construction	Architects, engineers, designers, planners; property developers, advisers, consultants, brokers; builders and building contractors; building materials and product suppliers; property industry and professional associations; facilities operators and maintenance; building owners, users, occupiers.

To be *Nature Positive*, buildings must not only prevent further loss of biodiversity during and after construction, but also contribute to biodiversity recovery and human wellbeing (Garrard et al., 2018; Kirk et al., 2021). Priority actions to deliver nature-positive buildings should include avoiding habitat conversion; creating new (or remediating existing) habitat for target species; minimising disturbance, pollution, and other threats to biodiversity; adaptively reusing and retrofitting existing buildings where possible; greater consideration of nature's values and circularity when selecting or using materials; addressing climate change and nature in an integrated way; and adopting socially-responsible *Nature-based Solutions* (NbS) to protect and restore nature (WBCSD, 2023a, 2023b). Integrating such approaches into the planning and design process at the start of a project, rather than as an afterthought, can improve building performance and increase synergies between ecological and societal goals (Wamsler et al., 2020).

We offer below 27 recommendations for actions to deliver buildings that advance nature-positive outcomes, organised under five themes:

- Reduce Threats to Nature
- Conserve and Restore Biodiversity
- Innovate and Share Knowledge
- Govern with Nature in Mind
- Foster a Nature-Positive Culture

These themes aim to frame a holistic approach to integrating biodiversity considerations into the built environment, from practical construction methods to policy-making and cultural shifts. For each recommendation, we provide examples of how it may be delivered. These examples are not exhaustive but are simply intended to illustrate the range of possibilities, suggest targets and/or benchmarks, and inspire further innovation. Importantly, our recommendations are not meant to be prescriptive or one-size-fits-all solutions. Rather, they should be adapted and applied in ways that are appropriate to the specific context and needs of each project, taking into account factors such as local ecological conditions, cultural values, and socio-economic realities.

7.2.1 Reduce Threats to Nature

This theme focuses on minimising the negative impacts of construction and building operations on biodiversity. It includes recommended actions such as avoiding development in high biodiversity areas, prioritising the *Adaptive Reuse* of existing buildings, adopting *circular economy* principles, using verified sustainable materials, and managing construction sites to protect biodiversity.

The actions listed under this theme are a necessary starting point for most industry stakeholders but they should not be the end of the story. Efforts to reduce direct and indirect impacts on nature must be complemented by broader actions, detailed under other themes, to address legacy and cumulative impacts on nature, and the underlying structural drivers of biodiversity loss.

Recommendations	Examples
1. Avoid development in areas of high biodiversity value to maintain habitat. Cluster developments and promote densification.	• Conduct impact assessments to identify critical habitats and biodiversity potential prior to clearing or construction • Adopt whole-system impact assessment approaches • Designate protected areas and biodiversity corridors prior to development to facilitate wildlife dispersal • Incentivise urban infill (development of vacant parcels in built-up areas) and brownfield redevelopment over greenfield development
2. Prioritise *Adaptive Reuse* over the demolition of existing buildings, to conserve resources.	• Retrofit and repurpose under-used office or industrial buildings as residential units • Convert abandoned factories into cultural or community spaces • Refurbish and reclad structurally sound buildings
3. Adopt *circular economy* principles to eliminate waste, reuse materials, and design for durability and disassembly. Specify locally-sourced goods and materials when possible.	• Use modular construction for easy fabrication, to reduce waste, and allow for future disassembly and reconfiguration • Incorporate salvaged materials and components • Source stone, timber, etc from local/regional suppliers

4. Adopt responsible material selection and procurement practices. Manage supply chains to address indirect social and environmental impacts based on improved traceability of products and materials.	• Incorporate sustainability criteria into purchasing, such as specifying credibly certified, non-toxic materials for construction and fitout. • Where possible, select recycled and bio-based options that reduce emissions, sequester carbon and require less resource extraction, such as hempcrete, certified sustainable timber, or low-carbon material construction systems • Implement supply chain traceability systems that verify social and environmental performance through transparent material sourcing documentation, regular supplier audits and supplier training/support.
5. Manage construction sites to minimise disturbance and protect biodiversity. Adhere to relevant biosafety protocols.	• Minimise soil erosion and control water runoff • Minimise the spread of invasive species by discouraging planting of problematic weeds and use of fertilisers • Reduce and recycle waste to avoid landfill • Reduce pollution from all sources • Prevent unintentional environmental exposure to toxins, or their accidental release
6. Avoid impacts that affect surrounding habitats and ecosystems by addressing stormwater management, preserving urban vegetation, and minimising dust generation, noise, and light pollution.	Adopt Biodiversity-sensitive and/or Water-sensitive urban design principles, such as: • Bioswales and permeable paving to reduce runoff • Manage stormwater runoff to prevent soil erosion • Orient buildings to minimise overshadowing of vegetation • Downlighting to prevent light pollution and reduce glare
7. Avoid using fossil fuels to reduce GHG emissions. Adopt renewable energy sources at all stages of the building life cycle.	• On-site solar PV and wind turbines to provide power for operational energy • Renewable energy to power onsite plant and construction activities • Renewable energy offsets for embodied emissions

7.2.2 Conserve and Restore Biodiversity

This theme emphasises the importance of preserving existing ecosystems and actively improving biodiversity. Recommendations include conducting thorough site analyses, retrofitting buildings with green infrastructure, conserving native vegetation, designing for habitat creation, and compensating for unavoidable impacts through off site restoration.

Recommendations	Examples
8. Conduct thorough site analysis to understand local ecosystem, climate, culture, and community needs, and use this data to guide project design and decision-making.	• Assess local biodiversity, habitat types, and ecological processes • Implement robust baseline assessment methods • Engage with local communities to understand their needs, values, and traditional knowledge • Design projects to respond and integrate with local ecological and cultural contexts • Develop or adopt metrics that can reliably assess nature-positive outcomes
9. Retrofit existing buildings by adding green infrastructure and habitat features to support wildlife and natural processes (e.g. pollination).	• Planters, native gardens • Green façade scaffolding • Green roofs, rain gardens • Ponds and water features
10. Conserve existing native vegetation and restore degraded ecosystems to maintain and create habitat and facilitate wildlife movement.	• Establish buffer zones around sensitive areas • Restore degraded habitats on-site • Restore disturbed adjacent off-site habitats • Preserve stands of established trees, native shrublands and grasslands, or remnant forests in designated urban areas • Support landscape-scale conservation initiatives
11. Design buildings and landscaping to increase or improve habitat for native species, including public spaces, transport networks.	• Use indigenous plants in landscaping • Green roofs and accessible roof terraces • Living walls • Rain gardens • Wildlife crossings
12. Compensate for verified unavoidable residual impacts through offsite habitat restoration, or by funding the protection of genuinely threatened areas.	• Invest in high integrity biodiversity offsets • Project budgets should include funding to conservation land trusts/organisations • All projects should include effective rehabilitation of degraded onsite and/or adjacent natural areas

7.2.3 Innovate and Share Knowledge

This theme encourages research, development, and knowledge sharing in the field of *Regenerative Design* and *Green Building* practices. It includes investing in research for nature-based materials and technologies, contributing to biodiversity science, educating building users about local biodiversity, and designing buildings to be resilient to climate impacts.

Recommendations	Examples
13. Invest in research into alternative, nature-based materials, technologies, and strategies for sustainable design.	• Advance integrated assessment tools • Conduct R&D into advanced wood/bamboo construction systems • Develop bio-based building materials e.g., bio-cement, mycelium panels • Promote and experiment with biomimetic and *Regenerative Design* practices and methodologies
14. Share knowledge and contribute data to continuously improve biodiversity science, benchmark monitoring and facilitate active stewardship	• Open-source sharing of environmental data • Foster academic/industry research partnerships and cross-sector collaboration • Encourage/sponsor citizen science biodiversity monitoring by building occupants and local community
15. Facilitate positive human-nature interactions and educate the local community, building users and occupants about on-site and surrounding biodiversity values.	• Install interpretive signage, trails, viewing platforms, etc, to emphasise nature highlights and encourage low-impact use and enjoyment • Offer biodiversity educational tours/programs • Share information via digital media about local ecosystems
16. Design buildings to be resilient to climate impacts, using passive design principles and nature-based solutions.	• Maximise natural cross-ventilation and sun shading • Incorporate shading, vegetation and water feature elements to promote passive cooling • Use permeable pavement surfaces and green infrastructure for flood mitigation

7.2.4 Govern with Nature in Mind

This theme addresses the policy and management aspects of biodiversity in the built environment. It includes setting ambitious biodiversity targets, fostering collaboration across stakeholders, reforming policies that harm biodiversity, using economic incentives to promote sustainable practices, and establishing robust monitoring, management and decision-making processes that account for system-wide impacts.

Recommendations	Examples
17. Set ambitious biodiversity targets. Regularly assess and disclose biodiversity impacts and dependencies. Promptly integrate new conservation science into development planning.	• Establish science-based targets for nature that are independently verified • Annual public disclosure of biodiversity impacts and responses • Dedicated in-house biodiversity specialists • Monitor and manage cumulative environmental impacts
18. Foster multi-disciplinary and community collaboration across the building supply chain. Involve a wide range of stakeholders in participatory project planning. Celebrate industry leadership on biodiversity conservation.	• Engage stakeholders through design charrettes • Hold regular public meetings to solicit community input, and report on actions taken • Sponsor industry awards/recognition for biodiversity leadership in the built environment
19. Reform policies, zoning, codes and harmful incentives that exacerbate biodiversity loss. Adopt a precautionary approach to building and development policy.	• Reform planning regulations to restrict development in environmentally sensitive areas • Require independent and public biodiversity impact assessments for development approvals • Require that developers demonstrate their projects will have no net harmful environmental impacts
20. Use economic incentives to reduce the risks and costs of adopting *Green Building* principles, as well as taxes or sanctions to penalise unsustainable practices and use of materials that result in adverse impacts.	• Offer financial incentives to encourage *Green Building* designs, sustainable construction methods and material choices, that align with positive ecological outcomes • Discourage the use of energy- and resource-intensive construction methods and materials (e.g. impose taxes on waste or materials with high embodied carbon content) • Issue *Green Bonds* to raise dedicated finance for *Green Building* projects
21. Establish robust monitoring and reporting systems to track key biodiversity indicators, such as species richness and abundance, habitat quality, and ecosystem services, and use this data to continuously improve project performance, inform future designs and benchmark projects.	• Set clear, measurable biodiversity targets and indicators • Conduct regular biodiversity surveys and assessments • Use monitoring data to adapt management practices and inform future project designs • Publicly report on biodiversity performance and progress towards targets

7.2.5 Foster a Nature-Positive Culture

This theme focuses on shifting mindsets and values to prioritise biodiversity to foster a nature-positive culture and behaviour. It includes providing training on ecological ethics, questioning outdated, harmful practices, enabling deep reflection on values, advocating for biodiversity conservation at all levels, rethinking human control of nature, and fostering cross-disciplinary processes.

Recommendations	Examples
22. Provide training on biodiversity, ecological ethics, and sustainability for construction industry professionals.	• University degree programs, including field studies, focused on these topics • Cultural Heritage and Indigenous land management practices integrated in core curriculum and ideally delivered by *Indigenous Knowledge* holders • Continuing education courses and certifications, including on-site training and 'toolbox talks' during construction, and place-based learning experiences guided by Traditional Owners on *Country*
23. Question assumptions and outdated, harmful practices. Be willing to change established methods and traditional techniques.	• Critically examine business-as-usual approaches • Build a better understanding of systemic impacts • Research, test and validate innovative *Green Building* techniques • Engage young professionals to re-think and reinvent conventional practices • Partner with Traditional Owners to understand local ecological systems and seasonal indicators
24. Enable deep reflection to re-evaluate values, motives, and assumptions driving biodiversity decline.	• Company values/vision exercises and workshops • Invite ethicists, philosophers, Indigenous leaders to provide alternative perspectives • Personal/professional coaching to shift the motivations, assumptions and core values that may drive behaviours harmful to biodiversity. • Partnerships with Traditional Owner groups for ongoing dialogue and knowledge exchange
25. Advocate for biodiversity conservation to be a core mandate at all levels of decision making in both the public and private sectors.	• Advocate for stronger environmental regulations and enforcement • Push for biodiversity to be embedded in corporate strategy at all levels • Encourage financiers to require regular biodiversity risk disclosure by clients • Ensure Indigenous voices are represented in policy development and implementation

26. Rethink human control of nature; recognise nature's intrinsic rights and diverse values	• Learn from Indigenous communities about human/nature balance and stewardship • Incorporate the rights of nature and concepts like ecological jurisprudence into rules/policies and practices • Value nature's existence as a stakeholder, independent of human utility
27. Foster cross-disciplinary and participatory processes	• Integrated multi-disciplinary Project Teams, including ecologists and *Indigenous Knowledge* holders, from conception through completion • Regular public participation in planning and feedback forums throughout the project lifecycle • Establish robust Indigenous engagement protocols and partnership frameworks

Creating a nature-positive built environment is not a one-off action but an ongoing process of learning, experimentation, and adaptation. As our understanding of the interactions between the built environment and natural systems continues to evolve, so too must our approach and strategies to facilitate integration. By embracing a culture of continuous improvement and innovation, and by staying attuned to the changing needs and values of both human and non-human stakeholders, we can ensure that our buildings and built environments remain resilient, regenerative, and responsive to the challenges and opportunities of the 21st century.

7.3 Future Research and Development Priorities

Our recommended actions to deliver buildings that advance nature-positive outcomes, set out above, are based on our current understanding of challenges and opportunities. Undoubtedly, progress would be faster if we had better information and more effective tools. To advance and accelerate the transition towards nature-positive buildings, several research and development opportunities stand out:

- **Create or strengthen tools to integrate biodiversity conservation**, ecosystem services, *Traditional Ecological Knowledge* and social wellbeing in the planning, design, construction, and operation of buildings.
- **Assess the performance of Nature-based Solutions** in the built environment. Interventions such as green roofs, living walls, urban forests, Indigenous design and related options should be evaluated in representative contexts, at various scales, in terms of their cost and impacts on biodiversity, ecosystem services, human wellbeing, and climate resilience.
- **Develop and test innovative and socially equitable financing mechanisms** to incentivise nature positive buildings at all stages of the building life cycle. This may include *Green* or environmental impact bonds, performance bonds, targeted tax incentives, biodiversity offsets and credits, or other mechanisms intended to monetise the value of biodiversity and ecosystem services.
- **Revise teaching and training to integrate nature** into educational programs in architecture, engineering, and planning, including the concepts and tools of *Regenerative Design*, biophilic design, and ecosystem services. Develop professional education and capacity building opportunities, in partnership with *Indigenous Knowledge* holders, so practitioners stay informed about the nature-positive research, tools, and best practices for the built environment.

- **Inform the development and implementation of policies and regulations** to support the transition to a nature-positive built environment. This may include empirical research on the effectiveness of green building standards, land-use planning policies, and/or incentives for regenerative retrofits.
- **Develop and test participatory planning and design** processes to engage communities, including meaningful partnerships with Traditional Owners and marginalised groups, in the creation of nature-positive buildings. Research the social and cultural dimensions of *Regenerative Design* and identify best practices for fostering a shared sense of stewardship and connection to nature.
- **Develop credible monitoring and evaluation frameworks** to assess the performance of nature-positive building projects over time. These frameworks should incorporate *Indigenous Knowledge* and include indicators to monitor biodiversity, ecosystem services, human wellbeing, and socio-economic outcomes at whole-system scale, as well as mechanisms for adaptive management and continuous improvement across spatial and temporal scales.
- **Foster collaboration and knowledge-sharing** by establishing networks and platforms for exchanging ideas, best practices, and lessons learned, and for coordinating research and action agendas on nature-positive buildings. Networks should be accessible to researchers, practitioners, policymakers, Traditional Owners, and community stakeholders from diverse disciplines and sectors, including architecture, engineering, ecology, social sciences, and the arts.

7.4 The Need for Collective Action

We live in a dynamic, fragile and increasingly interconnected world that is becoming harder to understand using concepts and tools developed for a simpler time. Indeed, many of the global environmental challenges we face today are at least partly the result of failure to understand the interconnections between different components of the complex socio-ecological systems we inhabit.

Halting biodiversity loss requires more *systems thinking*, grounded in a strong environmental ethic that recognises our interdependence with nature. A profound shift towards sustainable, regenerative, and ecologically-minded planning, design and construction is necessary but has hardly begun.

Creating nature-positive buildings starts with acknowledging the diverse values of nature and the varying perspectives of different stakeholders, including Traditional Owner relationships with *Country*, as well as the intrinsic rights of biodiversity. The transition to a nature-positive built environment requires collective effort by all sectors of society.

It also requires challenging conventional wisdom, taking risks, and learning from both successes and failures. The potential rewards of this transition are immense: a world in which people and nature thrive together, cities are engines of regeneration and resilience, and buildings are a source of natural beauty, meaning, and inspiration for generations to come.

The path towards nature-positive buildings offers not just challenges, but immense opportunities. By embracing a regenerative and whole systems approach, we have the potential to create buildings that both minimise harm to nature and actively contribute to its regeneration. In doing so, we can build cities and communities that are more resilient, healthier, and more deeply connected to the natural world upon which we all depend.

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Appendix 1

Research methodology: Web of Science search terms

The following tables show the search terms that were used to extract academic publications from the *Web of Science*. We conducted 2 separate enquiries: (1) the construction industry's impacts on biodiversity and (2) the role of *Voluntary Sustainability Standards* (VSS) in the construction industry.

For the first question, a literature review conducted using *Web of Science* identified 1,163 unique publications with keywords related to urban sustainability, building construction, operation, or demolition. A 5% random sample (60 papers) was selected for detailed review. Analysis of the sample revealed that climate and carbon-related studies dominated the literature (38% of citations), while biodiversity and species-related papers were significantly under-represented at around 5%. Even within the biodiversity-focused papers, many primarily discussed green roofs and façades as climate change mitigation strategies rather than for biodiversity conservation.

Search terms for biodiversity impacts at different stages of the building life cycle	Date run	Results
TOPIC: (((*urban*) AND (sustainab*) AND (impact* OR mitigat* OR footprint) AND (building*))) AND TOPIC: (((architectur* OR design) OR ("building *construction" or "construction of") OR ("building operation" OR "maintenance" OR "operational") OR (demolition OR "end of life") OR (waste OR recycl* OR disposal)))	10/04/2021	1163
Results refined:		
FOR CLIMATE CHANGE		
(climate change) OR (emission*) OR carbon OR greenhouse	10/04/2021	446
FOR BIODIVERSITY		
biodiversity OR species	10/04/2021	54
FOR HABITAT		
habitat OR ecosystem* OR land	11/04/2021	283
FOR POLLUTION		
pollut* OR contamina* OR waste*	11/04/2021	322
FOR INVASIVE ALIEN SPECIES		
(invasive species) OR (alien species) OR (weed*) OR (feral)	11/04/2021	6

A separate enquiry was undertaken to identify literature on the use of voluntary mechanisms in the building sector, particularly VSS. A targeted *Web of Science* search using keywords related to urban environmental impacts, building design, and sustainability standards yielded just 79 publications. The disciplinary breakdown showed limited engagement from architectural fields, with only 11 publications, while engineering contributed 23 papers. The methodology was supplemented with additional academic and grey literature focusing on building life cycle stages, environmental impacts, and VSS coverage, using both forward and backward citation chasing through the University of Sydney Library.

Search terms for Voluntary Sustainability Standards (VSS) for buildings	**Date run**	**Results**
TOPIC: ((((*urban*) AND (environmental impact* OR mitigat* OR footprint*) AND ((building*) AND design)) AND ((standard*) OR (certification*) OR (rating*)) AND (sustainab*)))	27/04/2021	79
Results refined by TOPIC: ((voluntary) or (*regulated))		
CONSTRUCTION BUILDING TECHNOLOGY OR ARCHITECTURE OR MATERIALS SCIENCE OR WATER RESOURCES Breakdown:	27/04/2021	28
Architecture		11
Construction building technology		13
Energy fuels		11
Urban studies		10
Engineering		23
Materials science		3
Water resources		2

Appendix 2

Generic interview guide

Theme – Knowledge of impacts on biodiversity and voluntary mechanisms to mitigate them
Based on your experience, at what point in a building's life cycle would you expect the biggest impacts on nature to occur? *(prompt: natural resource extraction, manufacturing, construction, occupancy, end of life, disposal / recycling)*.
Besides addressing energy consumption and climate change, or solid waste, what do you think is the most important thing the building construction industry could do to minimise impacts on nature?
Please describe your experience of using *Voluntary Sustainability Standards* (VSS), such as eco-labelling, certification, accreditations, in the organisation that you work for.
Have you had any experience working on projects that incorporated these or other voluntary sustainability schemes?
What do you see as the main challenges faced by the broader construction industry when adopting and implementing voluntary sustainability mechanisms?
What would make it easier for your organisation to consider adopting voluntary sustainability schemes?
Do you have any further thoughts about what architecture and the building industry is currently doing to address impacts on nature and how could this be improved?
Has your organisation / practice ever considered (or would you consider in the future) adopting any voluntary sustainability schemes?
Theme – Barriers to adopting / promoting voluntary mechanisms
What are the barriers to adoption of and/or tier progression within VSS in your organisation / the building industry?
Are there any challenges faced by the industry more broadly in adopting and implementing voluntary sustainability mechanisms?
Theme – Enabling factors to adopting / promoting voluntary mechanisms
Who or what is driving your organisation to use VSS?
What are the benefits to your organisation from adopting and implementing voluntary sustainability mechanisms?
Are there any factors (e.g. government incentives or penalties, interventions to influence customer preference) that might enable better adoption of VSS for biodiversity conservation / impact mitigation?
What would need to change for biodiversity to be given more consideration when implementing VSS on a particular project?