Towards Circular Renovation: An exploration of circular economy adoption in the architectural renovation of apartment buildings

A thesis

submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

by

Alysson Nicole Tamayao Lucas

Primary Supervisor: Associate Professor Sandra Karina Löschke

Auxiliary Supervisor: Professor Richard de Dear

School of Architecture, Design and Planning

The University of Sydney, NSW 2006, Australia

2025

Statement of Originality

This is to certify that to the best of my knowledge the content of this thesis is my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

Author: Alysson Nicole Lucas

Acknowledgements

Acknowledgement of Country

I open this PhD thesis with my acknowledgement of the Traditional Owners of the unceded land of Australia. I pay my respects to Elders past, present and emerging and to the Gadigal people of the Eora Nation, whose land I work and live on and have come to call home.

As the Indigenous Peoples of Australia and across the globe have advocated since time immemorial, we are all ***interconnected*** *– as nature sustains and nurtures us, so should we nurture, respect, and care for it. The emergence of Circular Economy thinking – which is at the core of this thesis – calls for rethinking our ways of living, for rekindling a symbiotic relationship with nature, for becoming active custodians of the planet we inhabit and the lives on it, for Caring for Country. I hope this thesis and the research contained in it contribute to this purpose and help create triumph, rather than tragedy, of our greatest commons – the Earth.*

Acknowledgement of Awards and Scholarships

This research was made possible and supported by several scholarships and prizes for which I am deeply grateful. During my PhD candidature, I am honoured to have been a recipient of an Australian Government Research Training Program (RTP) International Scholarship, an Australian Housing and Urban Research Institute (AHURI) Postgraduate Top-Up Scholarship, an Australian Council Research (ARC) Linkage Project Grant (LP200100053 – *Co-Design Guide for Transforming Ageing Apartment Buildings*) Postgraduate Stipend Scholarship, and a University of Sydney-Cornell University Mobility Scheme. These scholarships and prizes have not only afforded me to pursue doctoral studies in an area I am passionate about and the many opportunities that come with it but also enriched my journey immensely as a lifelong researcher.

Personal Acknowledgements

They say that it takes a village to raise a child, and my PhD journey has proven to me that it also takes a community for one to become a doctor. The PhD journey may at times feel lonely, *but it is never pursued alone*. This thesis is not merely a reflection of my perseverance, hard work, and growth over the past four years, it is also a manifestation of the enduring love, support, and guidance I have received from many people, for whom I am and will always be grateful.

First and foremost, my deepest gratitude goes to my supervisor, Associate Professor Sandra Karina Löschke. Your unwavering guidance and patience throughout this journey have made me a better scholar. Thank you for all your support in getting me to this point and for everything in between – I am incredibly lucky to be able to call you my *Doktormutter*.

I would like to acknowledge the Renew team and Professor Hazel Easthope for your guidance and company throughout this journey. Being a part of this team has enriched my PhD experience and made it far more exciting. I also extend my gratitude to Assistant Professor Felix Heisel, Joseph McGranahan, and the rest of the Circular Construction Lab at Cornell University for welcoming me into your team. It was an honour and inspiration to learn from and work with you. Thanks also to Professor Richard de Dear for your support and inspiration, and to Dr. Max Lemprière and The PhD People team for proofreading the conclusion chapter of this thesis.

To all those who have contributed to my PhD journey in ways big and small, my heart is filled with gratitude. The opportunities I have been afforded would not have been possible without your generosity and support. A special thanks to Dr. Jennifer Kent and Violeta Birks – you have been my lucky stars who lovingly led me to this path. Your acts of kindness have changed my life for the better. I owe it to both of you. To my previous leaders and colleagues in my professional roles, who provided the most supportive working environment while I pursued my doctoral studies, working with you for most of my candidature gave me the collegiality and stability that helped me to continue growing professionally. To my thesis examiners, Professor Ralph Horne and Professor Rob Raven, thank you for your valuable feedback to improve my doctoral work.

To my friends, whether from three kilometres or three thousand kilometres away, your words of encouragement have moved me in many ways. Thank you for inspiring and keeping me grounded; your belief in me pushed me to keep going – especially in the homestretch when it almost felt impossible to finish. To my best friend, Nikka, who has been a constant force that helped me get through the finish line – I will always be grateful to call you my soul sister in this thing we call life. To my family in the Philippines, especially my aunts, Tita Gigie and Tita Jake – your quiet but immense support has meant the world to me.

To Vincent – my partner in life – your presence throughout this journey and beyond has been my rock. You are the calm to my chaos, and your patience has never gone unnoticed. Thank you for dealing, for the last three years, with my "quick questions" about the architectural profession that almost always turn into two-hour conversations. I will forever be grateful to have gone through this journey with you by my side. I am lucky to be loved and cared for by you.

Finally, to my Mom and Dad, who have always empowered me to explore and pursue my curiosity and passion – this is all because of you and for you.

Authorship Attribution Statement

Chapter 2 of this thesis is based on the published manuscript:

> Lucas, A. N. and Löschke, S. K. (2024) 'Towards circular renovation: a comparative review of circular economy integration in sustainable building rating systems', Building Research & Information, pp. 1–22. doi:10.1080/09613218.2024.2394470.
>
> *I co-designed the study, analysed the data, prepared visual materials, and wrote the drafts of the manuscript. To improve readability, some parts of the published manuscript have been slightly revised and moved to other chapters as they appear in this thesis.*
>
> ***Appendix A*** *is a copy of the published manuscript.*

Chapter 4 of this thesis contains material previously published in the manuscript:

> Heisel, F., McGranahan, J., Lucas, A., Cohen, D., Stone, G., 2023. Carbon, economics, and labor: a case study of deconstruction's relative costs and benefits compared to demolition. J. Phys.: Conf. Ser. 2600, 192003. https://doi.org/10.1088/1742-6596/2600/19/192003
>
> *This material is adapted in Section 4.2.2, Section 4.3.2 (Case Description), and* ***Figures 4-31*** *up to* ***Figure 4-36*** *of* ***Chapter 4****. I contributed to the data analysis and drafted the economic implications section of the manuscript.*
>
> ***Appendix B*** *is a copy of the published manuscript.*

In addition to the statements above, in cases where I am not the corresponding author of a published item, permission to include the published material has been granted by the corresponding author.

Alysson Nicole Lucas, 31 March 2025

As supervisor for the candidature upon which this thesis is based, I can confirm that the authorship attribution statements above are correct.

Sandra Karina Löschke, 31 March 2025

Declaration of use of generative Artificial Intelligence (AI)

During the preparation of the thesis, the author used *Grammarly* for basic grammar and punctuation improvements, *Microsoft Co-pilot* and *ChatGPT* for sentence structure and general paraphrasing, and *sciteAI* for verification of scientific references. The author confirms that where text was modified by generative AI, the content was reviewed for possible errors, inaccuracies, and bias. The author takes full responsibility for the submitted thesis and ensures the work is their own and has used generative AI within the parameters of use (refer to the University of Sydney generative AI guide for researchers).

ABSTRACT

Abstract

Apartment buildings form an integral and enduring part of the Australian urban fabric and housing stock. However, approximately half of these existing apartment buildings were built before 2000, and are now ageing and posing various social, economic, and environmental challenges. The architectural renovation of these existing apartment buildings presents a compelling socio-ecological agenda to promote urban vitality and sustainability in Australian cities. However, it may also entail substantial resource use and associated carbon emissions under the current linear economy approach, a model widely regarded as the driving force of unsustainable practices that exacerbate the climate crisis. The emerging concept of Circular Economy (CE) – underpinned by resource conservation, regeneration, and waste elimination – counters the linear economy that has driven anthropogenic climate change. In the built environment, the CE proposition has gained significant traction in academia, policy, and industry in recent years for its potential to decarbonise the carbon- and waste-intensive sectors – lending architectural renovation of apartment buildings an alternative approach. While there is growing focus and literature on CE, current research falls short in two respects: 1) limited attention has been given to the concept's potential application in residential renovation contexts, and 2) it critically lacks a more profound understanding of the social dimension of CE adoption, which can hinder the broader practicalities of a CE transition. Grounded in the real-world need for a more sustainable housing stock and building sector, this thesis seeks to understand, "How can a Circular Economy approach be adopted in the architectural renovation of apartment buildings?" To this end, it employs pragmatism as the underpinning philosophical framework to contribute to practical solutions to these real-world issues and conceptually draws on sociomateriality and social practice theories in sociology and the multi-level perspective theory of sustainability transitions research. This thesis explores the social dimension of CE adoption, focusing on the social artefacts, actors, and activities that may embody, shape, and influence a CE approach to apartment building renovation. The research constitutes three core studies involving comparative reviews of building frameworks as artefacts, in-depth interviews with architectural professionals as actors, and a multiple-case study of CE initiatives in residential building projects as activities of CE adoption. Then, the research consolidates insights from these studies to propose a practical framework for a CE approach to architectural renovation of apartment buildings. Through the three core empirical studies, the social phenomenon surrounding CE adoption is better understood and lays the foundation for circular renovation to contribute to a more sustainable apartment building stock and a circular built environment in Australia. By expanding CE literature to the residential context and deepening the understanding of the social realm of the CE transition, the thesis illuminates the social complexities surrounding CE implementation and examines the barriers, enablers, and opportunities for CE adoption in this context and beyond. The findings of the thesis call for a CE transition grounded as a social agenda – reforming established social artefacts to be CE-driven and accessible, empowering social actors to be change agents, and formalising and protecting CE activities to support the formation and reproduction of circular renovation practice, which nurtures niche innovations and fundamentally reconfigures the existing architecture and apartment renovation regimes towards CE. Overall, the thesis empirically contributes to architecture, housing, and CE bodies of literature, and theoretically to the fields of social practice and sustainability transitions that can guide future research inquiry in these disciplines. Ultimately, the findings of the thesis can inform CE, housing policymaking, and the architectural practice alike to support sustainable housing and the CE transition in Australia.

Table of Contents

List of Tables

List of Figures

CHAPTER 1

1 Introduction

1.1 The Basis: the Anthropocene, buildings, and the linear economy

We live today in the *Anthropocene* – a proposed geological epoch characterised by the significant impact of human activity on the Earth's ecological systems, climate, and geology (Crutzen, 2006). In understanding what the Anthropocene signifies and encompasses, one can grasp the significance of the Circular Economy. While the Anthropocene remains to be formally recognised, research in the past several decades has solidified the scientific evidence that humans have an unequivocal influence on climate change. The urgency of anthropogenic climate change, accompanied by extensive scientific work and political movement, culminated in international climate treaties such as the *Kyoto Protocol* in 1997 and again in the global *Paris Agreement* in 2015 (Seo, 2017). The *Paris Agreement* seeks to limit global warming temperature to ideally 1.5 degrees Celsius and well below 2 degrees Celsius above pre-industrial levels (1850-1900) through national commitments on greenhouse gas (GHG) emissions reduction (United Nations, 2015). In 2023, the Intergovernmental Panel on Climate Change (IPCC) (2023), an authoritative figure in climate scholarship and discourse, determined that current emissions reduction commitments and efforts are still insufficient and warned that global warming will likely exceed 1.5 degrees Celsius in the 21st century. The IPCC called for substantial and rapid emissions reduction to mitigate and adapt to the worsening impacts of the climate crisis, identifying the building sector as a key area requiring systemic change to achieve deep and sustained emissions reduction.

Underscoring the IPCC's position, it can be fairly argued that the building sector is one of the evident manifestations of the Anthropocene – they are a physical embodiment of human development and its profound impact on the planet's systems. In their construction, operation and demolition, buildings contribute significantly to climate change through GHG emissions, material extraction, pollution and waste generation, and biodiversity loss from land use change. Globally, 37% of the total GHG emissions can be attributed to buildings, and 46% of these are emissions derived from residential buildings

(UNEP, 2022). Furthermore, the built environment (which encompasses all human-built structures and spaces, including buildings) is responsible for 31% of global material footprint, which indicates that a third of material resources are demanded and end up for final use in the construction of buildings and infrastructure (UNEP, 2024). Yet, the building sector remains highly waste intensive. Construction and demolition (C&D) generate a sizeable share of global waste, with approximately 35% of C&D waste being sent directly to landfills globally (Menegaki and Damigos, 2018). Nevertheless, the plethora of evidence showing that the building sector is a main driver of anthropogenic climate change paradoxically highlights that it is also a critical area for climate change mitigation and adaptation efforts.

Many of the ramifications of the Anthropocene can be traced to the linear economic model underlying our urban environments, which in turn shapes consumption and production patterns within these environments. Colloquially regarded as the "take-make-waste" economy, the linear economic model is evident in the dominant production and consumption practices in the building sector through resource extraction for building materials *(take)*, through construction using processed resources and operation using energy *(make)*, and through demolition and disposal of building materials at their end of life *(waste)*. It is contended that the culpa of the linear economy paradigm is its foundation in economic thinking that has assumed infinite resources on Earth and has historically failed to account for environmental impacts and societal costs of economic activities. As the impacts of anthropogenic environmental degradation became more evident, several scholars for decades have begun to critique such economic models and proffered alternatives. In his landmark essay, *The Economics of the Coming Spaceship Earth,* Kenneth Boulding (1966) questioned the dominant view at the time that the Earth and the world economy within it are open systems with illimitable plains for endless consumption and production. Conversely, he asserted that the Earth is a *closed system* without unlimited reservoirs for consumption or pollution – akin to a single spaceship. Boulding (1966, p. 7) concluded that "the closed earth of the future requires economic principles which are somewhat different from those of the open earth of the past." In the same yet more quantitative vein, the scholars from the Club of Rome published their

1972 groundbreaking piece that galvanised sustainability discourse, *Limits to Growth*. In this book, the authors warned with scientific evidence that exponential economic growth – measured by the increase of production of goods and services within an economy enabled and accompanied by growth in world population, industrialisation, pollution, food production, and resource depletion – is incompatible in our finite planet and can potentially lead to economic collapse and ecological crisis (Meadows et al., 1972). They put forward a compelling case to shift economic rationale away from growth to a sustainable state of global equilibrium, establishing a condition of "ecological and economic stability that is sustainable far into the future" (Meadows et al., 1972, p. 24). Otherwise, the Club of Rome scholars projected that "the global system of nature in which we all live probably cannot support present rates of economic and population growth much beyond 2100" (Meadows et al., 1972, back cover).

As Boulding and the Club of Rome previously pointed out, the oversight in the 19th to 20th century economic thinking that perpetuates mainstream economic models to this day drives anthropogenic climate change. It also points to the need for new economic models that take into account the Earth's carrying capacity and set social progress and wellbeing as the primary objective instead of endless economic growth (Costanza et al., 2013; Raworth, 2017). The same perspective carries on through the 21st century when Robert Constanza and colleagues for the United Nations urged that, "we are going to need an economics that respects planetary boundaries, that recognizes the dependence of human wellbeing on social relations and fairness, and that recognizes that the ultimate goal is real, sustainable human wellbeing, not merely growth of material consumption" (Costanza et al., 2013, p. ix). Several decades after Boulding proposed the closed earth and spaceship economy concept, the call for embedding nature in our economic model still resonates, perhaps even more deeply in the 21st century than before, as we inch closer to the predicted limits of growth and climate change impacts become more severe and tangible. The next section introduces the concept of the Circular Economy as the current response to this call and discusses its emergence, policy development, application in the building context, and current critiques.

1.2 The Concept: Circular Economy

1.2.1 Emergence and conceptualisation of the Circular Economy

Boulding's (1966) proposal of a closed Earth is often referenced as the first articulation of the concept of a Circular Economy (CE) (Blomsma and Brennan, 2017a; Leising et al., 2018). He describes CE as an antithesis to the linear economy, "the existing type of 'linear economy,' which runs from mines to dumps, cannot go on forever, and that in the course of the next century or so mankind will face a fundamental transition into what I and some others have been calling a 'spaceship earth.'" This will be a small, closed, limited, planetary society, almost certainly dependent on solar energy for its input or power, and it will have to recycle virtually all its materials into a circular economy, in which the dumps become the mines" (Boulding, 1972, pp. 350–351). Today, as a juxtaposition to the linear economy, CE is understood as a regenerative and restorative close-looped economic system that recognises ecological limits to economic growth and is grounded in three fundamental principles: 1) regenerating nature, 2) keeping materials in loop at their highest value, and 3) designing out waste and pollution (Ellen MacArthur Foundation, 2015, 2013). In a CE, the 'end of life' concept is said to be replaced by reducing raw material inputs with renewable sources, maximising material value through reuse, recycling and recovery, and preventing waste and pollution to preserve ecological systems and contribute to Sustainable Development (Ellen MacArthur Foundation, 2013; Kirchherr et al., 2023b). The concept of CE offers an alternative to the linear economy, encouraging to rethink production and consumption models and behaviours to respond more appropriately to the issues in the Anthropocene (Blomsma and Brennan, 2017b; Stahel, 2020). As a proposition, CE has been presented as a new economic paradigm that can contributes to Sustainable Development (Geissdoerfer et al., 2017; Kirchherr et al., 2023b) and climate change mitigation and adaptation (Wang et al., 2022).

Globally, the interest in CE has grown through its regulatory implementation in China (*Circular Economy Promotion Law*) since 2009 and through industry efforts and political rhetoric in Europe spearheaded by the Ellen McArthur Foundation (EMF) since 2013 (Geissdoerfer et al., 2017). The EMF is the most cited institution in the CE field for its seminal work in promoting CE (Superti et al., 2021). Conceptually, its emergence can be traced to diverse schools of economic thought spanning several decades of scholarship (Blomsma and Brennan, 2017b; Ghisellini et al., 2016; Stahel, 2020). In their 2013 seminal piece that galvanised CE discourse in Europe, EMF defined CE as a concept that "cannot be traced back to one single date or author" (p. 26) but was influenced and shaped by several existing ideas including regenerative design (Lyle, 1994), performance economy (Stahel, 2010), cradle to cradle (McDonough and Braungart, 2002), industrial ecology (Graedel and Allenby, 2003) and biomimicry (Benyus, 2009). Research progress in the late 20th century in the fields of environmental economics, industrial ecology, and ecological economics laid the foundation for the technical theories underpinning the concept (Geissdoerfer et al., 2017; Ghisellini et al., 2016; Stahel, 2020). Albeit different schools of thought, all three subscribe to the idea that economic systems are not separate from natural ecosystems and that conventional economic theory and policymaking require reform to incorporate nature into the economic equation (Geissdoerfer et al., 2017; Ghisellini et al., 2016; Kirchherr et al., 2017). Blomsma and Brennan (2017) provide an illustrative overview of the foundations of CE as shown in **Figure 1-1.**

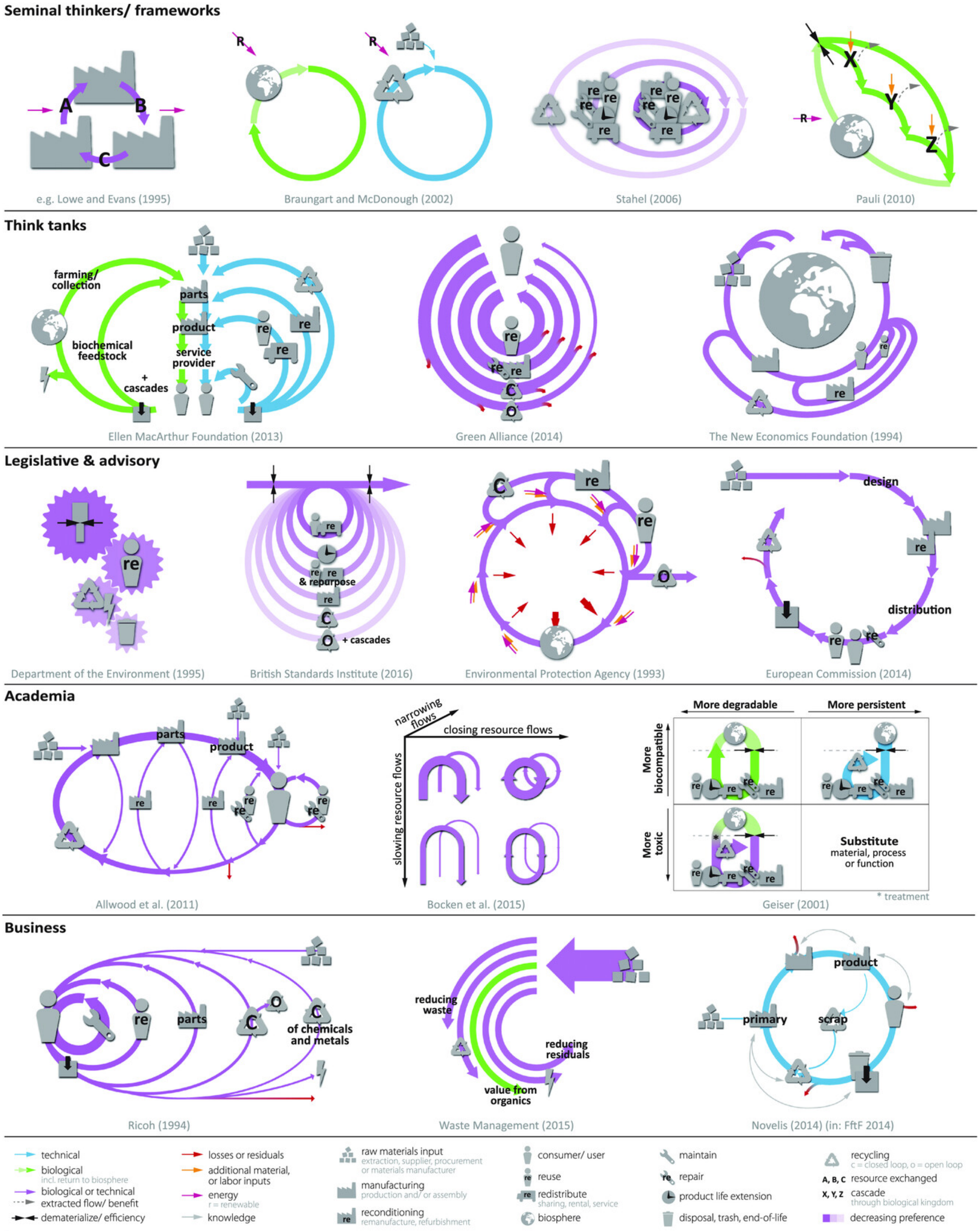

Figure 1-1 Conceptual foundation of CE (Blomsma and Brennan, 2017, p. 605)

At the turn of the 20th century, CE has received increasing attention due to its potential to decouple economic growth from resource use and depletion. In the academe, CE literature has remarkably grown with research outputs increasing exponentially since

2009 (Alnajem et al., 2021). CE research is burgeoning rapidly that it is argued to have become a research field of its own (Kirchherr et al., 2023a) and has reached a mainstream status (Fraser et al., 2024). However, due to its nascency relative to other research fields, its conceptualisation remains contested and continues to evolve, with some scholars labelling it as an essentially contested concept (Korhonen et al., 2018) while others see it as an umbrella concept that can unite pre-existing ideas to create an overarching vision (Blomsma and Brennan, 2017a).

To elucidate and capture the essence of CE, several frameworks have been proposed and have become influential in the conceptual development and implementation of CE. One of the most recognised frameworks is the butterfly diagram by the EMF, which describes the CE comprising two cycles, the biological and the technical cycles, as illustrated in **Figure 1-2**. The biological cycle comprises renewable materials which go through natural cycles (e.g. anaerobic digestion, water cycle), and in principle, produces no waste. The technical cycle consists of finite and non-renewable synthetic materials extracted or made by humans, which require stock management through various strategies (e.g. share/maintain, reuse, refurbish, recycle) to maximise resource use and eliminate waste (Ellen MacArthur Foundation, 2013). Other notable conceptualisation and visualisation of the CE is the 10R framework, a hierarchical framework of R-actions, developed by Potting et al. (2017), who expanded the simplistic 3R framework (reduce, reuse, recycle). The 10R framework assigns *refuse* as the most circular (R0), followed by *rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle*, and *recover* as the least circular (R9). Another prominent framework is the *slowing, closing, and narrowing resource loops* which extends the notion of “closing the loop” to slowing use of materials through maintenance, closing material loops through recycling and recovery, and narrowing loops by reducing material use, all through a regenerative system wherein resource input, waste, and emissions are minimised (Bocken et al., 2016; Geissdoerfer et al., 2017). Despite the various definitions proffered by different authors, a commonality among them is the notion of cyclical closed-loop system (Geissdoerfer et al., 2017), signifying that the essence of a CE is to shift away from the linear economic model of take-make-waste (open system) to a circular model that embeds socio-economic systems within the Earth's ecological systems (closed system).

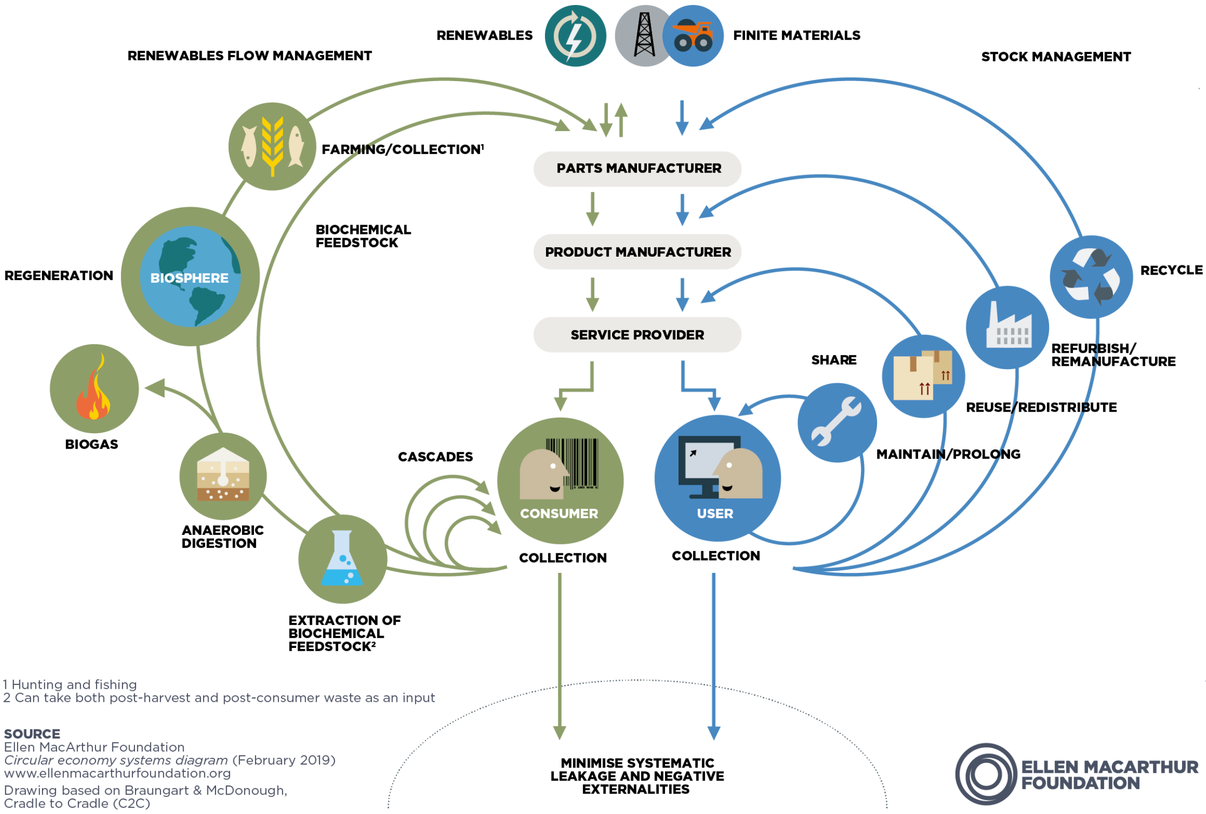

Figure 1-2 Butterfly diagram illustrating the Circular Economy (Ellen MacArthur Foundation, 2013, p. 25)

1.2.2 CE in the global policy landscape

As the global warming reduction pathway of 1.5 degrees Celsius is increasingly at risk of being surpassed, the transition to a CE has been highlighted and prioritised in various geographical and sectoral contexts, breaking through the policy landscape and evolving over the years to a salient political and economic vision, particularly in China and Europe.

In China, CE was adopted through a top-down approach when the *Circular Economy Promotion Law* was enacted in 2009 (Geissdoerfer et al., 2017). As a response to the country's worsening environmental state, CE was used as an overarching guiding principle in their long-term economic planning and national political strategy (Ghisellini et al., 2016; Murray et al., 2017). Since then, China has been considered a forerunner country in CE implementation, showing evidence of decoupling resource use from economic growth (Bleischwitz et al., 2022).

In Europe, the *Circular Economy Package* was adopted in 2015, which served as the European Commission's first CE action plan that focused on resource efficiency and waste management (Geissdoerfer et al., 2017). As a result, several European nations have implemented their country-specific CE frameworks from national to local levels (European Economic and Social Committee. and Spatial Foresight GmbH., 2019). In 2020, the European Commission updated the *Circular Economy Action Plan* to expand its scope and provide a future-oriented agenda for CE adoption across the region, focusing more on sustainable consumption and CE business models to achieve climate neutrality by 2050 (European Commission, 2020).

In Australia, while federal CE policy is lagging relative to other nations, pioneering efforts in CE adoption were observed as a direct result of the waste export ban by China in 2018, which revealed Australia's limited waste management and recycling capacity (Lasker and Goloubeva, 2018; Shooshtarian et al., 2022). In 2019, the federal-level CE research agenda for developing a national Circular Economy Roadmap (Schandl et al., 2020) and state-specific CE policy documents, such as the New South Wales (NSW) Circular Economy Policy Statement (NSW Environment Protection Authority, 2019) were some of the first explicit articulations of CE visions in Australia, signifying the shift from waste minimisation and management perspective to CE thinking. In 2022, Circular Australia was established as a government-funded initiative to drive circularity and a zero-carbon economy across the country, succeeding the NSW Circular founded two years earlier (NSW Circular, 2020). In the same year, official government commitments were established when the Australian government's environmental ministers committed to achieving a CE in Australia by 2030 (Australian Government Department of Climate Change, Energy, the Environment and Water, 2022). Finally, the National Circular Economy Framework was published in late 2024, guiding CE policymaking and implementation with the built environment identified as a priority sector (DCCEEW, 2024).

1.2.3 CE and buildings

The built environment is considered a key area in CE policy and research, given the significant pressure the building sector puts on the natural environment through excessive resource use, emissions, and waste (Pomponi and Moncaster, 2017). Research and policy interest in the circular built environment have grown exponentially since 2016 (Mhatre et al., 2021a; Munaro et al., 2020). CE adoption in the built environment could potentially reduce emissions by 38% by 2050 through building lifecycle extension, material reuse and recycling, and waste elimination in design and construction (Ellen MacArthur Foundation, 2019). To realise these opportunities, several practical and research frameworks have been developed to apply and implement the concept in the building context.

From a practical standpoint, the EMF developed the ReSOLVE Framework, which is considered one of the first attempts to guide CE implementation (Ellen MacArthur Foundation, 2015). EMF proposed the ReSOLVE framework to inform Europe's CE policy for a competitive economy and designed it as an operational tool to translate the three fundamental CE principles into six business actions that can be easily implemented across different sectors and scales. The ReSOLVE framework is an acronym for Regenerate, Share, Optimise, Loop, Virtualise, and Exchange, which are actions that altogether embody a circular economy:

- **Regenerate**: prioritising restoring and regenerating natural capital
- **Share**: maximising asset utilisation through sharing economy, reuse economy, co-location, and open-source information sharing
- **Optimise**: achieving system efficiency, reduction in material or energy consumption, reverse logistics, longevity, and durability of materials
- **Loop**: closing the material loop and minimising building material waste sent to landfills by restoring or reprocessing assets and recovering the value of materials
- **Virtualise**: dematerialising through digital technology, virtual products, and services
- **Exchange**: exchanging conventional methods and products with alternative and more sustainable or renewable options

Together with EMF, ARUP expanded and contextualised the ReSOLVE framework specifically for the built environment – the **RESOLVE Framework for Circularity in the Built Environment framework (ReSOLVE) (ARUP, 2016)** . As outlined in **Table 1-1**, the six main actions are broken down into 16 more concrete actions and exemplars to assist building professionals and clients in adopting more circular ways of delivering building projects (ARUP, 2016). ReSOLVE was found to be a relatively comprehensive framework for CE processes (Van Bueren et al., 2021), establishing its prominence as an effective framework for CE implementation. Over time, ReSOLVE has served a dual purpose – a practical guide for the industry as intended by EMF and an analytical tool for researchers driven by increasing interest in CE adoption (Payne and Kwofie, 2024).

Table 1-1 ReSOLVE Framework for circularity in the built environment (ARUP, 2016, p. 19, adapted from Ellen Macarthur Foundation)

ReSOLVE Framework for circularity in the built environment

ReSOLVE Principles	**Definition**	**Actions**
Regenerate	Regenerating and restoring natural capital	Safeguarding, restoring, and increasing the resilience of ecosystems *(Re1)*
		Returning valuable biological nutrients safely to the biosphere *(Re2)*
Share	Maximising asset utilisation	Pooling the usage of assets *(S1)*
		Reusing assets *(S2)*
Optimise	Optimising system performance	Prolonging an asset's life *(O1)*
		Decreasing resource usage *(O2)*
		Implementing reverse logistics *(O3)*

Loop	Keeping products and materials in cycles, prioritising inner loops	Remanufacturing and refurbishing products and components *(L1)*
		Recycling materials *(L2)*
Virtualise	Displacing resource use with virtual use	Replacing physical products and services with virtual services *(V1)*
		Replacing physical with virtual locations *(V2)*
		Delivering services remotely *(V3)*
Exchange	Selecting resources and technology wisely	Replacing with renewable energy and material resources *(E1)*
		Using alternative material input *(E2)*
		Replacing traditional solutions with advanced technology *(E3)*
		Replacing product-centric delivery models with new service-centric ones *(E4)*

From a research standpoint, Pomponi and Moncaster's (2017) research agenda framework for CE in the built environment has proven to be influential over time. Their framework proposed that CE can be appropriated to the built environment on three levels or scales (i.e. macro or city/urban level, meso or building level, and micro or material level) across six research dimensions (i.e. technical, economic, environmental, governmental, social, and behavioural) while implementation can be through either a top-down or bottom-up approach (Pomponi and Moncaster, 2017). An initial definition of a circular building was also proposed: "a building that is designed, planned, built, operated, maintained, and deconstructed in a manner consistent with CE principles" (Pomponi and Moncaster, 2017, p. 711). Leising et al. (2018, p. 977) refined this definition to integrate the closed-loop notion and alternative models that characterise CE, defining a CE approach for buildings as: “a lifecycle approach that optimizes the buildings’ useful lifetime, integrating the end-of-life phase in the design and uses new ownership models where materials are only temporarily stored in the building that acts as a material bank”.

On a building level, CE framing was extended by several scholars using the life cycle stages of the building, which can vary based on standards (e.g. life cycle assessment framework, building project stages) but typically include planning and design, manufacturing, construction, operation, and end-of-life stages (Benachio et al., 2020; Çimen, 2021; Guerra et al., 2021; Rahla et al., 2021). Using the life cycle stages, Benachio et al. (2020) listed emerging CE practices based on a systematic literature review of peer-reviewed articles. Likewise, Guerra et al. outlined the major CE strategies based on a global scan of CE strategies in the construction industry (Guerra et al., 2021). Similar efforts were undertaken by Eberhardt et al., who proposed a taxonomy of circular economy strategies comprised of 16 strategies from a systematic literature review, including grey literature, to represent industry developments (Eberhardt et al., 2022). The identified strategies in those previous studies are summarised in **Table 1-2**.

Table 1-2 CE strategies in buildings; adapted from Benachio et al., 2020, p. 7; Eberhardt et al., 2022, pp. 98–100; Guerra et al., 2021, p. 4

Life cycle stages	**Design**	**Construction**	**End-of-life**
Circular Strategy	• Design for Disassembly • Design for Modularity; • Design for Adaptability/Flexibility; • Material Selection, Reuse and Recycling Specification; • Design for Remanufacturing; • Design for Longevity/Durability	• Material Banks, • Prefabrication/off-site construction • Efficient Process, • Waste as a Resource	• Deconstruction and urban mine; • Resource Data Management; Reverse Logistics

Despite the significant developments in the conceptualisation and application of CE to the building sector, gaps and critiques remain that challenge its broad-scale adoption and the transition beyond the linear economy. The succeeding section explores these gaps and critiques of CE scholarship before presenting the pertinent context to this thesis, which seeks to address these gaps.

1.2.4 Critiques of CE: implementation challenge and the social dimension

Owing to its industrial ecology roots, CE scholarship has been dominated by a techno-economic agenda, resulting in the equally important social dimension of sustainability being neglected (Corvellec et al., 2022; Korhonen et al., 2018; Liu, 2024; Murray et al., 2017). Murray et al. (2017, p. 376) asserted that with extant research, "it is unclear how the concept of the circular economy will lead to greater social equality". Existing literature has mostly dealt with technological solutions in the production side (e.g. metrics, tools, instruments, measures, etc) and evidently paid less attention to the human layers of CE (Korhonen et al., 2018; Mies and Gold, 2021; Murray et al., 2017; Wastling et al., 2018; Zavos et al., 2024). Indeed, longitudinal research has shown that detailed empirical scholarship on the social phenomena surrounding the CE transition remains limited in the literature (Schöggl et al., 2020). The technocratic solutionism surrounding CE discourse is proving to be a constraint, as "the broader cultural and political consequences of the circular economy project – questions of meaning, cultural value, justice, equality, identity, rights, and so on" have been given marginal attention (James, 2022, p. 1210). This peripheral attention on the social aspect of CE points to a critical gap in the literature, which this thesis addresses in succeeding sections, to ensure that the transition to a CE does not undermine the social objectives of *living well* in relation to others and to the planet, for which its forerunning proponents have advocated (James, 2022).

It is argued that "the gap between the required social environment and actual social conditions is not merely theoretical but presents tangible difficulties in promoting CE" (Liu, 2024, p. 481). This is evident in existing critiques of CE, which argue that CE discourse struggles with implementation ambiguity across policy, organisational, and individual levels (Corvellec et al., 2022). Indeed, the global circularity rate has declined from 9.1% in 2018 to 7.2% in 2023 despite the surge in CE-related policies and research over the same period, indicating that CE implementation remains critically low (Fraser et al., 2024). In the built environment, Pomponi and Moncaster (2017) found that CE research lacks focus on the meso-level (i.e. buildings) and asserted that the social dimension and understanding the role of people, individually and collectively, in implementing CE is essential. Eberhardt et al. (2022) corroborate this with their findings that buildings present a challenging context for CE adoption due to the longer lifespan of buildings, a multitude of materials and components involved, and actors with potentially diverging interests. Despite the growing number of studies focusing on CE strategies for the building sector, implementation knowledge is still deemed inadequate (Antwi-Afari et al., 2021; Shooshtarian et al., 2023). As Holmes et al. (2021, p. 63) point out, "whilst the actors, scales and sometimes sectors are identified, the practicalities and potential circular activities are not," with limited instruction on how CE should occur. They argue that there is a lack of in-depth understanding of the 'doing' of CE and the recognition of the labour and skills involved (Holmes et al., 2021). Thus, future research investigating the role of actors and stakeholders in the construction value chain in implementing CE is endorsed (Antwi-Afari et al., 2021; Munaro et al., 2020).

As an influential CE proponent, Walter Stahel (2016) argued that people are at the centre of CE. This argument is shared by CE researchers who have pointed out that the incorporation of the social dimension and understanding human motivations and behaviours toward CE are research gaps that need urgent attention (Ghisellini et al., 2016; Giorgi et al., 2020; Murray et al., 2017; Wastling et al., 2018). Blomsma and Brennan (2017) put forward the invitation to integrate social theories to enrich CE research. Miles and Gold (2021) also stressed the needs and expectations of all members of society and the application of a value-based, normative approach to CE, which corroborates the earlier call of Hobson and Lynch for future CE debates to critically consider "the role, potential and place of the citizen" for a real paradigm shift towards CE (Hobson and Lynch, 2016, p. 22). Emphasising the need for a broader investigation of the activities and spaces that actualise CE, a more socio-political- and socio-cultural-oriented approach is proposed to explore what constitutes the social practice – the doings and sayings and the material dimension – of CE implementation (Pál, 2022; Schulz et al., 2019). Reframing CE conceptualisation and narratives is called for to re-embed CE into the *social*, developing a "strong formulation" for living sustainably. The social void and implementation challenges in CE literature are captured eloquently by Zavos et al. (2024, p. 3), who argued:

> As the transition to CE involves not only technological innovations and business development (for example in the form of redesigning products, services and business models to close resource loops and extend the value of products and materials as long as possible), but also a fundamental change in society and how we live, the social or sociotechnical and sociocultural underpinnings of the CE transition deserve more attention than they have been given in the research literature so far.

Underscoring the paradigmatic shift involving CE, investigation of the values and underlying worldviews of social actors (Korhonen et al., 2018), as well as the role of social embeddedness, will be crucial to implementing CE (Blomsma and Brennan, 2017a). A broader and stronger social foundation for CE is required to enable the radical transformation that a CE transition entails and ensure it creates a just society that is ecologically sustainable in the process (Genovese and Pansera, 2021; James, 2022). Therefore, further research into the social phenomenon surrounding CE, as well as the impacts and implications of the transition in the social realm, is necessary to enable a paradigm shift.

The thesis proceeds by presenting the architectural renovation of apartment housing as the specific context on which the research focuses and how this setting may potentially tackle the above critiques. The next section provides an overview of the historical development and future visions for Australia's apartment housing stock in relation to CE.

1.3 The Context: a CE approach to architectural renovation of apartment buildings

1.3.1 Australian apartment housing stock

Apartment buildings are an important urban housing typology, particularly as the share of people living in urban areas is projected to increase from 55% in 2018 to 68% of the global population by 2050 (United Nations, 2018). Also commonly referred to as a residential flat building, an apartment building, as defined in this thesis, is a multi-unit residential building consisting of two or more storeys with units stacked vertically, allowing people to live above or below each other (Australian Building Codes Board, 2022; Easthope et al., 2023a). In highly urbanised regions such as Europe, they house almost half (46%) of the total population (Eurostat, 2021). In Australia, about 10% of the population lives in apartment buildings. While they may not be as pronounced in the Australian urban landscape compared with other countries, apartment buildings and their place in the Australian urban fabric and housing mix have solidified over the past century and are expected to continue to grow and shape Australia's urban future, as discussed in the succeeding sections.

In recent decades, the share of apartment buildings in the housing stock has remarkably grown, concentrating in major cities such as Sydney, Melbourne and Brisbane (Rosewall and Shoory, 2017). As shown in **Figure 1-3,** apartment dwelling construction and approval saw an exponential growth between 2009 to 2018 and accounted for about a third of the residential building approvals when it peaked in 2015 (Australian Bureau of Statistics, 2020; Rosewall and Shoory, 2017). Today, apartment buildings represent 14.2% of total private dwellings (Australian Bureau of Statistics, 2022a). The percentage is significantly higher in metropolitan areas, such as in Greater Melbourne and Greater Sydney, where apartments comprise 15.6% and 30.7% of total private dwellings, respectively and represent a sizeable share of urban housing stock (Australian Bureau of Statistics, 2022a). With state governments committed to increasing the supply of apartment housing in the next decade in response to growing urban population and housing demand (NSW Government, 2023; Victoria State Government, 2022), apartment buildings as a housing typology are expected to endure and cement their place as a cornerstone of the Australian built environment.

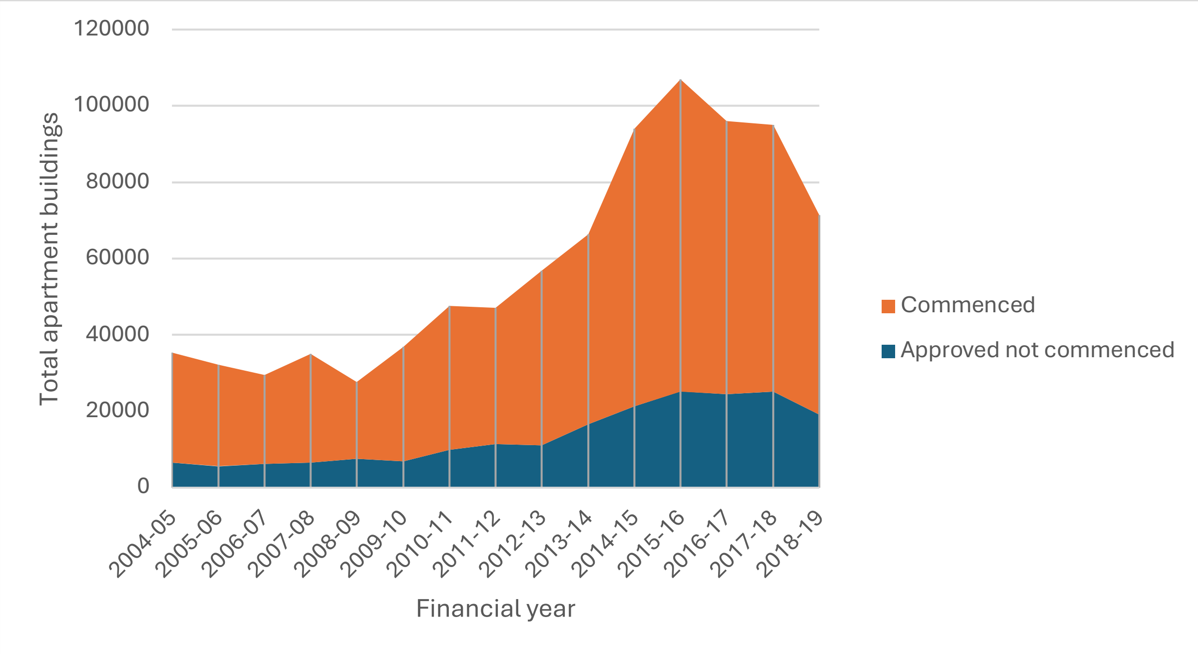

Figure 1-3 Apartment building construction from 2004 to 2019; (Australian Bureau of Statistics, 2020)

The course of interweaving apartment buildings into Australia's urban fabric had been a century of controversy (Butler-Bowdon et al., 2007). Apartment development began in Australia in the early 20th century but did not become a common housing typology until the 1930s-1940s during the interwar period (Butler-Bowdon et al., 2007; "Flats," 2008). The majority of the interwar apartment developments were driven by acute postwar housing shortages, increased preference for urban lifestyle and growing influence of Western modernism (Butler-Bowdon et al., 2007; GML Heritage, 2024). Interwar apartments were mainly small-scale, low-rise developments, occupied by private tenants, and catered to residents who were single, couples without kids, city workers, or branded bohème (Butler-Bowdon et al., 2007; Walker and Townsend, 2020). Most of these flats were built near the harbour and inner cities of Sydney and Melbourne, some being architect-designed, and the luxury penthouse apartment became a desirable asset amongst the upwardly mobile, as a symbol of urban cosmopolitanism (Butler-Bowdon et al., 2007; GML Heritage, 2024). However, many interwar flats were also built by small speculative builders or estate agents who developed and constructed one block at a time to maximise profit, while the architectural style was mostly based on external appearance and less about suitable planning or connecting with the outdoors (GML Heritage, 2024).

The typology received public criticism stemming from economic concerns, pervasive cultural issues (e.g. associating apartments with immorality and being a threat to the Australian value of family life), and entrenched aesthetic preferences towards cottages, which were the dominant housing typology that characterised Australian suburbia then (Butler-Bowdon et al., 2007; Walker and Townsend, 2020). Negative characterisations surrounded these apartment blocks, which were seen as urban monstrosities and a menace. The opposition against apartment buildings was also shared by local governments, which prohibited and limited apartment development through Residential District Proclamations enabled by the *Local Government Act 1919* (Butler-Bowdon et al., 2007; GML Heritage, 2024). As one alderman from Woollahra in the eastern suburbs of

Sydney argued in 1929, 'the promiscuous building of flats in Woollahra will turn the municipality from a thing of beauty into a thing of ugliness' (GML Heritage, 2024, p. 30).

Figure 1-4 1940s Garron Tower next to Redleaf beach in Sydney's Double Bay (Mead, n.d.)

Despite the negative opinion surrounding apartment living, flat construction and demand still grew until the eve of the Second World War. After the Second World War, a second wave of apartment construction growth gave way to what is collectively called postwar apartment buildings, as housing demand again increased due to population growth (baby boom) and rising international migration from the 1950s to the 1970s (Randwick City Council, 2006; Yang et al., 2022). During the postwar boom, apartment developments were concentrated in inner city areas, often tracing the harbour as in the case of Sydney and Brisbane. Apartment buildings in the city fringes from this era were highly influenced by modernism, characterised by concrete framing, brick infill, large glass windows, and were much larger in scale but less decorative than their interwar counterparts (Butler-Bowdon et al., 2007). Tall, wide, narrow apartment blocks that emulate the modernist European public housing and commissioned by state housing commissions of NSW and

Victoria were also representative of the apartments from this period, driven by increasing pressure for the government to house the poor and poorly housed (Butler-Bowdon et al., 2007; Zanardo et al., 2024). The 1960s apartment blocks of Sydney's Waterloo Estate and Melbourne's Carlton Housing Estate serve as prime examples. These public tower blocks, compared to ones from the interwar period, did not blend in with the existing character, but redefined the local urban form and character, which again drew criticism from the public for various aesthetic, social and economic reasons (Butler-Bowdon et al., 2007).

Figure 1-5 1960 Northcott Towers built by the NSW Housing Commission as part of the Waterloo Housing Estate, surrounded by earlier walk-up public housing flats from 1950s (Zanardo et al., 2024)

Figure 1-6 Example of a high rise pre-cast public housing towers in Melbourne built from 1962 to 1974 (Zeccola, n.d.)

The course for apartment buildings changed when the *Conveyancing (Strata Title) Act* was introduced in 1961, stimulating apartment developments for decades to come (Randolph, 2006). Strata Title enabled private developers to mass produce apartment buildings and facilitated the owner-occupier tenure in apartment units, which were practically impossible before the legislation was introduced (Randolph, 2006). Through Strata Title, in contrast to the interwar apartments, which were plagued with negative cultural connotations, postwar apartments became allied to a core Australian dream of homeownership (Butler-Bowdon et al., 2007; Randolph, 2006). The majority of apartment buildings in Australia today are owned through and governed by strata schemes, totalling approximately 340,600 schemes in 2020 (Easthope et al., 2023b)

Meanwhile, as modernist apartment buildings have started to punctuate the inner cities, a more modest style of apartment blocks heavily infiltrated the suburbs during the postwar boom. Distinct from the affluent apartments and public apartment blocks, the "six-pack" walk-up apartment buildings dominated the suburban areas (Butler-Bowdon et al., 2007; Townsend and Pert, 2020). These six-pack apartment buildings were typically two- to three-storey buildings with a ground-floor car park and provided housing for mostly young people and migrants (Townsend and Pert, 2020). The majority of these flats were built by small-scale developers and builders who sought municipalities with the least restrictive building codes to simplify construction and minimise financial risk (Butler-Bowdon et al., 2007). In stark contrast to the modernist apartment towers that accentuate the cities and harbourside suburbs, suburban apartments experienced architectural decline and were reduced to rudimentary dwellings (Butler-Bowdon et al., 2007). Architects, who are often leading proponents of apartment housing, were conversely critical of the six-pack development. A prominent practising architect and architecture critic at that time, Robin Boyd described the six-pack that characterised the 1960s suburban apartment blocks in Melbourne as “the most dispiriting kind of dwelling that has ever been devised by man – the small, three-storey walk-up block of flats in its concrete car-park non-garden” (Walker and Townsend, 2020, p. 482). In Sydney, several architects also expressed disapproval of the six-pack malaise that proliferated in the suburbs. Architect and educator Norman Edwards deplored that “the red texture brick home unit block has done even more to desecrate Sydney’s fine natural environment than the proverbial red brick and tile bungalow... The result, functionally and visually, is disastrous.” (Butler-Bowdon et al., 2007, p. 160). Despite the negative rhetoric surrounding these six-pack apartments, they were considered a logical response to the needs of that time and provided spacious and affordable housing options for Australia’s increasingly diverse populations in strategic inner city locations (Townsend and Pert, 2020). Recognising the variety of architectural styles and quality of build characterise the post-war boom, a typical 1950s-1970s apartment is described in relation to its architectural design merits in **Table 1-3.**

Table 1-3 Characteristics of a post-war apartment building (Randwick City Council, 2006)

Form/Design	Amenity	Performance/Operation
• Relatively slim buildings with a narrow street frontage; • 2, 3 or 4 storeys in height;	• Minimal landscaping, dominated by driveways and rows of garages;	• Relatively poor environmental performance;

• Minimal and repetitive design features and materials • Solid, well-built structure	• Limited private and communal open spaces; • Poor link between indoor and outdoor living areas	• Generally easily and cheaply maintained due to lack of communal facilities

In the postwar boom, whether the affluent apartments or the six-pack, apartment building construction was driven by economic conditions where function and efficiency were prioritised in the design (Randwick City Council, 2006; Yang et al., 2022). Moreover, while some notable apartment buildings were designed by influential mid-century modern architects such as Harry Seidler who worked on the first strata-titled apartment building *Blues Point Tower* in Sydney as seen in **Figure 1-7**, majority of apartment developments were driven by a speculative market – built by developer-builders to satisfy economic conditions without much regard to architectural design or urban amenity (Butler-Bowdon et al., 2007; Randwick City Council, 2006; Walker and Townsend, 2020). Butler-Bowdon et al. (2007) noted that apartments have become investments and a source of profiteering for developers through strata titles, resulting in poor quality of apartment builds. The low quality, bland, and repetitive design of the new apartment towers and blocks produced by speculative developers raised government concerns, although belatedly, before the turn of the 20th century. In 1999, a review initiated by the NSW Government to improve the quality of apartment buildings culminated in the introduction of State Environmental Planning Policy No. 65 (SEPP 65) and Residential Flat Design Code in 2022, restricting apartment design to accredited architects and designers (Butler-Bowdon et al., 2007; Yang et al., 2022). The Residential Flat Design Code was updated in 2015 and replaced by the Apartment Design Guide (NSW Government, 2015).

Apartment building construction peaked in 1971 and slowed down afterwards due to growing public opposition to this housing typology and unfavourable economic conditions (Butler-Bowdon et al., 2007; “Flats,” 2008; Randwick City Council, 2006). However, another surge began again in the 1990s through to the 2010s, which produced the high-rise residential towers that now dominate urban areas (Butler-Bowdon et al., 2007; Yang et al., 2022). Nowadays, controversies still surround apartment buildings. Building defects as grave as structural issues have plagued 21st-century apartments (Crommelin et al., 2021). One of the key reasons for these defects is the substandard building practices during an expansive growth for the apartment sector, driven by a reliance on Design and Construct (D&C) contracts as a method for building construction (Crommelin et al., 2021; Denman et al., 2024). A D&C contract allows for tendering with minimum design documentation, as the design is completed by a separate team of architects and consultants (e.g. engineers) is performed by the principal contractor (Australian Institute of Architects, 2019). This trend was found to have led to contractors deviating from the design documentation through material substitution to cut costs, for example (Australian Institute of Architects, 2019; Denman et al., 2024). The worrying implications of such a trend highlight the potential to return to more traditional forms of building construction to ensure design is completed and overseen by qualified architecture and design professionals and to prevent further building defects in apartment developments (Denman et al., 2024).

Figure 1-7 1960s Blues Point Tower in North Sydney designed by architect Harry Seidler (Hoskins, 2015)

Time and time again, apartment housing – and its place in our cities – is being challenged. But as has been the case historically, even after over a century of contestations, apartment buildings have proven to be an enduring part of the Australian cities. A striking commonality is the recurring subtraction of architectural input in apartment development in the name of financial gains, and the resulting ramifications becoming evident over time. Perhaps what can be learned from these controversies is the need for careful consideration of these apartment buildings and the role of architectural design in making them not only an enduring part of our urban fabric, but one that is accepted, valued, and reflective of Australian aspirations today and of future generations.

From modest low-rise apartment blocks to complex residential towers, the melange of socio-economic factors, legislative changes, shifts in cultural paradigm and architectural design, and advancement in technology in the last century generated a plethora of apartment building archetypes that make up the Australian urban fabric and collectively serve as a visible force that push the frontier of Australian urban form, economy, and social life. As Butler-Bowden et al. (2007, p. x) observed, "throughout their history, apartment buildings have formed the architectural cutting edge of social and cultural change. Apartments have provided an architectural context for the emergence of social grounds distinct from the suburban mainstream." Given their importance and unique development in the Australian context, apartment buildings provide an interesting field for exploring CE adoption through architectural renovation. The next section expounds on the case for this.

Table 1-4 outlines the common apartment building categorisation and characteristics such as height and density, configuration and function, and era of construction, as discussed in this section.

Table 1-4 Apartment building characteristics and categorisation

Categorisation	Types	Description
Height and density *(Australian Bureau of Statistics, 2021)*	Low rise	1-3 storeys
	Medium rise	4-8 storeys
	High rise	9-19 storeys
	Super high rise	20+ storeys
Function and configuration *(NSW Government, 2015)*	Infill	Low-rise walk-up (stairs only) apartment buildings in narrow and deep lots
	Shop top	Mixed-use apartment building with commercial/retail use on the ground level and residential use above
	Perimeter block	Compact apartment buildings that define street edge ranging from four to nine storeys
	Tower	Strong vertical form with more than 9 storeys, combined with a podium typically located in higher density areas
Era of construction *(Butler-Bowdon et al., 2007; GML Heritage, 2024; Randwick City Council, 2006; Yang et al., 2022)*	Inter-war	Built around 1910-1940s, typically walk-up apartments with art-deco architectural style, ranging from one to four storeys
	Post-war	Built around 1950-1970s featuring functional architectural style typically built with elevators
	Modern high-rise	Built around early 1990s to 2020s characterised by modern glass facades

1.3.2 Architecture in apartment development and in a CE

Architects play a central role in apartment development. From Le Corbusier's highly influential work on the Unité d'Habitation that revolutionised high-density living in the postwar era (Millais, 2015) to Lacaton and Vassal's contemporary architecture *PLUS* philosophy that allowed transformation of ageing social housing without resorting to demolition in France (Buckley, 2012; Gromark and Paadam, 2017), the architect's role in bringing soul to the apartment can be apparent and long-lasting. In Australia, Butler-Bowdon et al. (2007, p. 70) noted that "architects have a closer relationship with apartment design than with that of the suburban cottage... and have long argued that improved design would mollify apartment critics." Historically, architects had a key influence particularly during the post-war boom in advocating for architectural design in apartments, with the modernist works of Harry Seidler in Sydney and Robin Boyd in Melbourne as influenced by Le Corbusier's architectural philosophy (Butler-Bowdon et al., 2007). Although consistently challenged, this central role is still recognised today and applies not only to new developments as mandated in some state legislations (i.e. NSW) but also in the renovation of existing apartment buildings. For example, in 2006, the Randwick City Council, which hosts a significant share of interwar and postwar apartment buildings across Sydney, had recognised the value of architect involvement in renovation. They frame design excellence in apartment renovation not only as a renewal strategy on a building scale but also on an urban scale (Randwick City Council, 2006). However, architects find themselves in a less influential role in the apartment sector that is dominated by speculative developers and shaped by a practice of minimum standards (Australian Institute of Architects, 2023, 2019; Butler-Bowdon et al., 2007; Horne et al., 2023).

Likewise, architects are central to CE adoption in the built environment. CE literature emphasises that design is a core aspect of the CE transition (Dokter et al., 2021). The EMF in their seminal 2013 publication highlighted the role of design in a CE, defining CE as 'an industrial economy that is restorative or regenerative by intention and design' (Ellen MacArthur Foundation, 2013, p. 14). There is consensus in the literature that design is one of the important stages of building projects in facilitating circular practices (Dokter et al., 2021; Sáez-de-Guinoa et al., 2022; Stoiljković et al., 2023).

In the built environment, this means that the design role architectural professionals (e.g. architects and designers) play is crucial (Dokter et al., 2021) as principal building designers and client consultants in building projects (Nicholson and Miatto, 2024). However, the challenge of CE's implementation ambiguity, as discussed in **Section 1.2.4,** extends to the architectural practice. Dokter et al. (2021) emphasise that the extent to which the CE-driven systemic and fundamental shift is understood within the design practice remains unclear. While research on CE at the building scale has grown exponentially in recent years, there have been limited empirical investigations into the architecture profession's perspective on climate action and its role in CE (Warren-Myers et al., 2024). Due to the fundamental changes the CE transition brings to market and labour systems, further investigation of the potential workforce implications is essential for a just transition (Fairbrother and Banks, 2024). This extends to the architectural profession and warrants an in-depth exploration of the CE adoption from their perspective to allow for a broader understanding of CE transition.

The influential modernist architect, Le Corbusier (2007, p. 4), put forward that "the business of architecture is to establish emotional relationships by means of raw material." Architecture, when applied to an apartment building, not only create the basis for the fundamental human need of shelter but also renders affects from the people that inhabit and surround it and, more importantly, brings forth the apartment building's relationship to the broader society and ecology. While Le Corbusier (2007) emphasised the role of the architect in the creation or *birth* of affective houses, streets, and towns, Cairns and Jacobs, on the other end of the spectrum, underscored that architects and the architecture discipline have overlooked their role in the *death* of buildings. They argued that "the death of buildings is currently underdeveloped in architecture's sense of itself, yet it forms a necessary part of how architecture and architects are in the world" (Cairns and Jacobs, 2014, p. 1). Similar to Le Corbusier, who asserts that the first duty of architecture is to bring about "a revision of values", Cairns and Jacobs (2014, p. 1) ask "what would it mean for architecture to cultivate a sensitivity to how buildings waste, deteriorate and die" – a seeming foreshadowing of the role of architects in a CE as presented above. This thesis takes on the duality of the architect's role in creating enduring apartment housing and in dealing with buildings at risk of obsolescence. The architectural renovation of apartment buildings with a CE approach responds to these two important prompts that can recalibrate architecture's purpose in the Anthropocene. The succeeding section brings together the arguments discussed thus far and presents what architectural renovation with a CE approach entails for the apartment building sector.

1.3.3 Architectural renovation with a CE approach

As detailed in the Section **1.3.1**, apartment buildings as a housing typology have been a contested space, with issues ranging from housing quality and their place in the Australian urban fabric. Addressing the sustainability and adaptability of these existing buildings is therefore essential to their continued relevance in contemporary urban contexts. Several decades after the Strata Title Act was introduced, the number of strata schemes (which can indicate the number of privately-owned apartment buildings) have reached 340,601 by 2020 across Australia (Easthope et al., 2023b). Approximately 54% of total strata schemes were registered before 2000, which is equivalent to about 184,000 apartment buildings (Easthope et al., 2023b). This indicates that more than half of the apartment building stock is ageing and was built before the introduction of minimum sustainability standards (ClimateWorks Centre, 2023). The ageing apartment housing stock emphasises the need for renovation to not only reduce emissions from buildings but also bring these apartment buildings to current sustainability and living standards, breathing new life into these ageing buildings. This is especially crucial for complex yet vital housing typologies such as apartment buildings (Altmann, 2014; Löschke and Easthope, 2017; Pikas et al., 2021), which house an increasingly significant share of the urban population (Australian Bureau of Statistics, 2022b; Marinova et al., 2020; Rosewall and Shoory, 2017).

The current renovation wave across the globe focuses on Deep Renovation (DR), also called Deep Energy Retrofit, which entails integrative, whole-of-building renovation activities to substantially reduce the operational energy emissions of existing buildings

(Semprini et al., 2017). DR initiatives are particularly prevalent in Europe due to the European Union Energy Performance of Buildings Directives (European Union, 2024) , which have necessitated deep renovations towards Nearly Zero-Energy Buildings (D'Oca et al., 2018). While there is no universally accepted definition of DR, it typically involves upgrades to the building's envelope, mechanical systems, and energy sources to enhance energy efficiency during the operational phase of the building, improving indoor environmental quality and achieving substantial energy savings within a variable threshold depending on geographical context (Schnapp et al., 2013; Semprini et al., 2017) .

Although DR is an essential strategy to reduce emissions associated with apartment building stock, the Australian context compels a broader undertaking that looks beyond improving energy performance in apartment buildings. As presented in the earlier sections, the majority of apartment buildings are ageing, with some being characterised by poor design or defective construction due to a myriad of factors throughout their development over the past century. These apartment buildings, nearing their supposed end of life either due to deterioration or defects, are at risk of obsolescence (Thomsen and Van Der Flier, 2011), threatening a resilient housing stock and undermining the urban vitality of Australian cities if left unrenovated. In 2006, Bill Randolph (2006), a prominent Australian urbanist, had already pondered the issue of ageing strata buildings. He noted that ageing strata buildings are already causing an issue in some areas, particularly low value areas such as the middle suburbs of Sydney where renovation is less economically feasible, adding that "there are no systems in place to manage either the major overhaul of these properties or their eventual removal and redevelopment when they come to the end of their life... Indeed, there is much to learn about the potential life cycle of these buildings. These issues have been largely ignored by metropolitan planners in Australia" (Randolph, 2006, pp. 484–485). Two decades later, this observation ceases to become a rhetoric but an imperative that needs to be addressed. Indeed, the renovation agenda for the residential sector at both state and federal levels to this day has been piecemeal. The thesis underscores that the housing renovation agenda should look beyond energy efficiency and savings and embrace habitability as an objective through architectural perspectives. Otherwise, as Martin-Goñi et al. (2024, p. 20) argued, "buildings will remain in a state of obsolescence if only energy efficiency is improved."

Architectural renovation – defined in this thesis as a renovation approach that integrates architectural design and may encompass DR – is vital to not only reduce operational emissions of apartment buildings but also strategically extend their lifespan and maximise their value (e.g. social, economic, cultural, heritage, etc) to its owners, residents, and broader community. Previous architectural deep renovation projects of apartment housing in Europe provide evidence of this (Fotopoulou et al., 2018; Martin-Goñi et al., 2024). An exemplar of the architectural renovation approach is the transformation of the Bois-Le-Pretre Tower, a 17-storey public housing apartment tower in Paris built in 1962 (Buckley, 2012). The renovation involved a combination of DR, social sustainability, and architectural design quality that resulted in an increase of living space, addition of balconies and sunspaces, and energy consumption reduction of almost 50% (Fotopoulou et al., 2018). The architectural renovation of Bois-Le-Pretre Tower by project architects Frédéric Druot, Anne Lacaton, and Jean-Philippe Vassal was driven by the philosophy of *never demolishing* (Buckley, 2012; Gromark and Paadam, 2017). It is considered a radical approach to dominant urban housing renewal initiatives with a disposition for demolition (Gromark and Paadam, 2017). It is an urban and architectural manifesto that reengages with the call for "a different consciousness regarding the existing infrastructure of public housing as a resource secreted within the city and whose potential can be unlocked through architectural and urban acts capable of preserving while profoundly transforming" (Buckley, 2012, p. 50). In summary, architectural renovation of apartment buildings represents an important strategy to both decarbonise the residential sector and to future-proof and deliver housing that promotes sustainable development.

Furthermore, interest in 'circular renovation' – the application of Circular Economy (CE) approaches to building renovation – has grown in recent years for its potential to maximise material efficiency and reduce embodied emissions (De Feijter, 2023; Densley Tingley, 2022; Easthope et al., 2023a; EEA, 2022; Nigumann et al., 2024; Nußholz et al., 2023; Sáez-de-Guinoa et al., 2022; UNEP, 2022). In 2022, the European Union recognised that if it were to meet its climate-neutral goals, its green building renovation wave must expand its scope beyond the building performance targets of deep renovation schemes towards a "circular renovation" model, shifting the focus from operational to embodied emissions (EEA, 2022). CE adoption in ongoing and imminent renovation waves requires attention to avoid a legacy of waste and reduce the embodied emissions associated with substantial renovation activities (Densley Tingley, 2022; Kuittinen, 2023; Nigumann et al., 2024). It could also translate to reduced costs and an improved local economy (EEA, 2022; Marchesi et al., 2020; Rahla et al., 2021). If adopted at scale, circular renovation can effectively accelerate the attainment of climate goals under the Paris Agreement by decarbonising and future-proofing existing building stock against climate change impacts (EEA, 2022; Nußholz et al., 2023).

In Australia, although CE adoption is still considered in its infancy, particularly in the built environment (Shooshtarian et al., 2023), there is growing recognition of a CE approach to contribute to a more sustainable housing system (Horne et al., 2023). In 2024, the Australian Government published a first-of-its-kind Circular Economy Framework (CEF) (*Australia's Circular Economy Framework*, 2024). It aims to double the country's circularity rate (which is currently estimated at 4.6%) by 2035, enabling emissions abatement up to 23% of Australia's greenhouse gas emissions by 2050 based on scientific modelling (*Australia's Circular Economy Framework*, 2024). The built environment, which encompasses residential buildings, is one of the most material-intensive sectors in Australia (CSIRO, 2024), while also generating 35% of national waste from building and demolition materials (DCCEEW, 2025). As such, the Australian CEF identified the built environment as a priority sector in the nationwide CE transition, stating that it "represents the most significant opportunity for Australia to decrease material footprint and drive uptake of circular, sustainable materials... and also an opportunity to reduce GHG emissions through circular economy practices" (*Australia's Circular Economy Framework*, 2024, p. 19). Furthermore, it specified building renovation as a priority and identified embedding circular design as an enabler for the CE transition in the built environment. Yet, as the country's urban population and housing demand continue to grow, the default response to address such contemporary issues has been to demolish ageing dwellings and construct new ones. Knockdown and rebuild practices remain prevalent in Australia, as evidenced by the two-decade-long *relocate-demolish-rebuild* renewal approach taken by state governments, particularly Victoria and New South Wales, for large-scale interwar and postwar public housing apartment blocks (Zanardo et al., 2024). Such a response continues to challenge the sustainability of apartment buildings and fundamentally opposes the CE visions for Australia's built environment.

Alternatively, architectural renovation with a CE approach offers a pathway that can both address apartment housing and climate issues in Australia. However, due to the nascent state of the CE field, the application of CE to architectural renovation of apartment buildings remains underexplored in literature, and the practical knowledge of CE in this area remains largely limited – gaps that this thesis aims to address. Furthermore, Genovese et al. (2021) argue that CE proponents call for rethinking how we produce but fail to question why or what we produce. This thesis highlights this critique and responds to it by contextualising CE principles in the architectural renovation of apartment buildings. By doing so, it re-orients CE discourse towards a universal social agenda such as sustainable housing.

The architectural renovation of apartment buildings – given the typology's growing importance in Australian urban fabric and housing mix, substantial embodied values (e.g. material, economic, social, cultural, heritage, etc.), and contextual complexity – presents a compelling area for deeper CE investigation. Examining this context is an important step towards sustainable apartment housing renewal and the wider paradigm shift towards a circular built environment in Australia.

1.4 Research aims and questions

Acknowledging the imperative to transition to a CE and to promote the sustainability of Australian apartment building stock, this thesis aims to address the Primary Research Question (PRQ): *How can a Circular Economy approach be adopted in the architectural renovation of apartment buildings?* The thesis problematises the linear economic model underpinning the building sector and the current state of Australian apartment building stock. It recognises the opportunity in architectural renovation of apartment buildings with a CE approach to address the described housing and climate issues. Building on the critique that existing research on CE has largely overlooked its social dimension, the thesis explores the social elements that might constitute CE adoption in the architectural renovation of apartment buildings. By focusing on the social aspect of the CE transition in the apartment housing context, the knowledge generated by this thesis aims to bridge the theoretical, practical, and contextual gaps in CE literature described earlier and to inform research, policy, and practice to contribute towards sustainable housing and a circular built environment in Australia. To achieve these aims, the research inquiry is anchored in the following research objectives:

Objective 1

- Review relevant literature on CE and apartment building renovation to identify existing gaps and opportunities and propose research themes

Objective 2

- Explore the social dimension of CE adoption based on the proposed research themes:
  - 2.1 Investigate the integration of CE principles in existing building frameworks as *social artefacts* applicable to apartment building renovation and evaluate their potential to facilitate circular renovation
  - 2.2: Explore the role of the architectural profession as *social actors* in CE adoption and the barriers and enablers they face in implementing circular renovation of apartment buildings
  - 2.3: Examine how a CE approach is implemented in real-life residential building projects as *social activities*, and identify lessons learned to inform future circular renovations

Objective 3

- Propose a CE-oriented practical framework for the architectural renovation of apartment buildings to embed circular renovation in practice

The remaining sections of this Introductory chapter describe the overarching research approach to respond to the identified research question and objectives, detail the methods employed in the empirical chapters, and then discuss the relevance and contributions of the research. Lastly, the thesis outline is presented as a final overview.

1.5 Research approach

The research approach taken by the researcher reflects their epistemological understanding of the world (Yvonne Feilzer, 2010). Similarly, all writing is "positioned" and within a stance (Creswell, 2013). Prominent research methodologists Creswell and Poth (2018) emphasise that it is not only important to understand the certain beliefs and philosophical assumptions we bring to our research, but also beneficial to actively write about them. The following section engages with this invitation: it explicitly articulates the philosophical underpinning of this thesis that guided the choices of the researcher in approaching and conducting the research.

1.5.1 Pragmatism as the Research Paradigm

The primary aim of the research is rooted in real-world problems. As the aim of this research sits within the context of the climate emergency and relates to time-bound climate targets and CE visions, this research adopts *Pragmatism* as the underlying philosophical framework that guides the overall research process. In the late 19th to early 20th century, Pragmatism emerged as a philosophical movement through the works of Charles Pierce, William James, and John Dewey to free research from the metaphysical debates concerning philosophical beliefs on the nature of reality and truth and to propose a new philosophical paradigm that accepts the possibility of multiple realities (Kelly and Cordeiro, 2020; Morgan, 2014; Yvonne Feilzer, 2010). Pragmatism as a research paradigm reorients research to practice, creating actionable knowledge that purposefully responds to real-world problems (Creswell and Plano Clark, 2018; Yvonne Feilzer, 2010). A pragmatic inquiry focuses on the consequences and questions of the research rather than its methods, which dominant paradigms are particularly fixated on (Creswell and Plano Clark, 2018). As such, it enables flexible investigative techniques as the research progresses and encourages pluralism in methods to best address the research question

(Creswell and Plano Clark, 2018; Onwuegbuzie and Leech, 2005). Pragmatism also frames research as a process of inquiry rooted in real life and, at its core, considers research as a human experience based on beliefs and actions (Morgan, 2014). It upholds Dewey's value of *freedom of inquiry* that allows "individuals and social communities to define issues that matter most to them and pursue those issues in the ways that are the most meaningful to them" (Morgan, 2014, p. 1049). Thus, Pragmatism has been embraced in and considered suited for social research (Kaushik and Walsh, 2019; Morgan, 2014) as it drives meaningful inquiry aimed at improving our conditions through adaptation and accommodation (Cronen, 2001).

A pragmatic approach to this research is fundamental for two reasons. First, it enables the delivery of the research aim to contribute actionable knowledge relevant to the present context. Second, it equips the researcher with the flexibility to navigate the uncertainties of CE as 1) an emerging and dynamic research field (Kirchherr et al., 2023a) and 2) an *imagined future*, which Casson and Welch (2021) describe as socially-constructed visions that may still be contested but come to inform or influence the social world and its various areas such as professional practices, political projects and everyday consumption. These reasons align with Kaushik and Walsh's (2019, p. 11) assertion that pragmatism is interested in "what the world might be – it orients itself toward a prospective world, a world not yet realized." In the context of this research, a pragmatic approach allows for uncovering and making sense of CE, as it is grounded in the real world, with the hope of shaping an imagined future towards a more sustainable world.

1.5.2 Theoretical underpinning

As highlighted in **Section 1.2.4**, CE scholarship has inadequately incorporated socio-political and socio-cultural perspectives in the research agenda (Korhonen et al., 2018; Moreau et al., 2017; Murray et al., 2017; Pál, 2022; Schulz et al., 2019; Zavos et al., 2024) and needs reorientation to support sustainable development (Genovese and Pansera, 2021; Kirchherr et al., 2023a; Purvis et al., 2023). Kirchherr (2023a, p. 2) argues that there is "utter negligence" of the social impacts of CE, despite the established call to strengthen social perspectives in CE research, which to date remains marginal.

In the Australian context, similar shortcomings in CE scholarship are observed. The Australian Circular Economy Hub's industry surveys in 2021 and 2023 revealed that a lack of implementation knowledge has been the primary barrier to CE adoption (Collins et al., 2023; Parry-Husbands et al., 2021). This finding suggests that the shift towards CE entails not purely a question of technical capacity, but also considerations of social actors and their adaptive capacity. While efforts have been made towards a just and equitable CE transition for sustainable housing in Australia (Horne et al., 2023), information regarding the social aspects of circularity in the built environment is still sparse (Zaman et al., 2023).

Based on extant literature, the frontier of CE research and implementation lies in the social realm. This is no surprise when one examines the origins of the concept of CE, as Boulding (1972, p. 351) himself emphasised that the "spaceship" metaphor of CE entails fundamental social change:

> The ethic of the spaceship has to be very different from that of the cowboy on the Great Plains. This imminent "closure" of the human environment is a profound psychological change in the state of mankind... the consequences of this for personality, ethics, religion, the family, the nation, the corporation - indeed for all human institutions - will be profound. Human culture developed on a psychologically flat earth-that is, on an infinite plane, always with somewhere to go over the hill, always with a frontier, a place for escape. The transition from the infinite plane to the closed, limited, round ball of spaceship Earth is a psychological transition whose bare beginnings we have only just encountered.

In their proposed research agenda for a circular built environment, Pomponi and Moncaster (2017, p. 16) align with Boulding and underscore that "the greatest challenges that lie ahead will deal with the role of people, both as individuals and as society as a whole," prompting for interdisciplinary research to broaden the narrow technical focus of CE to a more comprehensive epistemology. Corroborating this assertion, James (2022, p.

1216) argued that emerging lines of critique are weak in producing a more adequate and holistic reformulation of a CE and that “an alternative conception of the CE needs to be embedded in the social as a whole.”

As a response to the call for a more socially oriented inquiry into CE adoption, the thesis draws on and builds upon several theories and frameworks from sociology and the sustainability transitions fields. Sociological theories provide a set of tools as a starting point through which the social dimension of CE can be examined. Meanwhile, sustainability transitions literature helps situate the context of the research (i.e. architectural renovation of apartment buildings) as a part of the CE transition.

The theoretical foundation of the research is informed by social practice theory (SPT) (Shove et al., 2012) and sociomateriality theory (Orlikowski, 2007; Orlikowski and Scott, 2008) in sociology, as well as the multi-level perspective (MLP) theory in sustainability transitions research (Geels, 2019, 2018, 2011, 2010; Geels and Schot, 2007). There is a growing body of work that recognises and employs these theories – either in isolation or in combination – in CE research (Köhler et al., 2020; Mylan et al., 2016; Oyinlola et al., 2023; Schulz et al., 2019; Van Uden et al., 2025). While not as established in domains such as energy transitions, the increasing relevance of these theories in CE research provides a rationale for their use in this thesis. Both frameworks recognise the power of social meanings and narratives in shaping transitions and offer conceptual tools not only for analysing interventions but also for designing and implementing them (Keller et al., 2022b). In this thesis, MLP and SPT concepts, specifically, are used to develop a conceptual framework that organises the analytical foci of the empirical studies and interprets empirical findings to inform recommendations. Although by no means an in-depth account of these theories, the following paragraphs provide an overview as they relate to the research context and their application to the conceptual framework that will be presented afterwards.

The MLP theory in sustainability transitions research provides a “big picture” integrative framework for understanding large-scale societal and technical changes that occur in societal systems such as housing, accommodating "multiple actors and dimensions and ranging from local projects to niche-innovation to sectoral regimes and broader societal contexts" (Geels, 2019, p. 197). Building on earlier works of Rip and Kemp (1998), Geels proposed that within the MLP framework, the socio-technical transition is a result of interactions between three structural layers of a socio-technical system: niche, regime, and landscape (Geels, 2010; Geels and Schot, 2007). Niche level comprises protected spaces where radical innovation can emerge and be developed by niche actors, which can later challenge or replace existing regimes. Regime level represents dominant paradigms that provide the stability and structure to the system and are characterised by established rules and practices shaped and maintained by regime actors. Landscape level comprises macro-level forces that can be gradual trends (e.g demographic shifts, climate change) or sudden shocks (e.g. pandemics, wars, economic crises, etc), which influence the regime and niche levels but cannot be easily influenced by the regime or niche levels. A transition happens when socio-technical configurations change as a result of landscape pressures on regimes or momentum gain by niches, allowing the latter to break through and scale up, which can then form new regimes or reform existing ones. Geels and Schot proposed a typology of four transition pathways depending on the nature and timing of interactions between the different levels (Geels and Schot, 2007). Although these pathways are not deterministic – meaning a new socio-technical regime may not necessarily emerge – they can coexist, evolve from one to another, and exhibit a recognisable logic observable in both historical and contemporary transitions (Geels and Schot, 2007). The typology (outlined in **Table 1-5**) highlights diversity in transitions, allowing for a better understanding of the influence of actors' agency and structures on the outcomes of the transition pathways.

Table 1-5 Typology of transition pathways based on Geels and Schot (2007); table summary adapted from Mazur et al. (2015).

Transition pathway	**Nature of Interaction**		**Timing of Interaction**	**Characteristics and main actors of the transition**
	Landscape pressure	Niche-regime interaction	Niche-innovations are well developed	
Reproduction (no transition)	None	N/A	N/A	Regime is stable and reinforces itself; niche innovations may exist but little no chance of breakthrough, landscape stabilises the regimes
Transformation	Moderate	Competing or symbiotic	No	Niche innovations are not yet developed; Regime actors respond to moderate landscape pressures and regime outsiders to adapt existing regimes
Reconfiguration	Moderate	Symbiotic	Yes or No	Niche innovations are developed, and regime actors adapt to new alternatives; new regimes are established from old ones
De-alignment and re-alignment	Strong	Competing	No (initially)	Landscape pressure destablises and erodes regimes, multiple niche innovations emerge and

				compete to establish new regimes
Technological substitution	Strong	Competing	Yes	Landscape pressure destabilises and erodes regimes, niche-innovations are well developed and break through to replace existing regimes; similar to reproduction pathway without landscape pressure to destabilise regimes

Within the sustainability transitions field, Smith and Fressoli (2024) summarised four broad types of interaction between niches and regimes, based on earlier works and empirical studies. They emphasise that analysing the niche-regime interactions is important in sustainability transitions, as it sheds light on how technologies, actors and institutions are reconfigured over time (Smith and Fressoli, 2024). The four types are: 1) differentiation, 2) co-option, 3) hybridisation, and 4) criticism. Differentiation arises from antagonistic or competitive interactions between niches and regimes, where niches operate in fundamentally different ways, presenting alternatives that aim to challenge and potentially replace the existing regime. Co-option occurs when specific innovations from niche spaces become competitive and are integrated into regimes without altering the latter's core structure or set of rules – reflecting a "fit and conform" empowerment dynamic (Smith and Raven, 2012). Hybridisation involves a "stretch and transform" process, where niche elements are embedded within regimes in ways that can lead to significant structural changes over time (Smith and Raven, 2012). Criticism represents more radical interactions that question the legitimacy of the regime, confronting the compromises from hybridisation interactions and advocating for deeper regime transformation (Smith and Fressoli, 2024). By understanding the interactions between niches, regimes, and landscape levels in this context, the transition can be better characterised and inform interventions.

In the context of this research, circular renovation practices can be understood as a niche innovation in the housing system that is a radical alternative to the mainstream practices underpinned by a linear economic model. The mainstream practices (e.g. knockdown and rebuild) and the actors, systems, and structures that support these practices characterise the existing regime. Landscape pressures in this context range from climate change impacts to resource depletion, affecting global building material supply. It is important to situate CE adoption in architectural renovation of apartment buildings as part of a broader socio-technical systems transitioning towards CE to avoid researching in a vacuum and to recognise exogenous factors that may implicate broad-scale circular architectural renovation of apartment buildings. As a process theory, the MLP provides the global model to situate the phenomenon of interest (i.e. CE adoption in architectural renovation) as well as a temporal reference to the transition.

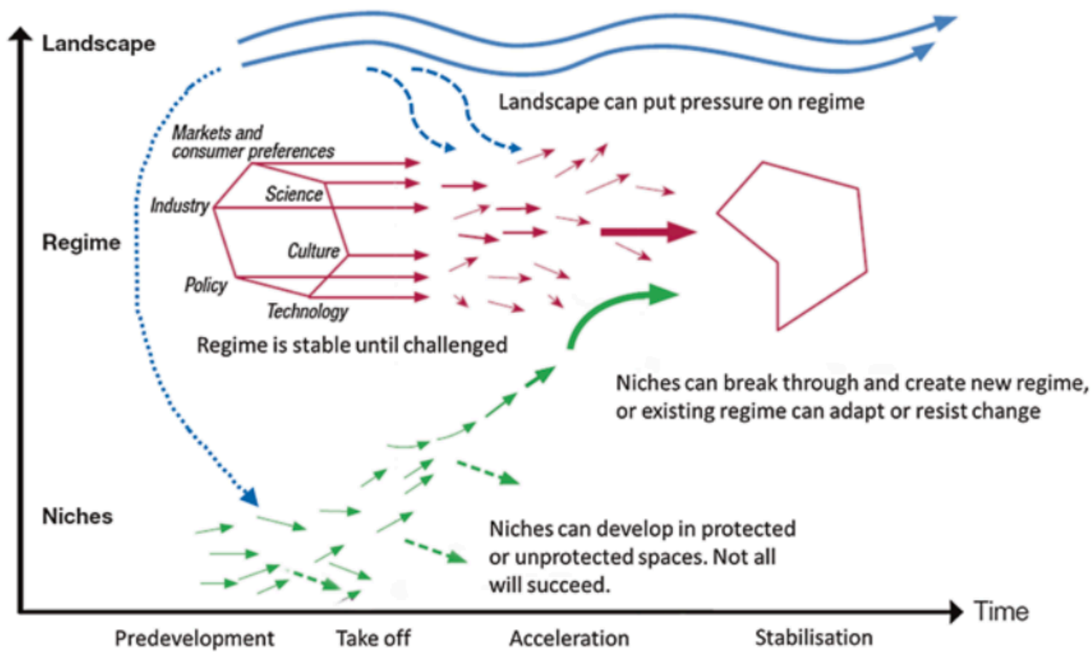

Figure 1-8 Multi-Level Perspective of Socio-technical Transitions (adapted from Moore and Doyon, 2023, re-illustration of Geels)

To provide a micro-perspective that can complement the meso-perspective of MLP, SPT and sociomateriality theory from social studies provide interesting lenses to understand the social dimension of CE. In sustainability research, SPT explains why economic incentives, technological advancement or knowledge diffusion alone cannot successfully instigate behaviour change towards sustainability (Shove et al., 2012). Contrary to theories that hold individuals as rational beings, SPT argues that social life is organised around practices and transformation can be engendered by understanding and changing social practices, shifting the focus from the individuals to the practices themselves to understand social action (Shove et al., 2012). Building on previous works by social theorists (Bourdieu, 1977; Giddens, 1984; Reckwitz, 2002), Shove et al. proposed that social practice is embedded in social activities which are routinised and shaped by three elements: materials (stuff or tangible material things), competences (knowledge, technical know-how), and meaning (symbolic meanings, ideas, beliefs) (Shove et al., 2012; Shove and Walker, 2010). Practices are dynamic and constantly evolving – they emerge, endure or disappear as links between these elements are made or broken. This evolution can take the form of emergence (new links forming from new elements), deformation (links disappearing or eroding between elements), and re-formation (new configuration of links between existing elements). Multiple practices can co-exist and may cluster into either bundles (loose-knit patterns) or complexes (stickier and more ingrained patterns) (Shove et al., 2012). Within SPT, a practice can be changed in three key ways: 1) through changes in the constituent elements (i.e. material, meaning, competence); 2) through changes in the carriers of practice (i.e. practitioner or the people who perform it); and 3) through changes in how practices bundle or interact with one another (Watson, 2012). Shove et al. (2012, p. 2) argued that top-down policy approach to sustainability is insufficient, rather changes to everyday practice, skills and shared values must also occur, adding that "policy initiatives to promote more sustainable ways of life could and should be rooted in an understanding of the elements of which practices and systems of practice are formed, and of the connective tissue that holds them together." The research aligns with this position and holds that circular renovation and the social dimension of the CE transition can be understood by examining existing practices, grounded in the social fabric of daily life, in architecture and apartment renovation, as will be explored particularly in **Chapters 3 and 4** of the thesis.

In line with Shove et al.'s conception that practice is constituted by materials, the thesis also acknowledges the sociomateriality theory. Sociomateriality posits that social elements (e.g. people) and material elements (e.g. technology) are inseparable and mutually co-construct each other, or what Orlikowski et al. (2007) refer to as constitutive entanglement. Sociomateriality attributes agency to material artefacts and challenges the idea that technological or physical artefacts are passive elements that only provide a background or a tool in social action and that they exist in a distinct sphere from the social. Rather, it poses that material elements are active agents that shape and are shaped by social practices. Orlikowski et al. (2007, p. 1444) argue that "all practices are always and everywhere socio-material, shaping the contours and possibilities of everyday life." In the context of this research, a sociomaterial lens frames CE adoption to be co-shaped by both social and material elements. In other words, to understand the *social* means to understand the *material*.

It is acknowledged that transitions are conceptualised differently by these schools of thought, particularly between social practice and multi-level perspective theories, due to their different ontological assumptions about transitions (Geels, 2011). STP assumes a flat social ontology, or a horizontal structure of practices that co-construct the socio-technical system, while MLP holds the system exists in different levels, which are degrees of structuration of local practices (Van Uden et al., 2024). Shove and Walker (2010, p. 476) argued that socio-technical transitions from an MLP perspective "obscure the central role that practitioners themselves play in generating, sustaining and overthrowing everyday practices", underscoring the "importance of attending to all requisite elements of practice, to forms of practical know-how, bodily activities, meanings, ideas and understandings, as well as to materials, infrastructures and sociotechnical configurations." Geels acknowledges these criticisms of the MLP but concludes that both positions share similarities in the kinds of phenomena of interest, and one could reformulate practice theory in MLP terms and vice versa (Geels, 2011). As a middle-range theory rather than a grand one, MLP welcomes conceptual elaboration in that it “could benefit from including insights from auxiliary theories” (Geels, 2011, p. 30) and acknowledges “openness with regard to conceptualisation of more detailed activities and mechanisms” of the local model (Geels, 2019, p. 197). Keeping consistent with the pragmatic stance of this thesis, the research does not seek to reconcile the disagreements between these theories but to apply relevant aspects of these theories to address their limitations and enrich the understanding of the problem at hand and the approach to inquiring about it. As Geels articulated, practice theories are more descriptive and emphasise heterogeneity and emergence in transitions, while MLP aims to generalise and explain the mechanisms and patterns of transition. The thesis argues that there is a benefit in exploring transitions from multiple perspectives. In their exposition of the crossover between SPT and MLP theories in sustainability research, Van Uden et al. (2024) found that there have been attempts, although limited, at developing crossover frameworks to address shortcomings from each perspective – underscoring the potential complementary nature of both theories. This limitation is more pronounced for the architecture, engineering and construction system, wherein practices are largely routinised and sustainability targets are critically lagging (Van Uden et al., 2024). However, they also argued that due to the ontological differences between the two theories, a perceived gap in the theoretical understanding of combining these approaches challenges researchers and their broader application to empirical investigations (Van Uden et al., 2024). The thesis recognises this challenge arising from their ontological differences by not attempting to coalesce the perspectives and reconcile their differences. However, it also argues that choosing one perspective over the other openly neglects the proclaimed limitations of each perspective and precludes an analysis that allows for both realities to co-exist and generate knowledge from a multiplicity of perspectives. Hence, the thesis proposes a conceptual framework that dialogically considers these perspectives to organise the exploration of CE’s social dimension. By consciously employing these perspectives through a conceptual framework described in the succeeding paragraphs, the thesis contributes to the academic community’s understanding of how the two theories can be further utilised in future research. Although not explicitly employed as analytical frameworks for the empirical chapters, these theories are used discursively to abstract insights and situate them within theoretical contexts (as will be discussed in **Chapter 5**), thereby expanding the thesis's theoretical contribution.

Drawing on MLP's concepts of niches and regimes, SPT's practice elements and change dynamics, and sociomateriality's notion of social-material entanglement, this thesis argues that CE adoption in architectural renovation is part of a broader socio-technical transition towards a CE. This transition both entails and emerges from transformations in socio-material practices that constitute the social dimension – a fundamental component and agentic force shaping the trajectory and pace of change. To capture this, the proposed Adaptive Social Framework for Circular Economy Transitions comprises three interrelated elements: actors, artefacts, and activities. These elements co-construct practices and influence system dynamics within the social dimension of CE in specific contexts, such as architectural renovation. In this framework, CE transitions are driven by changes in these interconnected social elements, which collectively underpin and steer the transition.

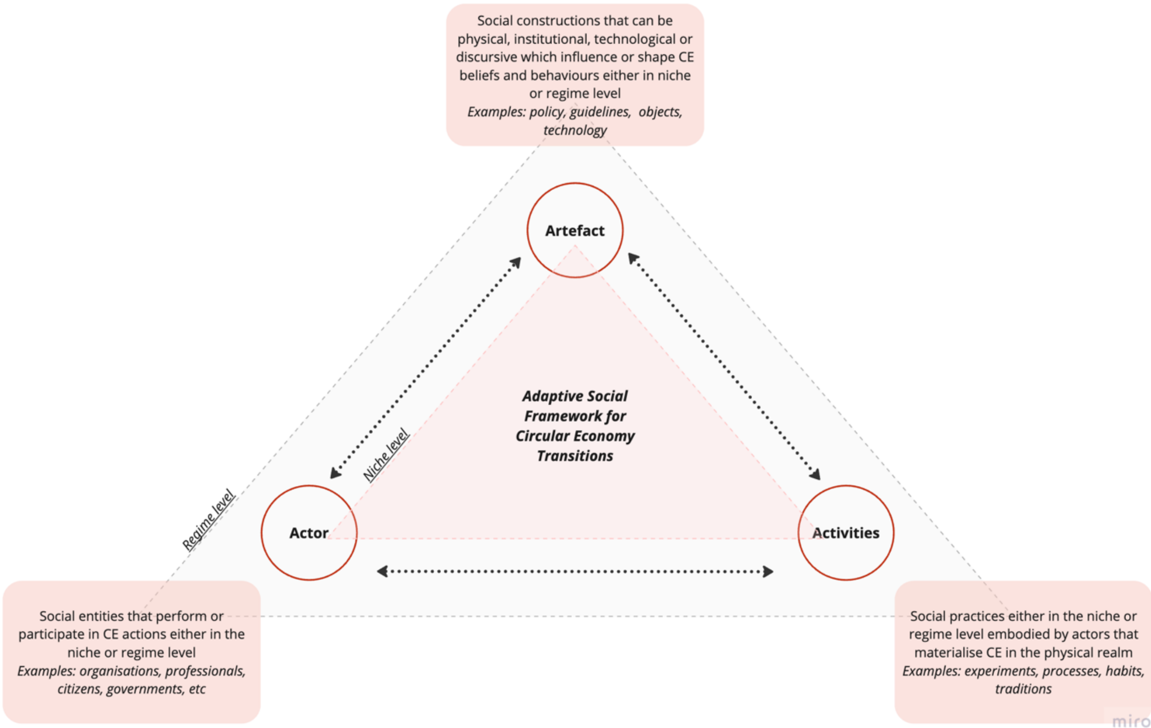

Figure 1-9 Adaptive Social Framework for Circular Economy Transitions

By adopting this framework, the thesis conceptualises the social dimension of the CE transition as consisting of social elements whose interactions co- and re-produce practices which characterise either niches or regimes within socio-technical systems. As illustrated in **Figure 1-9**, the three inextricably linked social elements are actors, artefacts, and activities, which, when investigated closely, can illuminate the social dimension surrounding CE adoption. This aligns with Keller et al.'s (2022a, p. 3) assertion of the merits of combining SPT and MLP approaches to sustainability transitions research in that "a fine-grained analysis of practice elements (skills, shared meanings, material objects) and their reconfigurations enables us to examine the mechanisms underlying how niches emerge, flourish or decline, or how regimes reproduce and transform." The arrows connecting the three elements signify that they co-construct the practices of the social dimension. Meanwhile, the triangles represent the niche and regime levels of socio-technical systems, indicating that these elements can exist in either or both of these levels and interact with each other. It is important to note that the landscape level from the MLP is not diagrammatically shown, but it is assumed as an exogenous factor and considered in the framework discursively. The conceptual framework defines the three elements as follows: Actors are social entities that perform CE actions and can range from organisations, governments, professionals, citizens, etc. Artefacts are social constructions, whether physical, institutional, technological or discursive, which influence or shape CE beliefs and behaviours of actors. Activities encompass embodied practices by actors that materialise CE in the physical world. By analysing these three distinct but interconnected social elements, the social dimension of a phenomenon can be characterised and better understood.

It is important to note that the conceptual framework does not attempt to replace established frameworks and theories, nor does it provide an exhaustive list of the elements that comprise the social dimension. Rather, it extracts key relevant elements based on sociological and sustainability transitions knowledge to create a reference point that can benefit further examination of CE's social dimension in different contexts. While it may resemble similar diagrams associated with the theories adopted in this thesis, such as Geels' (2007, p. 903) three interrelated analytic dimensions of systems, actors and rules, the framework is developed for the purposes of organising the inquiry. It is descriptive rather than predictive, grouping concepts that are broadly defined and systematically organised (McGregor, 2018). As a conceptual framework, it integrates bodies of knowledge to generate new insights and research opportunities, emerging from the creativity and ability of the researcher to link existing theories in interesting ways to "link work across disciplines, provide multi-level insights, and broaden the scope of our thinking" (McGregor, 2018, p. 63). Thus, the conceptual framework presented here opens possibilities for more analytical exercises concerning CE's social dimension and is designed to be adaptive when applied to various settings or contexts. As Van Uden et al. (2024, p. 2) explained, both approaches (i.e. social practice theory and multi-level perspective theory) offer a piece of the complex puzzle of how to analyse transitions. Therefore, the framework enables an approach that can strengthen the social discourse and agenda in CE scholarship and contributes to efforts for a more holistic perspective of the CE transition.

1.5.3 Research scope and design

The research scope is illustrated below, which combines the proposed conceptual framework and the main gaps identified in the literature review. To examine the social dimension of CE adoption, the research focused on 1) Sustainable Building Rating Systems as social artefacts, 2) Architectural professionals as social actors, and 3) Multi-residential demonstration projects as social activities that form part of the social dimension of CE adoption in the architectural renovation of apartment buildings. These three elements serve as the units of analysis of the three core empirical studies presented in the succeeding chapters of this thesis.

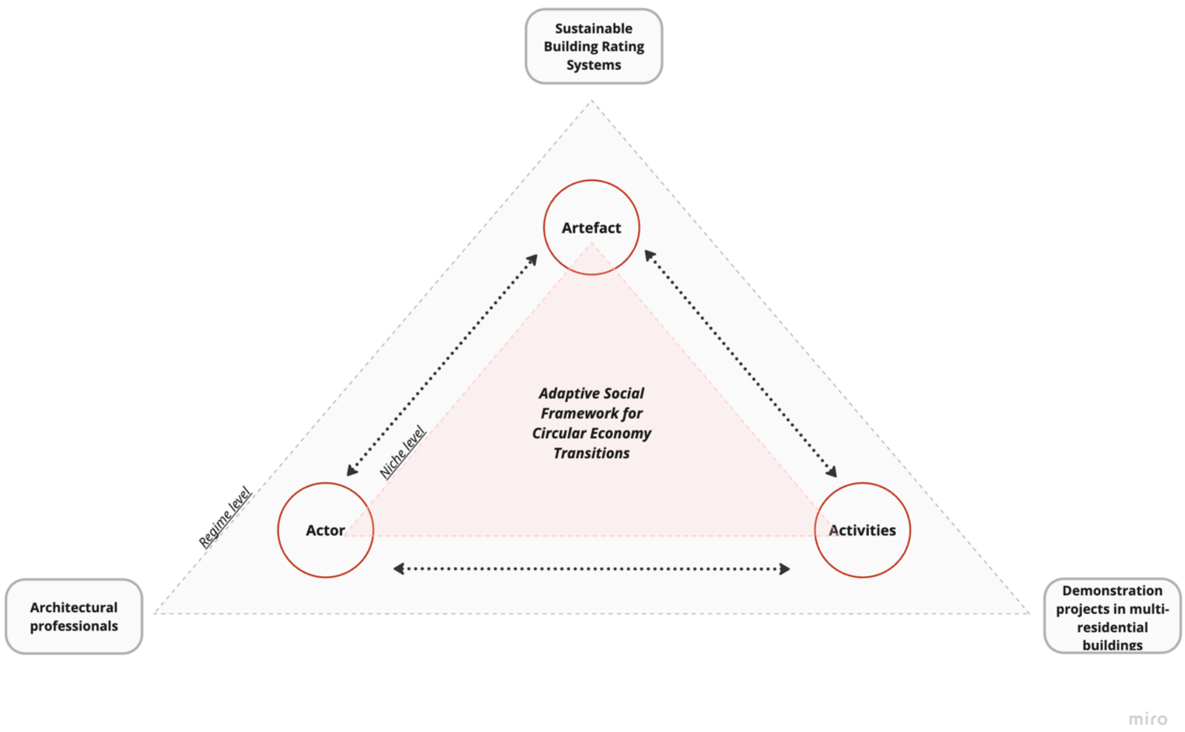

Figure 1-10 Research scope based on the Adaptive Social Framework for Circular Economy Transitions

The thesis is underpinned by mixed methods research, which aligns well with its pragmatic philosophy. Methodological openness and innovative methods have been encouraged in CE (Pomponi and Moncaster, 2017; Schulz et al., 2019), and this thesis acts on this prompt. The diversity in research approaches in the CE can strengthen it as a research field and expand its influence. The research design is described in the succeeding paragraphs and depicted in **Figure 1-11**.

First, a traditional literature review is conducted to identify research gaps and opportunities. Based on the literature review, a conceptual framework was developed, and three research themes were identified based on this framework. The research themes comprise Sustainable Building Rating Systems (SBRS), architectural professionals, and CE demonstration projects in multi-residential buildings. Second, informed by the literature review, three distinct studies that respond to the identified themes were undertaken employing a range of methodologies. The first study employed comparative content analysis with expert consultation, focusing on SBRS as social artefacts that influence apartment renovation design and construction. The second study is a phenomenological study involving in-depth interviews with architectural professionals who are key actors in apartment renovation. The third study is a qualitative case study of multi-residential building projects framed as social activities that exemplify CE adoption in housing renovation. Third, combining the findings from the three studies, a practical framework for CE adoption in the architectural renovation of apartment buildings is developed and proposed.

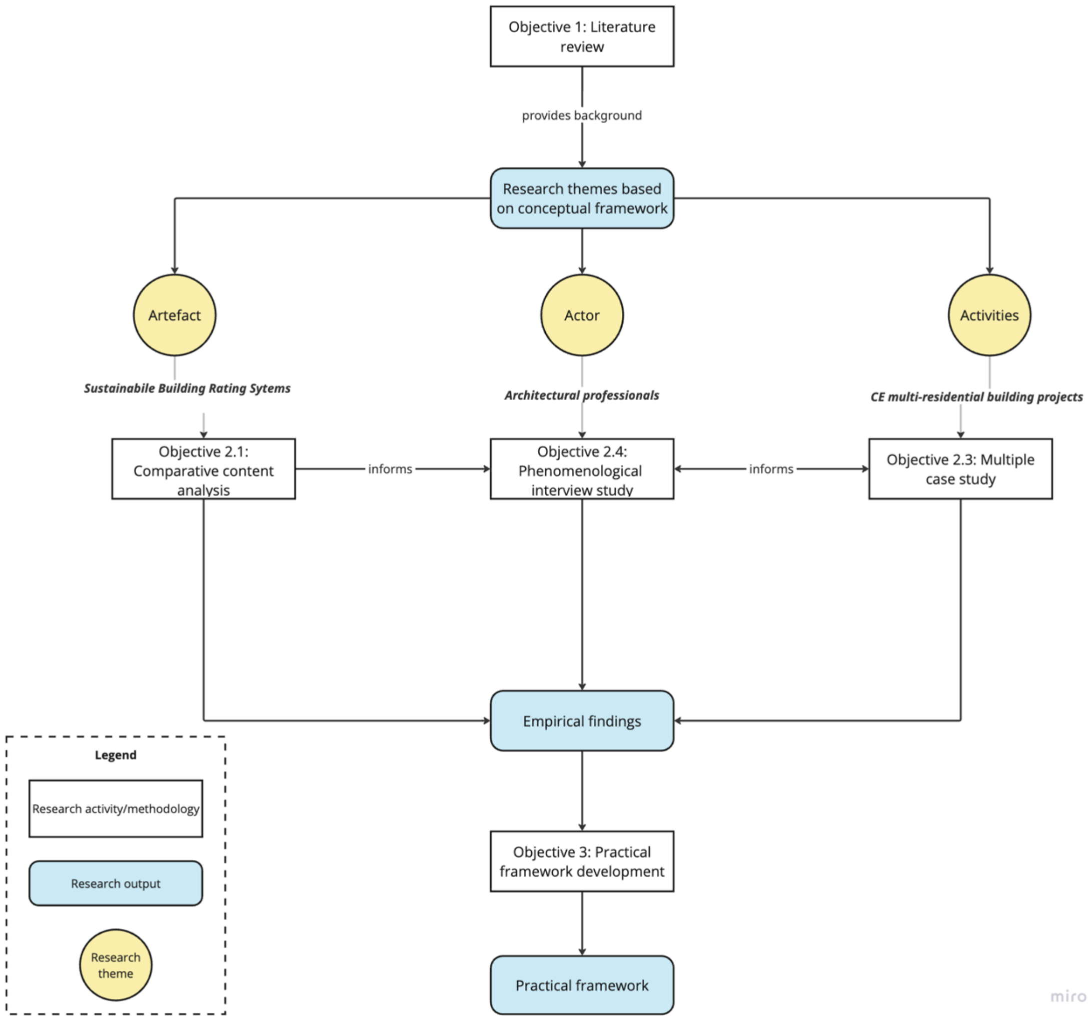

Figure 1-11 Research design

1.6 Empirical methods

This section provides a detailed account of the research methods used for each of the empirical studies discussed in the succeeding chapters.

1.6.1 Chapter 2 Research Methods

The empirical study contained within Chapter 2 was designed as comparative research employing mixed methods. As shown in **Figure 1-12**, the four-step methodology was adapted from previous studies that examined the alignment of SBRS with various emerging and leading sustainability frameworks (Braulio-Gonzalo et al., 2022; Ferrari et al., 2022; Goubran et al., 2023).

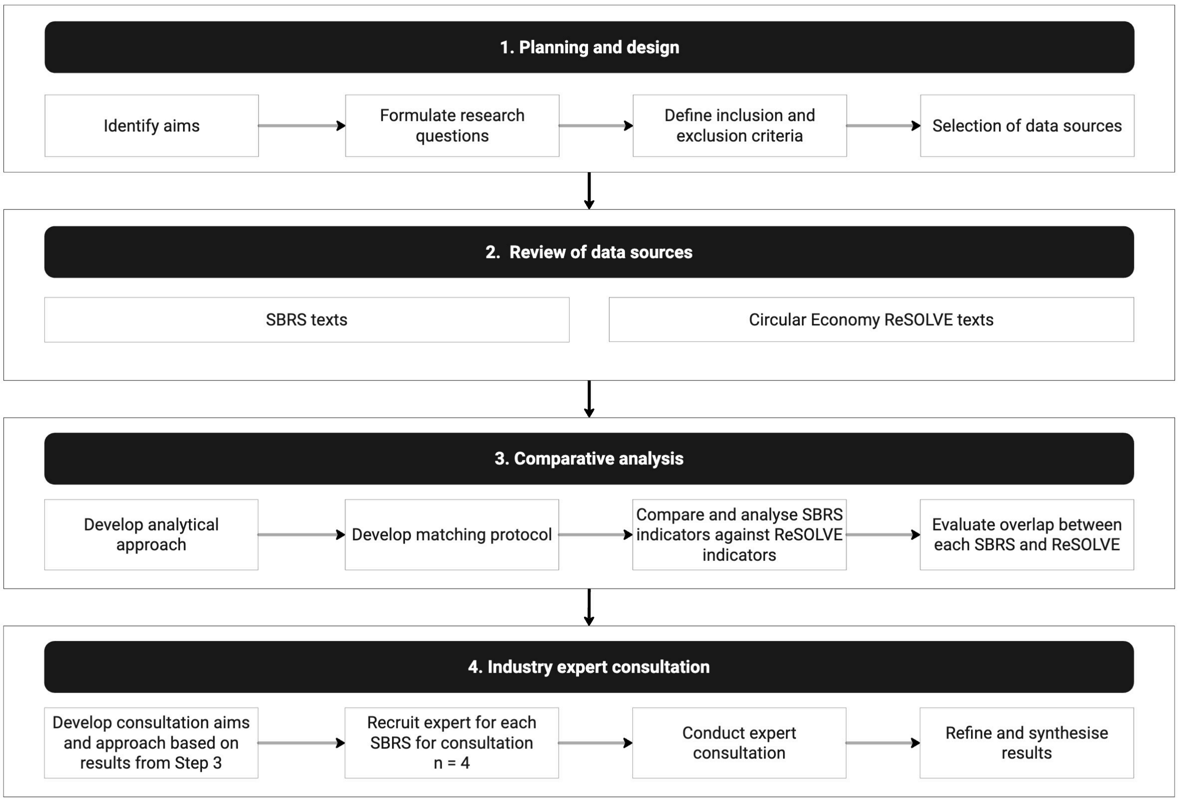

Figure 1-12 Research Methodology

Review of SRBS and ReSOLVE texts

The published guidelines of each SBRS (see **Table 1-6**) were reviewed to understand the scope, structure, and assessment approach of each SBRS. For CE, authoritative sources on ReSOLVE (ARUP, 2016; Ellen MacArthur Foundation, 2015) were reviewed to determine the structure, intent, definitions, and practical applications of ReSOLVE.

Table 1-6 Data sources for SBRS

SBRS	**Living Building Challenge**	**Green Star Buildings**	**BASIX**
Developer	International Living Future Institute	Green Building Council of Australia	New South Wales Government
Implementation	Voluntary	Voluntary	Mandatory
Geographical Scope	Australia / Global	Australia	New South Wales, Australia

Versions	2006, 2008, 2009, 2012, 2014, 2016, 2019	2014, 2015, 2017, 2020	2004, 2017, 2023
Version reviewed	Living Building Challenge 4.0 (June 2019) (ILFI, 2019)	Green Star Buildings Version 1 Revision B (December 2021) (Green Building Council of Australia, 2021)	A comprehensive guide to BASIX (September 2023) (NSW Department of Planning and Environment, 2023); About BASIX (September 2023) (NSW Government, n.d.)

Comparative analysis

The review of SBRS guidelines and ReSOLVE texts informed the formulation of a comparative framework. As shown in **Figure 1-13**, ReSOLVE and the three SBRS have a two-level hierarchical structure, consisting of first- and second-level indicators which are referred to using various terms (e.g. petal, credit, index, etc.). The comparative framework uses the second-level indicators as the unit of analysis, enabling a uniform and consistent comparison across the three SBRSs against ReSOLVE.

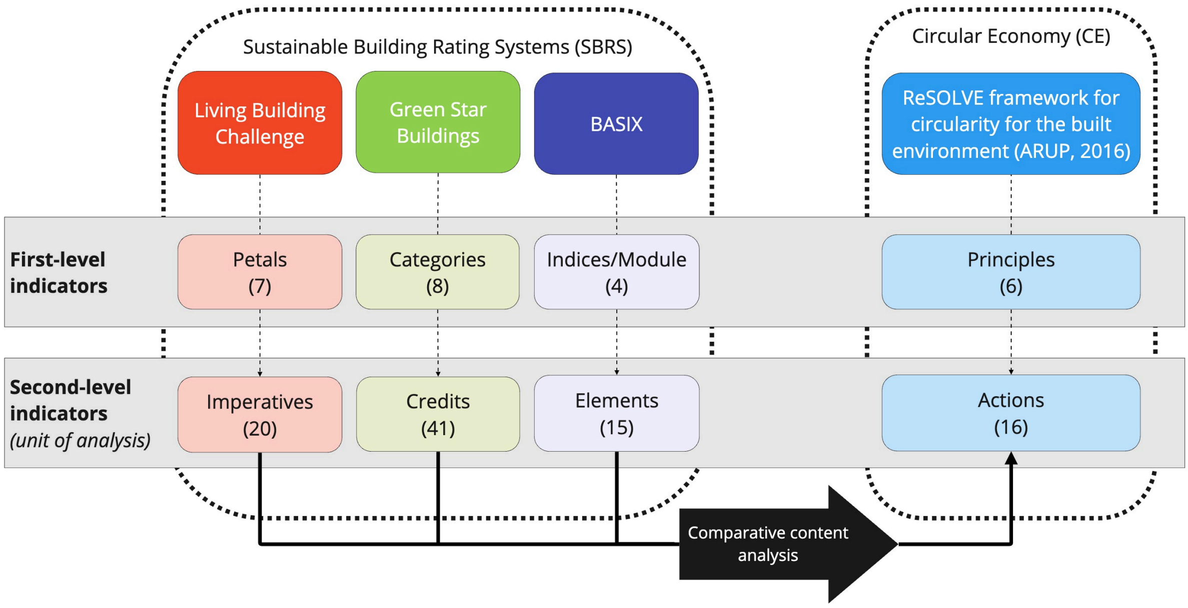

Figure 1-13 Schematic diagram of comparative framework

The comparative content analysis employs a mixed-method approach wherein text description of each SBRS second-level indicator was extracted, qualitatively analysed and compared against ReSOLVE second-level indicators, and then matches are encoded into quantitative data to evaluate the findings. The qualitative content analysis was guided by a matching protocol, and the quantitative analysis was aided by an evaluation matrix (see Appendix 1 – Evaluation Matrix). In the matching protocol, as detailed in **Figure 1-14**, second-level indicators of each SBRS were first compared and mapped into the 16 actions of ReSOLVE for the built environment (ARUP, 2016). If the results were deemed ambiguous, then the SBRS data was reviewed for a second round against the more general principles of ReSOLVE initially defined by EMF (Ellen MacArthur Foundation, 2015). The authors independently reviewed each SBRS against ReSOLVE. When the reviews diverged or remained ambiguous, the indicators were reviewed for a third round by both authors, and an industry expert was consulted. After all possible rounds, each SBRS indicator was either successfully matched with at least one of the 16 ReSOLVE actions or marked as no match. Based on a binary approach, matches are accounted for in the evaluation matrix, with 1 representing a match and 0 representing a no-match. The matches are summed in the evaluation matrix and used as an indicator of alignment between the SBRS and CE.

This mixed-method approach of qualitative analysis followed by quantification of findings has been employed in previous research comparing SBRS against notable sustainability frameworks (Braulio-Gonzalo et al., 2022; Vitale et al., 2021; Wen et al., 2020). More importantly, the qualitative approach used in the content analysis addresses limitations in a similar previous study, which identified that semantic analysis of the content – which considers values and conceptualisation of sustainability embedded within the SBRS indicator – is recommended to effectively assess the potential of SBRS to contribute to sustainability outcomes (Goubran et al., 2023).

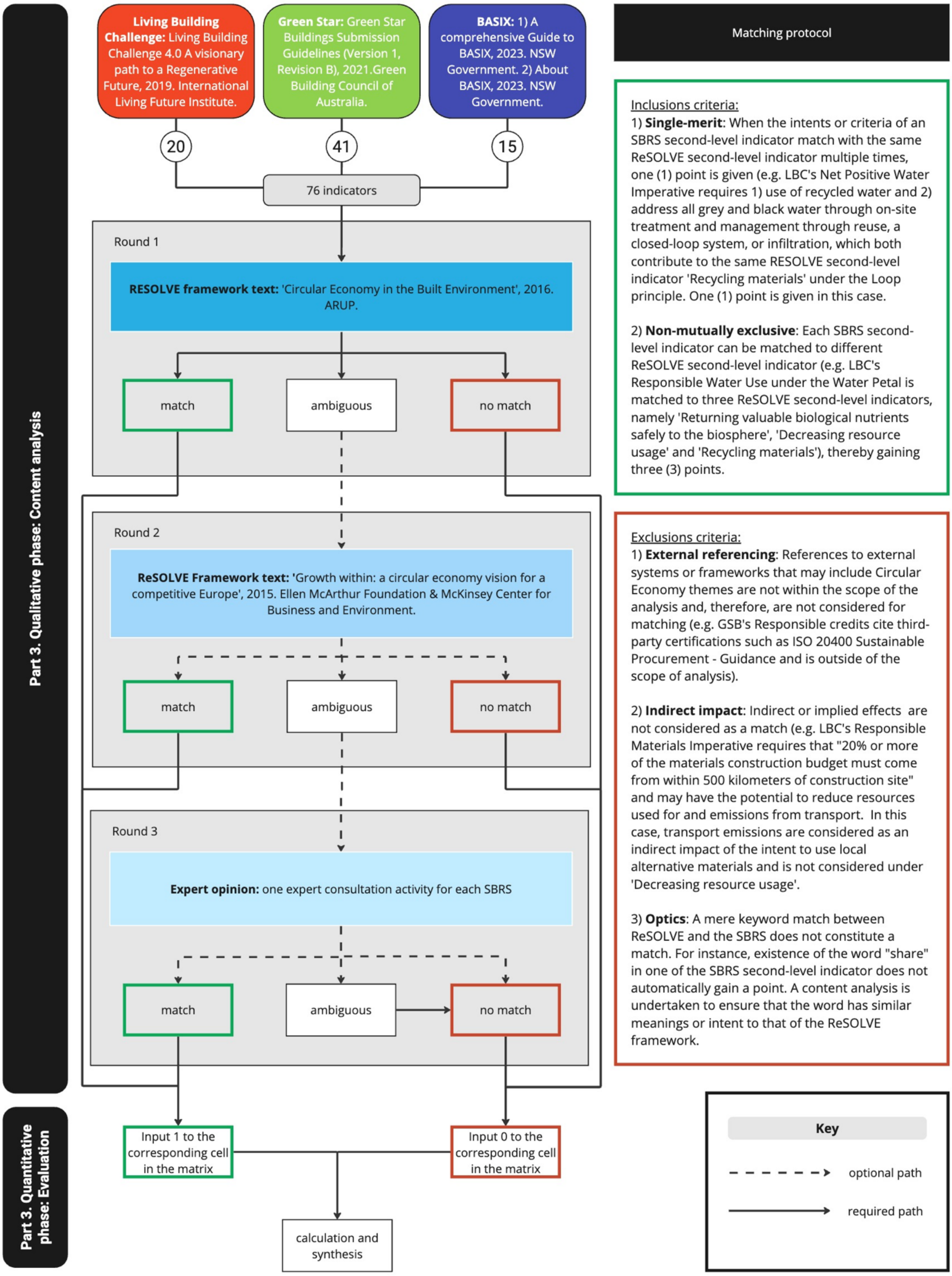

Figure 1-14 Matching protocol

In addition, it is important to recognise that sustainability indicators can be synergistic in nature (Kroll et al., 2019; Xiao et al., 2023), therefore the protocol considers that the matching of second-level indicators of SBRS to those of ReSOLVE is not mutually exclusive. This means that a second-level indicator, for instance, an LBC imperative, that is deemed to address various ReSOLVE actions, can result in multiple matches. Lastly, numerical weights applied to SBRS sub-categories (as in the case of GSB only) are excluded from the evaluation to allow for uniform comparison across the selected SBRS.

Industry expert consultation

Industry expert consultation was employed to confirm any uncertainties or questions that have arisen during the qualitative content analysis stage and collect narrative data on the practical applications of each SBRS that are not covered by publicly available information (referred to as Round 3 in **Figure 1-14**). Industry experts were recruited using purposive sampling and identified through desktop research and the authors' professional networks. Purposive sampling of experts is employed to select information-rich cases to achieve depth of understanding of the phenomenon of interest (Creswell and Plano Clark, 2018; Palinkas et al., 2015). The primary criterion for expert selection is the possession of official first-hand experience either in developing and implementing an SBRS or in successfully acquiring an SBRS certification. A total of three separate consultation activities were conducted (one for each SBRS), two online and one in-person. Expert 2 and Expert 3 were both present in the consultation activity for GSB.

Table 1-7 provides the profile of the industry experts who were consulted.

Table 1-7 Profile of industry experts consulted

SBRS	**Expert**	**Profession**	**Role/Involvement with SBRS**	**Industry Experience (years)**	**Location**
LBC	1	Registered Architect (Practice Director)	Project Architect for the first LBC-certified building in Australia	30+	Sydney, Australia
GSB	2	Building professional	Green Building Council of Australia executive (Green Star Strategy and Development Manager)	20+	Sydney, Australia
GSB	3	Building professional	Green Building Council of Australia executive (Green Star Responsible Products Manager)	15+	Sydney, Australia

BASIX	4	Scientist	New South Wales (NSW) Department of Planning and Environment BASIX technical specialist	15+	Sydney, Australia

1.6.2 Chapter 3 Research Methods

Th empirical study contained within Chapter 3 employs a phenomenological approach involving semi-structured interviews with architecture professionals. Phenomenological research is suitable for understanding a phenomenon (in this case, CE adoption in the architectural profession) by exploring the lived experiences of those who have experienced it to capture shared meaning and gain deep and contextual insights (Creswell and Poth, 2018; Neubauer et al., 2019; Starks and Brown Trinidad, 2007). The aim of phenomenological inquiry, as Schwandt expressed according to Wang and Groat (2013), is to seek an understanding of the complex lifeworld – or the everyday world of lived experience – from the point of view of those who live it, paying attending to *what* was the experience and *how* it was experienced (Neubauer et al., 2019; Starks and Brown Trinidad, 2007). Creswell suggests that phenomenology is best suited to respond to problems in which it is important to understand several individuals' shared experiences of a phenomenon in order to develop practices, policies, or a deeper understanding of the features of the phenomenon (Creswell, 2013).

Phenomenological inquiry is one of the most established qualitative research strands employed in architectural research (Wang and Groat, 2013). In CE literature, phenomenological studies, although rare, are starting to emerge with the growing recognition of the need for socially focused inquiry through the early empirical works of Akinade et al. (2020), Terzioğlu (2021), and Van der Berg et al. (2024). While acknowledging that there is a growing body of research on the role of designers, the barriers and enablers of circular design, and design strategies, extant research has ignored "what it's like to be engaged in and how to live through circular design: they overlook designers' lived experiences" (Van Den Berg et al., 2024, p. 93). As Van Den Berg et al. observed, because phenomenology is rarely employed in sustainable construction research, “our collective understanding of the circular design experience has been incomplete thus far, lacking deep, user-centric insights into and theorisation of how circularity is lived through by participants” (Van Den Berg et al., 2024, p. 99).

A phenomenological approach is fitting in the context of this research, which aims to illuminate the overlooked social dimension of CE adoption, to arrive at a deeper understanding of the meanings assigned to CE by architectural professionals and uncover the social implications of the CE transition. It sheds light on the lived experiences of architectural professionals in adopting CE principles in their practice, which remains in the periphery of CE literature. Conceptually, it allows for a focused exploration of the *carriers of practice*, in SPT language, or the *actors of transition* in MLP terms. Although a phenomenological inquiry does not lead to determinate conclusions, it is a method for questioning in which, as van Manen asserts, “there exist the possibilities and potentialities for experiencing openings, understanding, insights” (Van Manen, 2014, p. 29). Thus, it allows for an in-depth investigation of the current CE perceptions and practices in the architectural profession to understand how architectural professionals understand CE and their role in a CE, leading to a more nuanced understanding of the opportunities and challenges they encounter in adopting the concept in apartment building renovation contexts.

Recognising the different variants of phenomenology, this study leans towards hermeneutic phenomenology developed by early 20th-century philosopher Martin Heidegger, who argued that phenomenology is fundamentally interpretive, and thus put the interpretive role of the researcher inherent to the analysis (Creswell, 2013; Van Manen, 2014). The research design for this study consists of three stages: interview planning, participant recruitment and interview, and thematic analysis, as illustrated in Error! Reference source not found.**Figure 1-15**. The next sections describe in detail each of these stages.

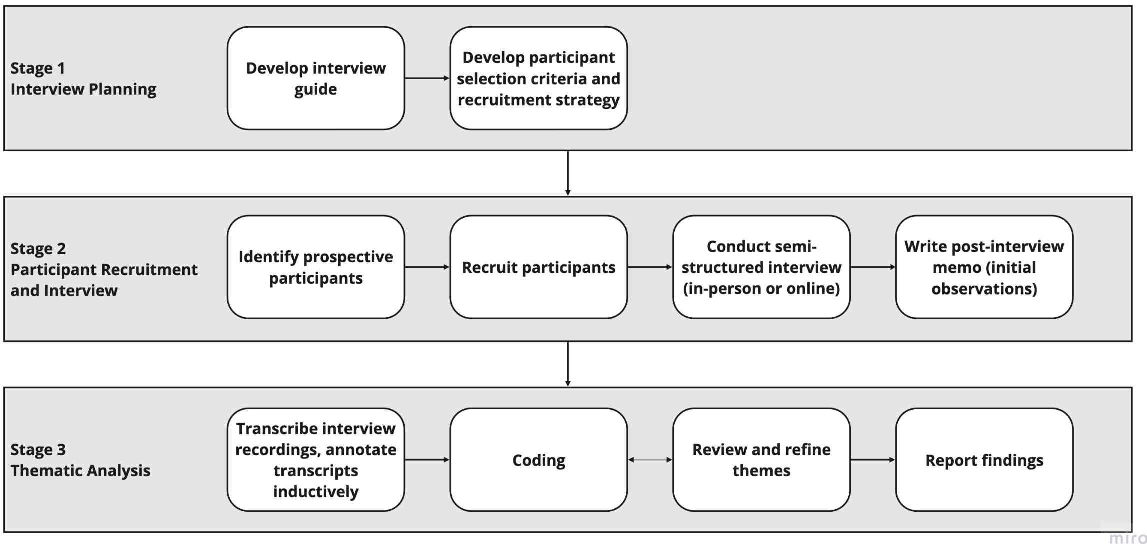

Figure 1-15 Research design

Interview planning

Stage 1 involved interview planning, including developing the interview guide, participant selection criteria and participant recruitment strategy. The semi-structured interview was selected as a research method as it enables the researcher, especially in qualitative research, to gather in-depth information from participants while affording structure and flexibility - allowing for a deeper but more adaptable probing of the topics of interest (Ruslin et al., 2022; Smith, 1995). The flexibility of semi-structured interviews supports the aims of the research to explore in-depth the CE transition from the perspective of architectural professionals by focusing on identified research questions (see **Table 2**) of the empirical study while allowing participants to share about their professional and social contexts, supplementing the research with background information that enriches the data and its analysis.

Table 1-8 outlines the interview guide developed and used in the semi-structured interviews, as informed by the findings of the literature review in **Chapter 1** and preliminary findings from Chapters 2. The interview guide was tested separately with four architectural professionals from project partner organisations for further refinement before finalisation. The interview guide also utilised the funnelling technique, wherein general sustainability questions were first asked before proceeding to more specific CE questions (Smith, 1995). The funnelling technique enabled the participants to ease into the interview by speaking about sustainability first rather than CE, as the former seemed to have broader familiarity in the industry than the latter. During the actual interviews, some guiding questions were slightly amended based on the interviewee's context and follow-up questions were asked spontaneously as the researcher deemed fit.

Table 1-8 Interview Guide

Research Question	Example Guiding Questions
How do social actors in building renovation projects such as architectural professionals perceive and practice their role in a CE?	• *What are some of the existing initiatives that aim to adopt CE in your practice? How were they received and implemented?* • *How is the concept of CE being translated into practice?* • *What are/have been the benefits or advantages of implementing CE in your projects?* • *What are/have been the drawbacks/benefits of implementing CE in your projects?* • *How has your role as an architect changed as a result of implementing CE? What do you think is the architect's role in a circular economy?* • *How was your experience in implementing CE in apartment building renovation projects?*
What are the barriers and enablers that they face in implementing circular renovation?	• *What challenges or enablers have you encountered?* • *How do you learn about CE? What do you think is the most effective way to impart knowledge about circular economy to the profession?* • *What would have been/would be helpful for you to implement CE in practice?*

	• *Based on your experience, what opportunities do you see in this context?*

Interview participants were selected and recruited using a purposive and snowball sample to gather information-rich cases about the phenomenon of interest, which aligns with the phenomenological approach (Palinkas et al., 2015; Starks and Brown Trinidad, 2007). The selection criteria for the participants were practising architectural professionals in Australia from either a) a sustainability-oriented architectural studio based on signatory to Australian Architects Declare Climate & Biodiversity Emergency that can service the apartment building typology, or b) an architectural studio with experience in apartment building renovation projects. These selection criteria allow for combining insights from architecture professionals who either have knowledge or experience in implementing circular economy approaches in their projects or have expertise in apartment building renovation to explore the intersection of circular economy and apartment building renovation.

In identifying prospective participants, first, a list of member studios under the Australian Institute of Architects, categorised by studio size, was collected. Second, a list of signatory studios to the Australian Architects Declare Climate & Biodiversity Emergency (Architects Declare) was developed by extracting signatory information from the Architects Declare official website as of July 2023. Third, a desktop review of architectural studios with experience in apartment building design and renovation in Australia was undertaken to create a third list. Using these three sources, architectural studios that are 1) AIA studio members and either 2a) an AD signatory or 2b) provide apartment building design and renovation services were extracted to create a list of prospective architectural studios for recruitment. The studios that are both identified as AIA members and AD signatories were further filtered to select only those studios that have demonstrated experience in the apartment building or multi-residential sector, verified through desktop research. When selecting prospective studios, the studio size was considered to get representation from each studio size type based on Australian

Bureau of Statistics business size classifications (i.e. micro-small, medium, large-extra large).

After the list of prospective architectural studios was created, a desktop review of each of the architectural studios' websites and social media platforms was undertaken to identify the appropriate participants to recruit from these studios based on their positions or areas of expertise. Professionals in roles such as practice or managing directors, sustainability leads, or multi-residential sector leads were prioritised in the recruitment through email invitations. During the semi-structured interviews, the participants were then asked for other suitable interviewees to be recruited, following the snowball sampling method. Referred participants who were eligible based on the selection criteria were invited to an interview. The Participant Recruitment Strategy is illustrated in **Figure 1-16**.

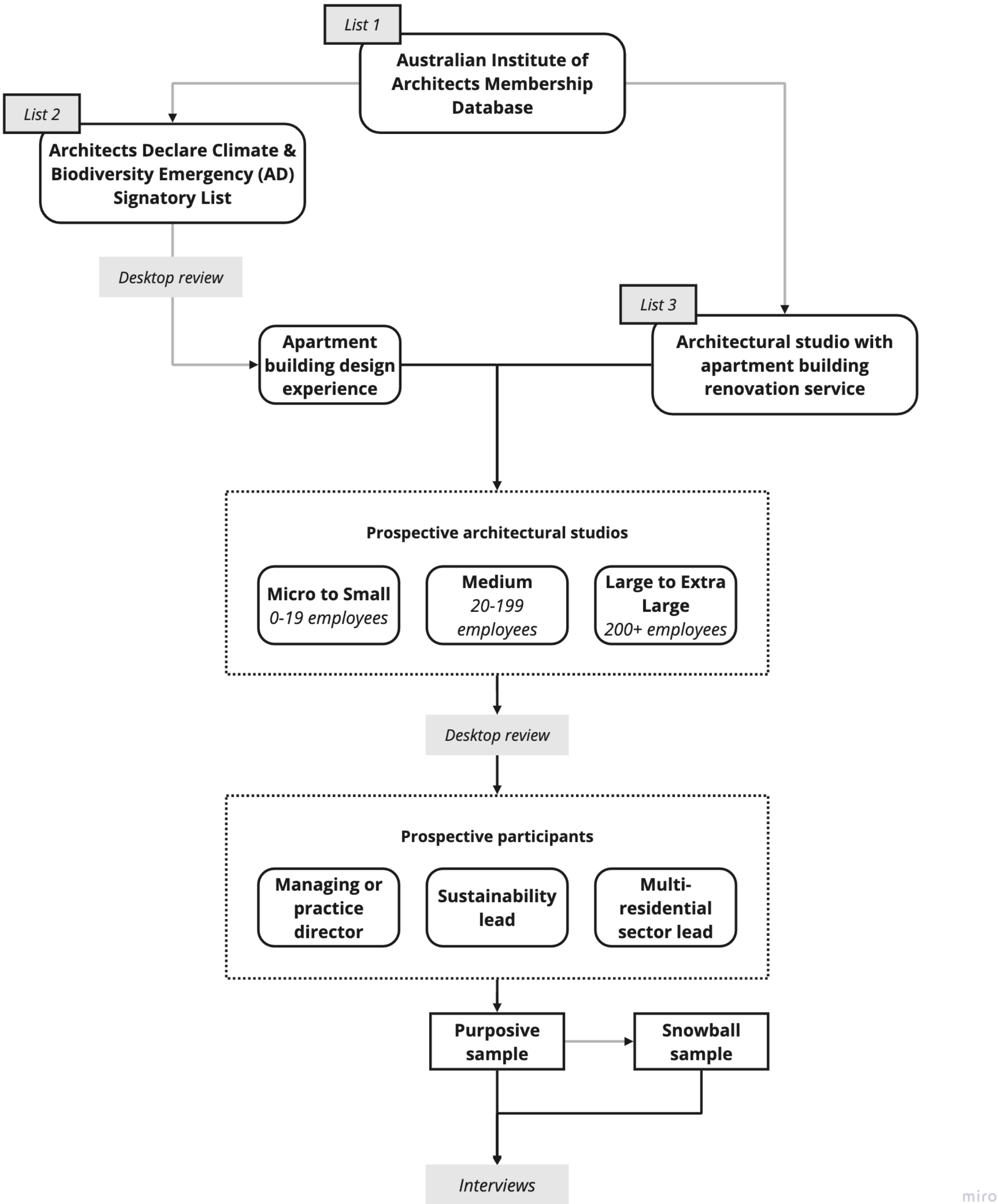

Figure 1-16 Participant Recruitment Strategy

Participant recruitment and interview

Participant recruitment lasted from August 2023 to May 2024 through a direct email approach. Of 48 official recruitment invitations sent, a total of 12 participants agreed to participate in an interview, resulting in a 25% response rate. The study's sample size is deemed adequate for the purpose of the research and its phenomenological underpinning, which typically range from1 to 10 persons (Starks and Brown Trinidad, 2007) or at least 5 to 25 participants suggests 5 to 25 participants (Creswell, 2013).

The profile of the participants is detailed in **Table 1-9**, with an average year of experience of 19.6 years. The high average of years of experience indicates that the sample contains information-rich participants. The face-to-face interviews were held either online or in person from September 2023 to May 2024. Participants 7 and 8 were present in the same interview. The interviews lasted between 28 to 90 minutes, with an average duration of 54 minutes. Among Australian states, NSW is the most represented by the participants' studio locations. While participant recruitment aimed to include all studio size types, the participant sample resulted in four participants representing each firm size.

Table 1-9 Participant profile

Participant			***Architecture Studio***		
P#	***Profession, Role***	***Years of Experience***	***Size***	***Studio Location***	***Geographical Coverage***
P1	Architect, Director	40+	Micro-small	Sydney	NSW
P2	Architect, Managing Director	20+	Large	Brisbane, Melbourne, Perth, Sydney, International	NSW, QLD, VIC, WA
P3	Architect, Principal	20+	Micro-small	Sydney	NSW, ACT

P4	Architect, Director	30+	Micro-small	Sydney	NSW
P5	Architect, Regenerative Practice Lead	15+	Large (200+ employees)	Brisbane, Sydney, International	NSW, NT, QLD, VIC, SA
P6	Architect, Sustainability Team Member	10+	Large (200+ employees)	Adelaide, Brisbane, Darwin, Melbourne, Perth, Sydney	ACT, NSW, NT, QLD, SA, VIC, TAS, WA
P7	Interior Architect, Sustainable Materials Team Member	10+	Medium	Melbourne, International	NSW, VIC, WA*
P8	Interior Architect, Sustainable Materials Team Member	10+	Medium	Melbourne, International	NSW, VIC
P9	Architect, Associate Director	20+	Micro-small	Sydney	NSW, VIC
P10	Architect, Head of Sustainability	20+	Large	Adelaide, Melbourne, Sydney	ACT, NSW, QLD, VIC, SA, WA
P11	Architect, Partner	20+	Medium	Sydney	ACT, NSW, SA, VIC, WA
P12	Interior Architect, Associate Director	20+	Medium	Melbourne, Perth, Sydney	NSW, WA, VIC*

Interviews were conducted either online or in person and were audio-recorded. Immediately after each interview, an analytical memo was produced to capture the researcher's initial observations. The audio recording files were then automatically transcribed using university ethics-approved transcription software. The transcripts were reviewed in parts and reconciled with the recordings to correct any errors during the automatic transcription process. The transcripts and the analytical memos were used as the qualitative text for the thematic analysis conducted with the aid of NVivo, a widely used qualitative data analysis software.

Thematic analysis

A thematic analysis was conducted in line with phenomenological studies that typically present findings through rich thematic descriptions to provide insight into the meaning of the lived experience (Creswell, 2013; Starks and Brown Trinidad, 2007). The thematic analysis involved an iterative process of data coding consisting of first and second cycle coding, as guided by the Saldaña (2013) method for qualitative coding and analysis. Before coding, each transcript and memo for all interviews was reviewed for data familiarisation, while annotations were created inductively in parallel as an initial attempt at meaning-making of the data. A first cycle of coding (open coding) was undertaken wherein initial codes were generated inductively (i.e. data-driven) and used the research questions as a broad framework to organise the codes. Then, a second round of coding (pattern coding) was undertaken to review the first round of coding choices and create meaningful categories from them. The categories are analysed and grouped into high-level categories representing higher-level concepts within the data, which are then grouped and finalised into themes. The structured coding framework for themeing the interview data is shown in **Figure 1-17** and an illustrative example is depicted in **Figure 1-18**.

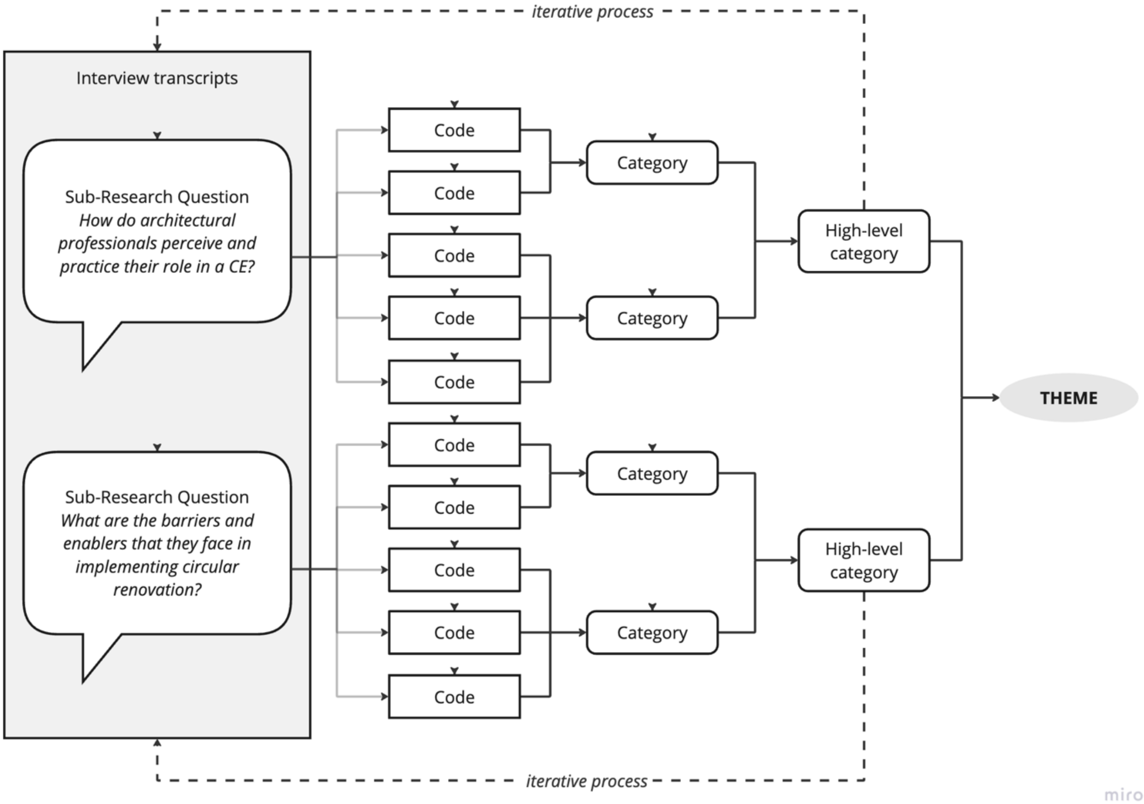

Figure 1-17 Structured coding framework for themeing the data

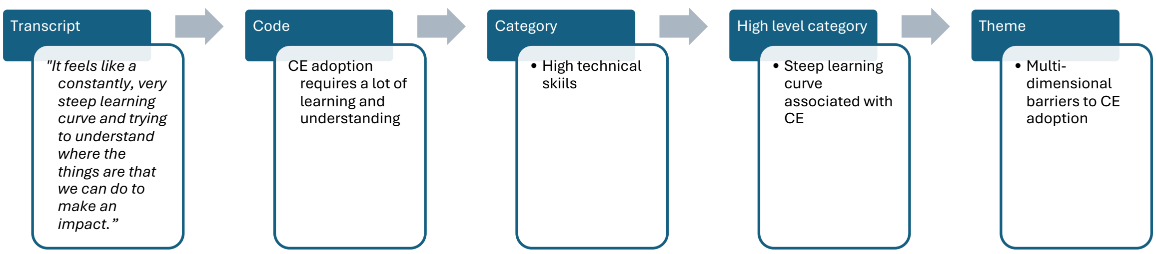

Figure 1-18 Illustrative example of coding and themeing the data

1.6.3 Chapter 4 Research Methods

The empirical study contained within Chapter 4 employs case study research methodology. A case study is a research methodology that allows the researcher to investigate in depth a complex social phenomenon within its real-life context (Yin, 2018). It is useful when the research aims to understand a new topic or an emerging phenomenon. Case studies are best suited for research wherein: 1) "how" or "why" questions are being posed, 2) the researcher has little control over events, 3) contextual conditions are covered because they are believed to be relevant to the phenomenon under study, or 4) the boundaries are not clear between the phenomenon and context (Yin, 2014). The methodological advantage of a case study is not only limited to providing a rich description of a case within its context in an emerging research area, but also allows for theory building with scientific rigour and lends itself as a vehicle for the researcher to assess their research approach and better understand the phenomenon of interest (Creswell, 2013; Creswell and Poth, 2018). As White and Cooper summarised, a "case study is suitable for identifying key themes and introducing recommendations that may help to predict trends, to illuminate hidden issues applicable to practice and/or to provide a means for understanding a research problem – or "learning tangle" – with greater clarity" (White and Cooper, 2022).

Case study research is important in CE scholarship because context-dependent implementation knowledge is still lacking to concretise the concept of CE. As Flyvbjerg (2006, p. 221) argues, case study research contributes to the body of "context-dependent knowledge" needed for humans and human social systems to improve and evolve. Following the above considerations and given the nascent CE adoption in apartment building renovation, as discussed in the introductory chapter of this thesis, a case study approach is deemed well-suited to address the aims and questions of this chapter and to contribute to the primary research question of the thesis. Case study research is often employed in research on CE adoption in building renovation and housing (Çetin et al., 2022; De Silva et al., 2023; Gillott et al., 2023; Leising et al., 2018; Marchesi and Tweed, 2021; Mêda et al., 2024; Nußholz et al., 2023). By employing case study as a methodology, the research contributes: 1) thick case descriptions of demonstration projects, 2) identification of CE initiatives based on ReSOLVE framework that can contribute to the production of exemplars in the CE-Architecture-Housing literature nexus and 3) case themes of lessons learned from real-world CE adoption, which may apply to other cases and can influence policy or practice.

Case Study Selection

The research aimed to select instrumental case studies to illustrate practical examples of how CE can be adopted in apartment building renovation and understand the barriers and enablers associated with this process.

The research utilised purposive and opportunistic sampling for case study selection. Purposive (also called purposeful) sampling is when the researcher selects participants or sites as they can purposefully inform an understanding of the research problem (Creswell, 2013). For this research, purposeful sampling was used to identify cases that involve CE adoption in residential building projects. While still being purposeful, the sampling strategy was also opportunistic in that instrumental cases were limited and were identified through new leads or opportunities arising with the aid of the professional network of the researcher (Creswell, 2013). Combining these sampling strategies allowed the identification and selection of cases representing real-life CE implementation while addressing practical limitations such as the limited availability of exemplar CE apartment renovation projects in Australia, resource constraints, and participant interest. The selection criteria are as follows: the case 1) involves a residential building, and 2) demonstrates implementation of CE in the project.

Data Collection

The qualitative analysis and reporting follow Cresswell's approach for qualitative case study research, which uses multiple sources of information and reports case description and themes and a cross-case analysis (Creswell, 2013). Data collection involved document gathering, site visits and observation, and semi-structured interviews. Given that the cases being explored have occurred in the past, access to primary resources was limited by participant availability and interest. Where possible, secondary resources from both public and private records were utilised. Although the interview sample for each case study was low (*n=1)*, the participants were identified as key players in the cases.Error! Reference source not found. **Table 1-10** outlines the collected data sources for each case study.

Table 1-10 Case study data sources

Research method and data source	**Coogee Waters (Case Study 1)**	**Catherine Commons (Case Study 2)**
Document review	Public source: Development Approval (DA) application documents including Statement of Environmental Effects reports, architectural plans sourced from Randwick City Council DA portal, online project profiles, visual materials Private source: Architectural drawings, tender documents, project brief, project-specific presentation/communication materials, visual materials	Public source: Conference publications, Online forum/website publications, visual materials Private source: Project documents including Base model (pre-deconstruction) audit data, Material salvage data, Expense and revenue reports
Site visit and observation	Visual materials and unstructured field notes	Visual materials and unstructured field notes
Semi-structured interviews	Project Architect *(n=1)*	Project Partner/Coalition Member *(n=1)*

Data Analysis

An integrated analytical framework was developed based on the CE ReSOLVE framework to achieve the aims of the study. The ReSOLVE framework was used to identify and classify CE initiatives in the cases, and an inductive thematic analysis was employed to explore lessons learned and enabling conditions for CE adoption. ReSOLVE is discussed in depth in **Chapter 2**, while the thematic analysis was done through data coding following the empirical methodology described for **Chapter 3**. By examining the lessons learned and implications from these cases, a better and nuanced understanding of CE initiatives can be produced to facilitate mainstream adoption in apartment building renovation.

1.7 Research relevance and contribution

This thesis makes a theoretical, empirical, and practical contribution to CE, architecture and apartment housing fields of study. Overall, the thesis broadens the theoretical and empirical investigations of CE adoption to the overlooked areas of apartment housing renovations and architectural practice. Furthermore, it deepens the understanding of the social dimension of the CE transition through a proposed *Adaptive Social Framework for Circular Economy Transitions*, expanding socially oriented inquiry in the CE research landscape. While it focuses on and elucidates only three social elements that shape, embody and characterise CE adoption in the specific context of apartment housing renovation, the findings of the thesis reveal potential broader social implications of the CE transition, unlocking novel lines of research inquiry and a more holistic CE policymaking.

More specifically, the thesis contributes to knowledge in a number of ways. First, the proposed conceptual framework (see **Figure 1-9**) for CE's social dimension, which borrows and links existing sociological theories and sustainability transitions framework, provides a reference point for future studies examining the social dimension of CE. Second, the comparative review of SBRS as social artefacts in **Chapter 2** provides SBRS and CE practitioners and policymakers with insights into how to leverage SBRS to influence and shape design and building practices towards CE. Third, by positioning the architectural profession as a key social actor in the Circular Renovation of apartment buildings, **Chapter 3** bridges the theoretical and empirical gaps in architectural perspectives of the CE transition and climate action. The findings provide empirical evidence to inform implementation strategies of architectural educational institutions, professional practice, industry regulators, and peak bodies in support of the CE transition. Fourth, **Chapter 4** responds to research gaps in practical knowledge and perspectives from real-life cases of CE adoption by exploring CE demonstration activities undertaken in different societal contexts. The description and analysis of these cases can provide practitioners and policymakers with insights into how CE activities emerge and can be reproduced as social practices. Lastly, with the development of the *CARE framework*, a practical framework presented in **Chapter 5**, the thesis lays the conceptual foundation for a CE approach to the architectural renovation of apartment buildings, providing a practical and heuristic design tool for future renovation projects and theoretical avenues for further development.

In line with the global sustainable development agenda and national objectives to achieve a CE in Australia, the research will produce much-needed actionable knowledge to stimulate the CE transition in apartment housing and, more broadly, the built environment to respond to the climate and housing crises experienced locally and globally. Through this research, what can possibly emanate from the circular renovation of apartment buildings is a more profound and long-lasting outcome: it creates and contributes to more sustainable apartment buildings at present and revives existing apartment housing that can endure the future and nurture the generations to come.

1.8 Thesis outline

This thesis comprises six (6) chapters: *Introduction* (**Chapter 1**), *Findings* (**Chapter 2-4**), *Discussion* (**Chapter 5**), and *Conclusion* (**Chapter 6**), as outlined in **Table 1-11**. **Chapter 1** provides the overarching research context and approach, while **Chapters 5** and **6** present the overall discussion of the thesis. **Chapters 2** to **4** report on the results of the three core empirical studies, each containing a more specific background, results, discussion and conclusion sections.

Chapter 1 introduces the broader context of the research: the emerging concept of CE and the unsustainability of the Australian apartment building stock in the Anthropocene. It presents a narrative review of relevant literature on CE and its application to buildings, identifying the social dimension of sustainability as a missing critical area in this field. Then, it provides an overview of the apartment building as a housing typology in Australia and presents the research problem of the need to renovate existing apartment buildings sustainably through a CE approach. Lastly, it discusses the philosophical positioning, theoretical underpinning and the proposed conceptual framework and overall research design that governs the thesis.

Chapter 2 investigates SBRS as social artefacts of CE and a potential implementation pathway for circular renovation by examining their integration of CE principles based on the ReSOLVE framework. The chapter provides a comparative review and analysis of three SBRS applicable to apartment building renovation projects. It then discusses the implications of the review and identifies gaps and opportunities for SBRS to embed CE as a social practice in apartment building renovation.

Chapter 3 delves into the architectural profession as a social actor in the broader CE transition and in apartment renovation. It reports on the results of a phenomenological interview-based study on the architectural profession's perceived role in a CE and the barriers and enablers they encounter as a change agent for circular renovation. The implications of the empirical findings on CE policy, architectural practice, and housing renovation regulations are discussed.

Chapter 4 turns to real-life CE demonstration as social activities in two residential building projects through a multiple-case study. It reports on factual and empirical descriptions of CE activities in their unique contexts and presents a thematic analysis of CE activities based on the ReSOLVE framework and the enabling factors of these activities to inform future circular renovation projects of apartment buildings.

Chapter 5 coalesces the previous findings' chapters and proposes a practical framework (CARE framework) as a pragmatic proposition towards circular renovation. The chapter first discusses the empirical findings in relation to the theoretical framing of the thesis and provides a methodological note on the development of the CARE framework. The CARE framework serves as a social artefact that links architectural professionals as social actors, with evidence-based social activities from the case study to facilitate an empowered, socially driven CE transition and a successful adoption of a CE approach to apartment building renovation. It is a regime-practice-informed framework that allows for the emergence of niche practices of circular renovation. It also discusses the limitations of the research and recommends future research areas.

Chapter 6 revisits the research aims and objectives of the thesis and summarises the key findings and contributions. The chapter concludes with a discussion of the thesis findings' significance and contribution to knowledge and implications on architecture, housing, and circular economy scholarship, policy, and practice.

Table 1-11 Thesis outline

Chapter	Title
1	**Introduction**
2	**Circular economy and sustainable building rating systems** *Artefacts for Circular Renovation: A comparative review of circular economy integration in sustainable building rating systems* *Based on the published manuscript:* *Lucas, A. N. and Löschke, S. K. (2024) 'Towards circular renovation: a comparative review of circular economy integration in sustainable building rating systems', Building Research & Information, pp. 1–22. doi:10.1080/09613218.2024.2394470.*
3	**Circular economy and the architectural profession** *Actors in Circular Renovation: Architects' perspectives on their role in a CE*
4	**Circular economy and residential buildings** *Activities of Circular Renovation: Multiple-case study of circular economy initiatives in residential building projects* *Partly based on the published manuscript:* *Heisel, F., McGranahan, J., Lucas, A., Cohen, D., Stone, G., 2023. Carbon, economics, and labor: a case study of deconstruction's relative costs and benefits compared to demolition. J. Phys.: Conf. Ser. 2600, 192003. https://doi.org/10.1088/1742-6596/2600/19/192003*
5	**Circular economy and architectural renovation of apartment buildings** *A Blueprint for Circular Renovation: CARE Framework, a proposed framework for niche-building practices in the architectural renovation of apartment buildings*
6	**Conclusion**

CHAPTER 2

2 Circular Economy and Sustainable Building Rating Systems

Artefacts for Circular Renovation: A comparative review of circular economy integration in sustainable building rating systems

2.1 Chapter overview

This chapter centres on the first social element described in the research scope and investigates Sustainable Building Rating Systems (SBRS) as a *social artefact* that informs and shapes renovation practices. SBRS are widely used to set sustainability standards for new residential developments and renovations in Australia, indicating a potential to influence and implement CE adoption in architectural renovation of apartment buildings. The integration of CE principles in SBRS may deliver standardised and effective implementation pathways – a solution that is still under-investigated. To address this gap, this chapter queries the potential of SBRS for supporting circular renovation through a rigorous comparative analysis of residential SBRS against the widely recognised ReSOLVE circularity framework (Regenerate, Share, Optimise, Loop, Virtualise, Exchange). The study employs qualitative content analysis and focuses on three SBRS with global relevance and local influence (Living Building Challenge, Green Star Buildings, Building Sustainability Index) that apply to apartment building renovation. This chapter addresses Objective 2.1 of the thesis identified in **Section 1.4**.

The chapter begins with an introduction of SBRS as a social artefact, its emergence in practice, and research developments. The chapter proceeds with an overview of the selected SBRS for this study and expounds on the ReSOLVE framework as the study's analytical tool for CE. A thorough description of the methodology is provided in **Section 1.6**. The results are then presented, showing the extent to which SBRS are progressing towards circularity and identifying CE principles that are prominent or need further integration in SBRS. Opportunities in SBRS and gaps in the ReSOLVE circularity framework are also discussed. Although limited to three SBRS, the findings provide a contemporary assessment of CE integration in diverse SBRS, contributing to the advancement of SBRS as a social artefact that can assist CE implementation in architectural renovation of apartment buildings.

2.2 Background

2.2.1 Sustainable Building Rating Systems as social artefacts

As defined in this thesis, artefacts are social constructions that actively shape the beliefs and behaviours of actors. Beyond having physical properties, social artefacts can be institutional, effectively grounding them in broader institutional arrangements. The thesis adopts the definition proposed by Boyd and Schweber (2018, p. 18):

> "Institutional artefacts are shaped by rules or conventions, which exist prior to and independent of any particular project. Relevant rules may be formal or informal; the important point is that they are socially recognised."

SBRS, also referred to as Green Building Rating Systems or Building Certifications, are considered institutional social artefacts in sustainable building design and construction practices. They are widely recognised assessment frameworks that aim to influence the way buildings are designed and built to reduce the environmental impact of buildings (Ade and Rehm, 2020). They have been developed extensively over the past three decades by a variety of entities ranging from local governments to international organisations in the building sector (Shan and Hwang, 2018). Recognising their influence in shaping a sustainable built environment, SBRS have formed part of the global decarbonisation index to track decarbonisation progress in the built environment (UNEP, 2022). Evidently, SBRS serve as institutional artefacts in the building sector that are socially constructed and concurrently influence social activities in building design and construction (Boyd and Schweber, 2018).

SBRS Development and CE

The first SBRS to be developed was the Building Research Establishment's Environmental Assessment Method (BREEAM) in the UK in 1990, which was initially designed for commercial buildings but has been adopted for different typologies, including residential buildings (Ade and Rehm, 2020). Since then, multiple SBRS have been established in different countries that are patterned from BREEAM and customised to suit local conditions and needs (Lazar and Chithra, 2021; Mattoni et al., 2018; Shan and Hwang, 2018). Moreover, SBRS have progressed gradually from being "green" to adopting the other pillars of sustainability, such as social, economic, and governance (Doan et al., 2017; Varma and Palaniappan, 2019). As a result, the complexity and comprehensiveness of SBRS have evolved since their introduction. SBRS can be categorised in multiple ways (Ade and Rehm, 2020) and can differ based on implementation approach (voluntary vs mandatory), coverage (e.g. holistic vs thematic), level of standard (minimum vs aspirational), assessment method (qualitative vs quantitative), and geographic application (local vs global), among other categorisations.

With the proliferation of SBRS, SBRS research has grown subsequently in the last decades (Lazar and Chithra, 2021), covering various methodological studies on SBRS (Ascione et al., 2022) that range from bibliometric reviews (Lazar and Chithra, 2021; Zhao et al., 2019), critical comparisons of global SBRS (Doan et al., 2017; Mattinzioli et al., 2021; Mattoni et al., 2018), evolution and research trends (Shan and Hwang, 2018; Wang et al., 2024; Wu et al., 2021), to integration of SBRS with other frameworks (Braulio-Gonzalo et al., 2022; Chen et al., 2015; Ferrari et al., 2022; Goubran et al., 2023; Sánchez Cordero et al., 2019; Vitale et al., 2021). SBRS were found to have played a key role in introducing sustainability principles across building industries and influencing sustainable building design and practices (Martek et al., 2019; Shan and Hwang, 2018). However, potential limitations remain, including concerns about their suitability for renovation and influence on residential markets. Adoption rates of SBRS in the residential sector have been low, mainly due to the high costs associated with certification (Ade and Rehm, 2020; Darko and Chan, 2017). Moreover, existing SBRS are more geared towards planning, design, and construction of new buildings than existing ones (Ade and Rehm, 2020; Jiménez-Pulido et al., 2022), as a majority of SBRS indicators address emissions in the Design, Construction and Use operations, while the End of Life (EoL) stage is poorly approached (Braulio-Gonzalo et al., 2022).

Nevertheless, incorporating CE in SBRS has been identified as one of the vital CE drivers that can help standardise the concept of CE (Olanrewaju et al., 2024; Wuni, 2023). The multitude of forms and evolution of SBRS indicate that they are often context-specific, evolving to suit local needs, but also globally driven, adapting to worldwide megatrends. Noting that there is still no set standard for CE implementation in building projects, more so in building renovation (Benachio et al., 2020; Ossio et al., 2023; Sáez-de-Guinoa et al., 2022), SBRS are then positioned to respond to the emerging global shift to CE while remaining effective in the local context.

However, the relationship between SBRS and CE has only been investigated by a few in recent years. Current research has generally covered globally prominent SBRS to investigate CE content within them. On a building level, Kubbinga et al. were one of the first to analyse BREEAM New Construction (NC) and Refurbishment and Fit-Out (RFO) and propose a CE strategy framework within these SBRS (68). Likewise, Trubina et al. (2024) reviewed four SBRS (BREEAM in the UK, Leadership in Energy and Environmental Design (LEED) in the USA, Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) in Germany, and SBToolCZ in the Czech Republic), and proposed a single comprehensive rating system that can be applied to office buildings. (On a neighbourhood scale, Lami et al. (2021) qualitatively reviewed BREEAM Communities (C) and LEED Neighbourhood Development (ND) to investigate how SBRS are evolving towards the CE transition within cities. To date, research is limited to leading SBRS in Europe and America and has yet to focus on SRBS for residential buildings. Knowledge from other regional perspectives and for the residential sector is warranted to address geographical and typological gaps in the literature. Hence, investigating SBRS framed as a social artefact and their integration of CE principles can indicate CE's social recognition in the building sector and can reveal insights into how SBRS, as a social artefact, can introduce CE principles in architectural renovation norms, rules, and conventions.

Research Scope

The study analyses and compares three residential SBRS: two internationally comparable SBRS (Living Building Challenge and Green Star) and one local SBRS (Building Sustainability Index) established in Australia (see **Figure 2-1** for an overview). These were selected to cover a diverse range of SBRS types based on 1) implementation (voluntary or mandatory), 2) level of sustainability standard (aspirational or minimum), and 3) geographical application (international vs local). This selection allows for a broader understanding of contemporary CE adoption in various residential SBRS in a specific region where SBRS remain the primary mechanism for influencing and assessing the sustainability of buildings, such as Australia (Martek et al., 2019). The succeeding sections provide an overview of each of the SBRS.

Figure 2-1 Overview of LBC, GSB, and BASIX

Living Building Challenge

Living Building Challenge (LBC) is an aspirational and voluntary SBRS first introduced by the International Living Future Institute in 2006 in North America. LBC 4.0 is claimed to be the “most advanced measure of sustainability in the built environment today” (ILFI, 2019, p. 4). Although less studied than the more prominent SBRS in the American region (i.e. LEED), existing research on LBC has claimed higher sustainability standards compared to LEED and other global SBRS such as BREEAM (Forsberg and De Souza, 2021). Since its introduction, only 105 projects have been certified, and over 500 projects have been registered across the globe as of 2019 (ILFI, 2019, p. 77). In Australia, LBC is considered an emerging SBRS with 21 projects registered. As of October 2023, only one project has achieved a Living Certification, and one project has been awarded with a petal certification ("Living Building Projects in Australia," n.d.). The limited number of LBC-certified buildings reflects the high level of aspiration set within LBC.

LBC is an indicator-based SBRS that assesses projects based on the achievement of 20 imperatives (second-level indicators), which are categorised under seven petals (first-level indicators): Place, Water, Energy, Health + Happiness, Materials, Equity and Beauty. LBC can be applied to both new and existing buildings and to a range of building typologies, including apartment buildings. Certification is undertaken by an authorised professional using 12-month performance data, and outcomes vary depending on which imperatives were achieved by the project.

Green Star Buildings (GSB)

Green Star is one of the leading voluntary SBRS in Australia, established by the Green Building Council of Australia in 2003. Green Star is considered one of the most prominent global SBRS and was intended to be an internationally comparable SBRS after being patterned from the pioneer SBRS, BREEAM (Ade and Rehm, 2020). Green Star is considered a market-leading SBRS in Australia, similar to the UK's BREEAM and the USA's LEED rating systems (Varma and Palaniappan, 2019). After its establishment in Australia, Green Star has been adopted in other geographical locations such as Green Star South Africa (SA) and Green Star New Zealand (NZ) (Mattoni et al., 2018). Similarly, Green Star SA and Green Star NZ have become the primary SBRS in their respective countries (Doan et al., 2021; GhaffarianHoseini et al., 2017; Hoffman et al., 2020). Green Star offers multiple rating tools, including Green Star Buildings (GSB) for new building construction and renovation. GSB and its previous iterations have certified over 300 buildings since 2015, including major refurbishments as of October 2023 (Green Building Council of Australia, n.d.), indicating its wider sphere of influence in Australia than that of LBC.

Similar to LBC, GSB is described as a rating tool with "aspirational benchmarks for design, construction, and operational performance" (Green Building Council of Australia, 2021, p. 9). It assesses projects based on the requirements of its 41 credits (second-level indicators), which sit under 8 categories (first-level indicators), namely Responsible, Healthy, Resilient, Positive, Places, People, Nature, and Leadership. Each GSB certification comes with a star rating based on the accumulated points from achieving a set of credits, assessed and calculated by an accredited professional.

BASIX

Building Sustainability Index (BASIX) is a mandatory SBRS introduced by the Australian New South Wales (NSW) Government in 2004 as part of its development approval process for any new single or multi-unit dwelling, including alterations or additions (e.g. renovation). As a regulatory tool, it sets minimum sustainability targets for energy and water use as well as minimum performance levels for thermal comfort using benchmarks. In contrast with LBC and GSB, which require an accredited professional in their certification process, the BASIX platform can be accessed by the public, and the certification process can be facilitated by non-professionals.

BASIX is composed of 15 assessment elements (second-level indicators) organised under four indices (first-level indicators), with each index having a specific target score that must be met to obtain a certificate. Unlike GSB and LBC, which measure the performance of buildings based on a suite of indicators after practical completion or post-occupancy, BASIX assesses the sustainability of projects based on estimated savings from energy, water, and thermal efficiency measures at the design stage. The project's savings are compared to 2003 state-wide benchmarks (before BASIX was introduced), and certification is awarded if minimum standards are achieved (NSW Department of Planning and Environment, 2023, p. 7). The targets evolve and are based on local climate and housing typology, hence there is no fixed one-size-fits-all target.

2.2.2 ReSOLVE circularity framework for the built environment

As initially described in **Chapter 1,** the ReSOLVE framework for circularity in the built environment (ReSOLVE) was developed by ARUP together with EMF to contextualise the six actions in the built environment context (ARUP, 2016). Now recognised as one of the most prominent CE frameworks, ReSOLVE has been employed in multiple studies as an analytical framework to assess CE developments in different contexts, sectors, scales, and geographies. These include CE research in European policymaking (Mhatre et al., 2021b), the agricultural (Payne and Kwofie, 2024) and food sectors (Gonçalves and Maximo, 2023; Sehnem et al., 2023), forestry (Tedesco et al., 2022), the water sector (Smol et al., 2023), business management (Lopes de Sousa Jabbour et al., 2019; Marcon et al., 2023), and digital technologies (Aristi Capetillo et al., 2023; Cagno et al., 2021; Ding et al., 2023; Findik et al., 2023; Lopes de Sousa Jabbour et al., 2018; Rusch et al., 2023; Tutore et al., 2024) among others. In the built environment, ReSOLVE was utilised to analyse CE transition in European Cities (Prendeville et al., 2018), CE challenges and opportunities in the construction sector (Iyer-Raniga, 2019; Torgautov et al., 2021), critical success factors for CE transition in construction industries of developing countries (Koc et al., 2023), CE implementation in the construction value chain (Dewagoda et al., 2022), CE adoption in social housing (Marchesi and Tweed, 2021), best practice for CE assessments of regions (Van Bueren et al., 2021). ReSOLVE was found to be a relatively comprehensive framework for CE processes (Van Bueren et al., 2021). Over time, ReSOLVE has served a dual purpose – a practical guide for the industry as intended by EMF and an analytical tool for researchers driven by increasing interest in CE adoption (Payne and Kwofie, 2024). ReSOLVE, as seen in **Figure 2-2**, has been adapted in this study for its relevance, practical underpinning, and built-environment-specific elements. The next subsections expound on each of the six principles and corresponding actions.

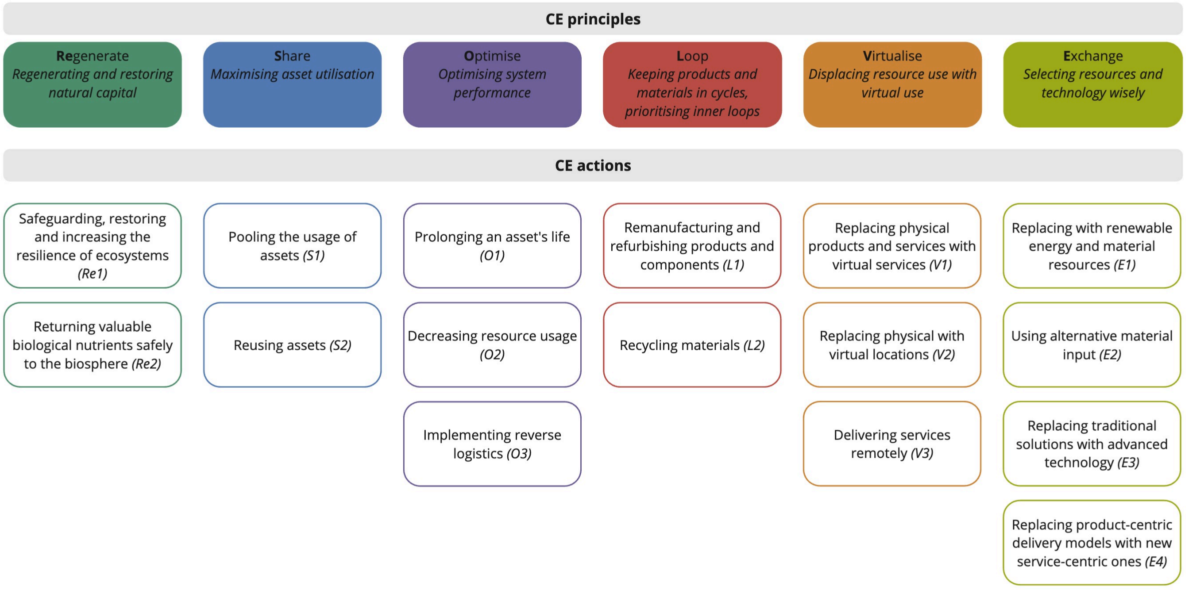

Figure 2-2 ReSOLVE framework for circularity in the built environment (ReSOLVE) (adapted from ARUP, 2016)

Regenerate

The Regenerate principle of ReSOLVE focuses on restoring and regenerating natural capital. Based on the EMF and ARUP descriptions, the principle is operationalised through several aims, such as 1) protecting or restoring natural ecosystems and their resilience, 2) returning biological resources safely to the biosphere, 3) adopting nature-based solutions, and 4) reducing negative externalities to nature. In summary, the Regenerate principle can be implemented through a set of actions: 1) actions that protect or restore natural ecosystems and their resilience and implement nature-based solutions and 2) actions that safely return biological resources to the biosphere and reduce negative externalities such as pollution and waste.

The definition of restoration and regeneration in relation to CE has been previously studied and debated by Morseletto, who follows the ecologically-focused interpretation of the Regenerate principle and recognises the proposed definition of regeneration as "promotion of self-renewal capacity of natural systems to reactivate ecological processes damaged or over-exploited by human action" (Morseletto, 2020a, p. 769). This definition is congruent with "Nature Positive", an emergent concept developed by the

Australian government, described as “circumstances where nature – species and ecosystems – is being repaired and is regenerating rather than being in decline” (DCCEEW, 2022).

Share

The Share principle is underpinned by the objective of maximising asset utilisation through peer-to-peer sharing or sharing economy, reuse economy, co-location, and open-source information sharing. The Share principle, based on the ARUP and EMF definitions, can be applied through the following specific actions: 1) actions that encourage peer-to-peer sharing of assets (material or intellectual), and pooling assets for common use either through shared ownership or co-location and 2) actions that relate to reusing assets (i.e. same use of materials without chemical processes involved). The concept of the Sharing and Reuse economy aligns with the 10R Circular Economy Framework proposed by Potting et al., 2017, which assigns Reuse as the fourth-level R-strategy (R3) with the first-level (i.e. R0 Refuse) having the highest level of circularity. Reuse can be defined as further use by another user/owner of a product that is still in good condition and manages to fulfil its original function without any chemical or mechanical changes involved. Reuse can be in the form of transfer of ownership of the material through relocation (e.g. gifted) or resale of the material and of contracted ownership of the material through hired or shared services, as in the case of product-as-a-service models (Morseletto, 2020b).

Optimise

The Optimise principle is characterised by system efficiency, reduction in material or energy consumption, reverse logistics, longevity, and durability of materials. The Optimise principle can be implemented through actions that 1) promote longevity and durability of assets through maintenance, 2) reduce consumption of resources either through demand-reduction or technology improvement (efficiency), and 3) encourage return of assets from end-user to retailer or manufacturer. In parallel with the 10R Framework, the Optimise principle can be characterised by three R strategies, namely, R2 Reduction, R4 Repair and R5 Refurbish. Potting et al., 2017 define the Reduce strategy

(R2) as an increase in efficiency by using fewer natural resources and materials. Meanwhile, the Repair (R4) strategy constitutes maintenance of an asset to keep its original function, while the Refurbish strategy (R5) entails upgrading or modernising the asset to keep its original function.

Loop

The Loop principle relates to actions that aim to close resource loops, usually through what is referred to as outer loops or the R6 to R9 of the 10R Framework, namely Remanufacture, Repurpose, Recycle and Recover (Potting et al., 2017). These R strategies typically involve a production or chemical process that may alter the original use of the material. In ReSOLVE, Loop actions relate to 1) restoring assets or parts of them to extend their use for the same or similar purpose and 2) recovering the value of materials and reprocessing assets to extend their lifespan for the same or other use. In a practical sense, the Loop principle in the built environment can be described as using remanufactured or recycled building materials or designing for disassembly and deconstruction to close the material loop and minimise building material waste sent to landfills.

The Virtualise principle refers to dematerialisation through digital technology and virtual products and services. Based on ReSOLVE, the Virtualise principle can be applied through actions such as 1) use virtual products and services instead of physical products, 2) use virtual products and services instead of physical locations, and 3) delivering services remotely through use of digital technology such as Building Information Management systems, remote sensing, smart monitoring and Internet of Things to provide a service.

Exchange

The Exchange principle is centred on exchanging conventional methods and products with alternative and more sustainable options – these include exchanging fossil fuel with renewable resources, traditional solutions with advanced technology, and business-as-usual processes with alternative approaches to material selection and mode of procurement. The principle is characterised by 1) use of renewable energy and materials, 2) actions that encourage selection, procurement and use of alternative materials that are low impact to the natural environment, 3) actions that relate to innovative use of advanced technologies to replace traditional solutions and 4) actions that encourage delivery of assets through service rather than product ownership.

2.3 Results

2.3.1 ReSOLVE coverage in SBRS

Living Building Challenge

In comparing LBC against ReSOLVE, 14 out of 20 LBC imperatives could be matched with at least one ReSOLVE action (orange links) while six were deemed to be outside of the ReSOLVE scope (grey links) and clustered under "Not covered". The 14 imperatives that correspond with ReSOLVE come from the Place, Water, Energy, and Materials petals. The six imperatives that were not covered were from the Materials, Equity, Beauty, or Health + Happiness petals. These imperatives relate to social indicators such as indoor comfort of building occupants and inclusive local workforce and supply chain. **Figure 2-3** shows the results of mapping LBC imperatives into RESOLVE.

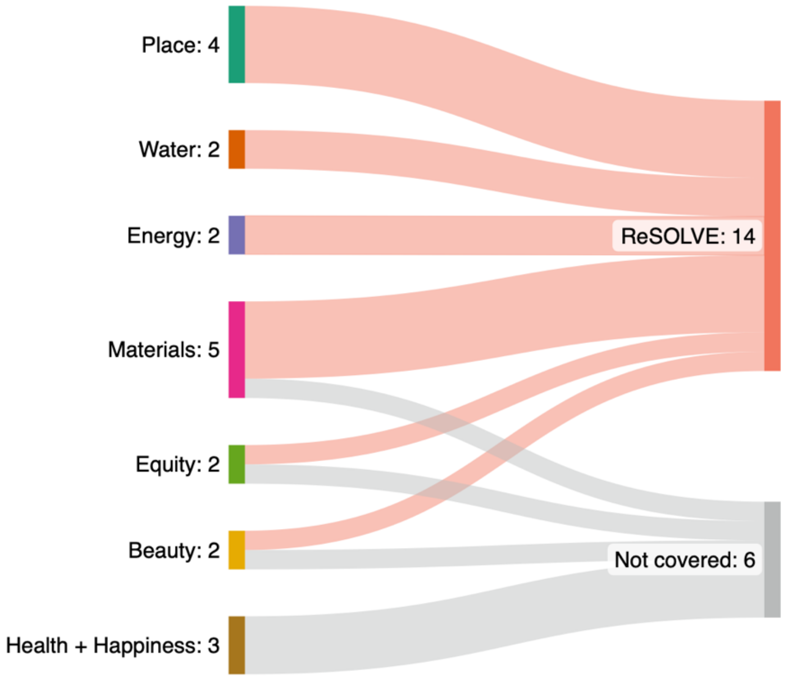

Figure 2-3 Mapping LBC imperatives into ReSOLVE

From the 14 imperatives, a total of 43 matches with ReSOLVE actions were found. This figure – 43 matches from 14 imperatives – indicates that some imperatives contributed to multiple ReSOLVE actions and principles. For instance, the intent of Imperative 16: Net Positive Waste of the Materials petal was deemed to align with the Regenerate, Share, Loop, and Optimise principles, gaining four matches from this imperative. **Figure 2-4** shows how the 14 imperatives from **Figure 2-3** flow into the different ReSOLVE actions, summarised by principle.

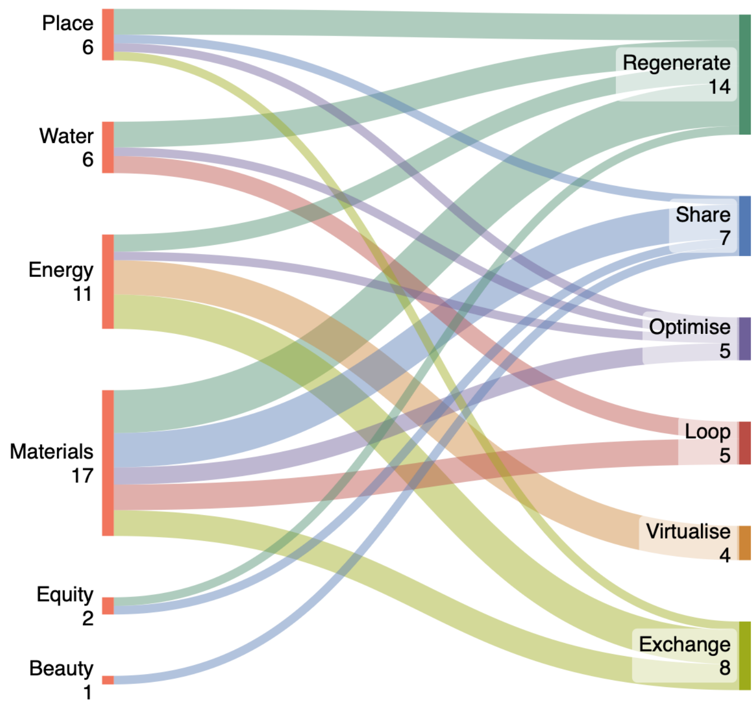

Figure 2-4 Flow of LBC imperatives into ReSOLVE principles

In LBC, ReSOLVE principles were largely represented by imperatives under the Materials and Energy petals such as *Responsible Materials, Responsible Sourcing, Red List, Energy + Carbon Reductions,* and *Net Positive Energy.* As seen in **Figure 2-4**, the Materials petal (17) showed the largest coverage of CE principles in LBC, highlighting the importance of materials in CE transition.

At a principle level, LBC imperatives represented the Regenerate principle the most, accounting for 14 out of 43 matches. At an action level, LBC imperatives most frequently addressed the ReSOLVE action *Safeguarding, restoring, and increasing the resilience of ecosystems (Re1)*, with a total of ten matches. The Exchange and Share principles were the second and third most salient ReSOLVE principles in LBC, with a total of eight and seven matches, respectively. LBC imperatives generated the least number of matches with the Virtualise principle, with only four out of 43 matches, while the Loop and Optimise principles have five matches each. Overall, LBC demonstrated alignment and potential application of the Regenerate, Share and Exchange principles of CE through its imperatives but was short in integrating the Virtualise, Loop, Optimise principles.

Green Star Buildings

For GSB, 32 out of 41 credits corresponded with at least one ReSOLVE action (green links), as shown in **Figure 2-5**. Nine GSB credits were not covered by ReSOLVE (grey links), which belong to the Health, Resilient, Places, or People categories. This result echoes the mapping for LBC, wherein indicators that could not be matched with ReSOLVE often can be categorized as social indicators, for instance, *Culture, Heritage and Identity*, and *Workforce Inclusion* credits.

Figure 2-5 Mapping of GSB credits into ReSOLVE

Out of the 32 credits that were mapped into ReSOLVE, a total of 67 matches were found between GSB credits and ReSOLVE actions (see **Figure 2-6**), indicating that some credits addressed multiple ReSOLVE actions, similar to LBC. Credits from the Responsible category generated the highest number of matches (15) shadowed by the Positive category (10) – suggesting that these two categories present the greatest potential in embedding and promoting CE principles in GSB. The Responsible category, in particular, is anticipated to further integrate CE principles into GSB with the introduction of the Responsible Product Framework currently in development as of writing (GBCA, n.d.). It is noted that GSB has implemented a Circular Economy Challenge credit under the Leadership category, which covered each ReSOLVE action and added a total of 18 points. However, the credits under the Leadership category are still voluntary and can be entirely disregarded. It is worth highlighting that for GSB, Circular Economy actions in the planning and design stages of the development are still explicitly integrated into a "challenge". Expert consultation revealed that the industry does not yet consider the CE approach as the norm and the Circular Economy Challenge credit is tackled currently only by a select number of market leaders.

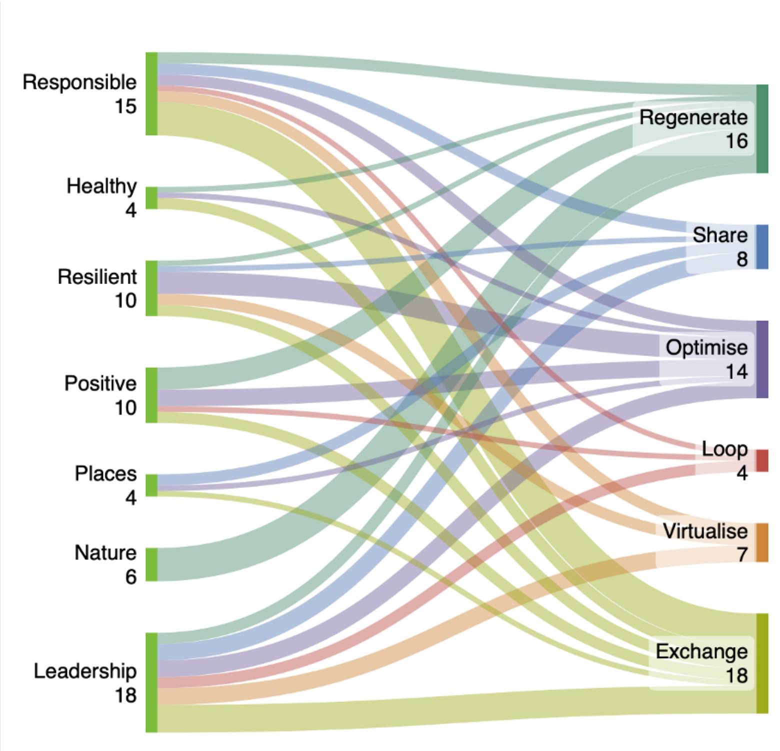

Figure 2-6 Flow of GSB credits into ReSOLVE principles

At a principle level, GSB credits addressed the Exchange principle the most with 18 matches, followed closely by the Regenerate (16) and Optimise (14) principles. The Loop principle was the least represented with 4 matches, while the Virtualise and Share principle had 7 and 8 matches, respectively. At an action level, GSB credits showed the greatest overlap with *Safeguarding, restoring, and increasing the resilience of ecosystems (Re1)* followed by *Using alternative material input (E2)*. Based on the total number of matches, the results showed that the Exchange, Regenerate, and Optimise principles are the three most prominent CE principles found in GSB credits, while the other three principles (i.e. Share, Loop, and Virtualise) have limited presence amongst GSB credits.

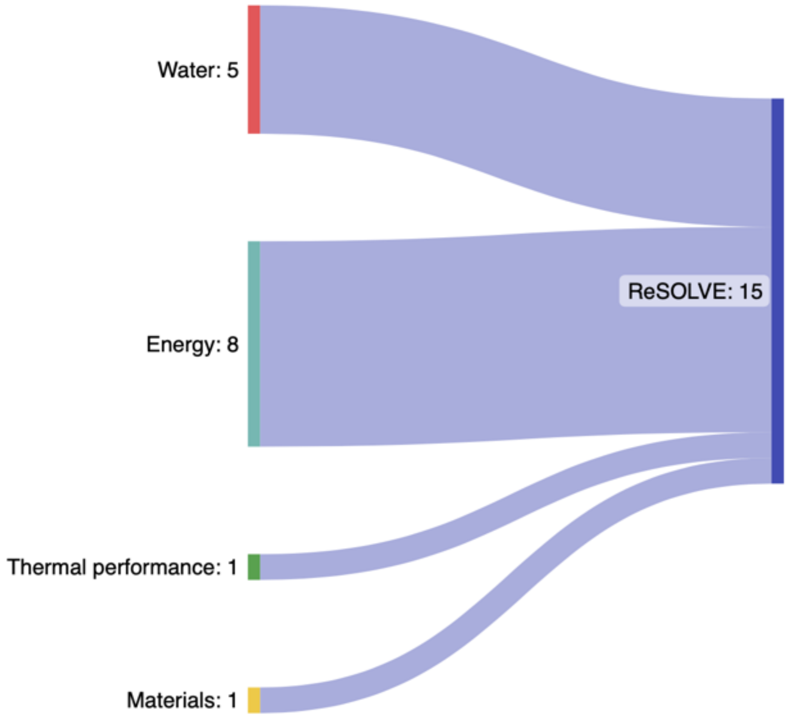

Figure 2-7 Mapping of BASIX elements into ReSOLVE

BASIX

As shown in **Figure 2-7**, the 15 BASIX assessment elements under the four indices were matched with at least one ReSOLVE action, which denotes that ReSOLVE comprehensively covers the indicators currently included in BASIX. Unlike LBC and GSB, there were no indicators that were classified as “not covered”.

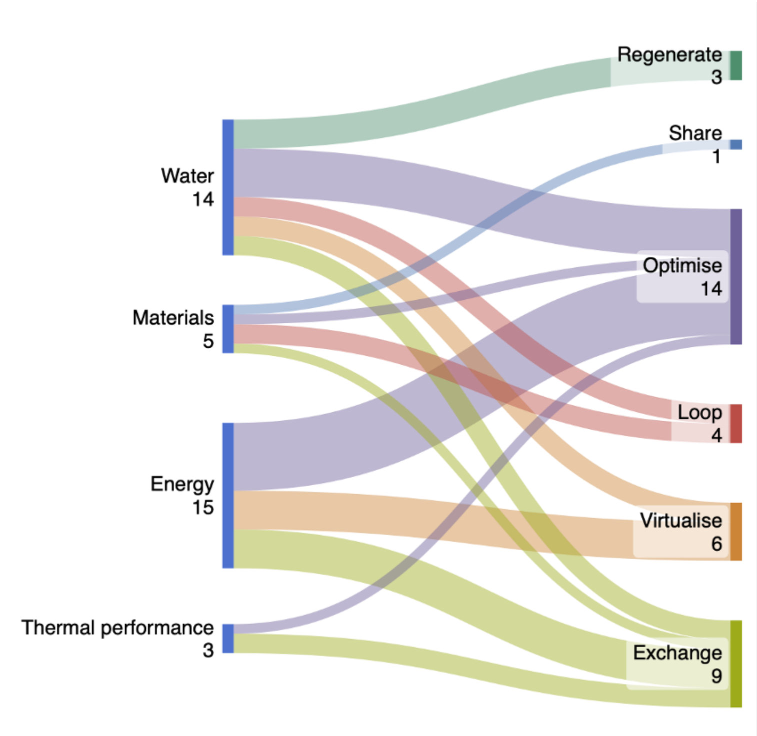

Figure 2-8 Flow of BASIX elements into ReSOLVE principles

The comparison of BASIX elements with ReSOLVE actions resulted in 37 matches, as evidenced in **Figure 2-8**. Matches were largely from the Energy (15 matches) and Water (14 matches) indices. Optimise was the most strongly represented principle in BASIX, totalling 14 matches. The second most salient ReSOLVE principle in BASIX was the Exchange principle with nine matches. At an action level, BASIX elements corresponded the most to the ReSOLVE action *Decreasing resource usage (O2)*, representing a significant share (35%) of the total matches.

The other three principles (Loop, Regenerate, and Share) were poorly represented, with the Share principle having only one match. Nevertheless, these underrepresented principles were typically integrated into the Materials and Water indices, implying that these indices could be key to expanding the application of these principles in BASIX. Overall, BASIX largely reflects the Optimise and Exchange principles of CE given its focus on energy and water efficiency. However, CE principles like Regenerate, Share and Loop are still insufficient and may be further incorporated through the Materials index.
ReSOLVE coverage by the three SBRS

The results show that each of the three SBRS covered all the ReSOLVE principles, although represented at varying levels. LBC significantly contributed more to Regenerate than any other principle, while covering the other principles at similar levels. GSB provided a more balanced coverage, representing half of the principles at comparable levels and the other half at a lower level. BASIX highlighted the Optimise principle the most and covers the others at notably lower levels.

Aggregating the matches of each SBRS, Exchange was the most prominent principle amongst all SBRS (35 matches), with the Regenerate and Optimise principles coming a joint second (33 matches). Meanwhile, Loop, Virtualise and Share principles were represented the least by SBRS indicators, with more than 50% lower number of matches. **Figure 2-9** presents an aggregated result of the comparative analysis for all three SBRS. *Safeguarding, restoring, and increasing the resilience of ecosystems (Re1)* and *Decreasing resource usage (O2)* were the ReSOLVE actions with the highest number of matches (23) with SBRS second-level indicators (see **Figure 2-10**). Meanwhile, *Implementing Reverse Logistics (O3)* and *Replacing physical with virtual locations (V2)* were the ReSOLVE actions that have the weakest representation in the SBRS, each being referred to only once by an SBRS second-level indicator (i.e. GSB's Circular Economy Challenge credit).

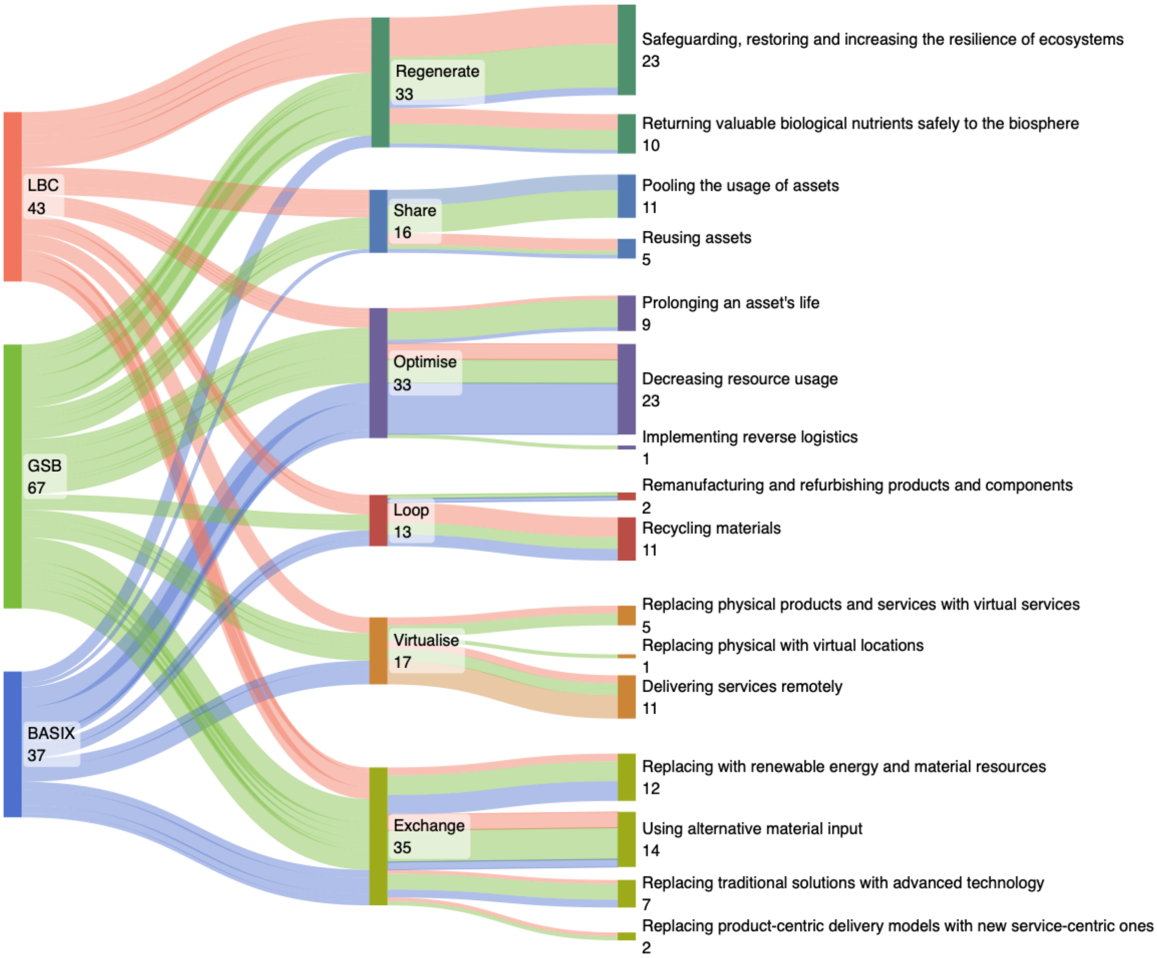

Figure 2-9 Sankey diagram showing connection flows of SBRS indicators to ReSOLVE principles and actions

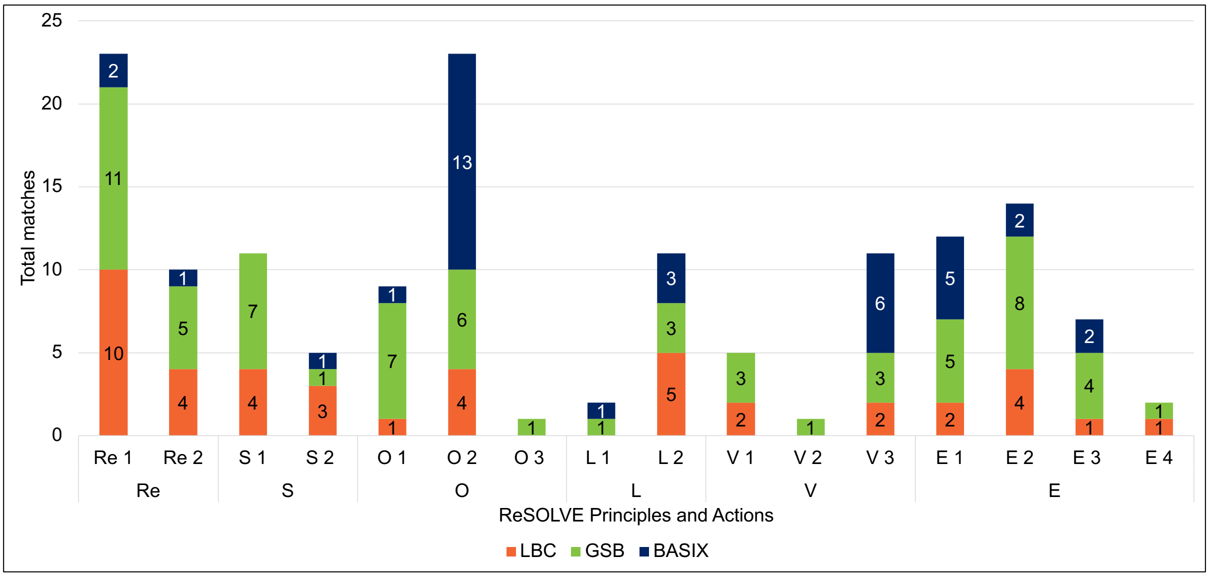

Figure 2-10 Aggregate matches between SBRS indicators and ReSOLVE actions

2.3.2 Approaches to Framing ReSOLVE principles across SBRS

The qualitative approach to the comparative analysis and expert consultation outcomes revealed the different approaches to CE adoption in each SBRS. The following subsections discuss the framing of each ReSOLVE principle across the three SBRS.

Regenerate

The Regenerate principle is one of the most salient CE principles in the SBRS studied. It was mostly addressed by indicators from LBC's Place, Water, and Materials petals, GSB's Positive and Nature categories, and BASIX's Water Index. However, the qualitative content analysis showed that this principle is represented differently and to varying degrees by each of the SBRS. For LBC, the language by which the Regenerate principle is expressed has a strong emphasis on positive ecological outcomes. The intents of LBC imperatives are described as being underpinned by proactively protecting and improving the ecological environment, and not only by minimising negative externalities to natural ecosystems. For example, the *Ecology of Place* imperative of the Place petal explicitly asks projects to "protect wild and ecologically significant places and encourage ecological regeneration" (ILFI, 2019, p. 30). In line with its aspirational claims of moving beyond the paradigm of “doing less harm”, LBC imperatives are set out to facilitate nature-positive outcomes. GSB credits that reflect the Regenerate principle promote nature-positive outcomes, but also largely emphasise the reduction of negative environmental impacts by the building project. For example, the intended outcome of *Upfront Carbon Emissions* credit is that “the building's upfront carbon emissions from materials and products have been reduced and offset” (Green Building Council of Australia, 2021, p. 137). The language of reduction and offset is also found in credits such as *Life Cycle Impacts*, *Responsible Construction*, and *Heat Resilience*. Compared to LBC and GSB, BASIX elements that represent the Regenerate principle are framed as a water efficiency measure rather than a nature-positive strategy.

Share

The Share principle is one of the least reflected CE principles in the SBRS studied. LBC leads in integrating the principle in its imperatives, mainly through its Materials petal. LBC covers the concept of sharing and reuse economy through its *Responsible Materials*, *Responsible Sourcing*, and *Net Positive Waste* imperatives, which encourage “imaginative reuse of salvaged waste materials” (ILFI, 2019, p. 58). In addition, open-source information sharing is embedded in imperatives such as *Responsible Material*, *Red List*, and *Responsible Sourcing* imperatives, which call for a transparent materials economy, and the *Education + Inspiration* imperative, which requires the provision of educational materials to the public. GSB applies the Share principle through credits under the Responsible, Resilient, Place, and Leadership categories. Information sharing is embedded in the *Industry Development* and *Market Transformation* credits, which both intend to facilitate knowledge-sharing, collaboration, and innovation. Co-ownership and co-location are also integrated into GSB through its *Enjoyable Places* and *Movement and Place* credits. The reuse and sharing economy is weak in the GSB credits and is only reflected under the voluntary Circular Economy Leadership credit. BASIX least integrates the Share principle amongst selected SBRS. The Materials Index of BASIX potentially applies this principle by encouraging building material retention and information sharing regarding the embodied carbon of building materials.

Optimise

In all SBRS, the Optimise principle generally has a strong presence across the board. This finding supports previous SBRS research, which found that SBRS credits largely contribute to energy efficiency (Optimise) and focus on the Design, Construction and Use stage of the building lifecycle (Braulio-Gonzalo et al., 2022; Olanrewaju et al., 2024). The Optimise principle has one of its actions, *Decreasing resource usage (O2)*, as one of the most addressed actions by SBRS indicators. This suggests that there is a strong push by all SBRS to reduce resource usage and demand for new materials. This Optimisation action is widely reflected, especially in BASIX, where its calculation and benchmarking method is underpinned by savings from energy and water consumption. However, it is equally important to note that the Optimise principle also has an action, *Implementing reverse logistics (O3),* which is one of the least referred to by SBRS indicators, with only one match found across all three SBRS. This finding suggests that the Optimise principle embedded in SBRS gears more toward consumption reduction of users and producers and less toward implementing reverse logistics or returning assets to retailers or manufacturers. If this CE action is integrated further into SBRS, this presents the potential to eliminate externalities in the supply chain and enhance value capturing from existing building materials.

Loop

The Loop principle is the least represented principle amongst the selected SBRS. This result supports the previous assessment of SBRS which found that embodied emissions are poorly addressed in SBRS (Olanrewaju et al., 2024). Loop is integrated in LBC's Water and Materials imperatives, GSB's Responsible, Positive and Leadership credits, and BASIX's Water and Materials index. Although the action *Recycling materials (L2)* is a common theme across SBRS, *Remanufacturing and refurbishing products and components (L1)* is one of the least addressed ReSOLVE actions by SBRS indicators. Loop actions are evident and straightforward in indicators addressing water use through recycled water initiatives. However, Loop actions related to building material use are less explicit. For instance, construction waste diversion from landfills is explicitly encouraged, particularly in LBC and GSB, but promoting the use of remanufactured, repurposed, or recycled materials in the design and construction of buildings is not overtly incentivised. It is important to note, however, that the use of third-party certifications and guidelines such as LBC's Declare, GSB's Responsible Product Framework, or Environmental Product Declarations (EPDs) to assess and promote responsible sourcing of building materials is already being incorporated in the SBRS. Furthermore, although Loop concepts such as Design for Disassembly or Deconstruction are present in LBC and GSB, they are rarely referred to or only treated as industry-leading initiatives. Loop concepts such as Buildings as Material Banks and Materials Passport (Luscuere, 2017) are yet to be fully embedded in the SBRS.

Virtualise

The Virtualise principle is one of the weakest ReSOLVE principles amongst SBRS indicators, with action *Replacing physical with virtual locations (V2)* being addressed once. In the selected SBRS, the Virtualise principle is commonly integrated in indicators related to energy and water management, such as in LBC's Energy petal, GSB's Responsible, Resilient and Leadership Categories and BASIX's Energy and Water indices. Across all SBRS, the Virtualise principle is represented using smart meters, sensors and other digital devices for energy and water consumption monitoring and management, which are meant to deliver services remotely mainly during the operational phase of the building. However, actions that may facilitate the adoption of the Virtualise principle during the design and construction phases of renovation, such as utilising Building Information Management (BIM) systems or Digital Twins, are still lacking in the current SBRS indicators. This finding aligns with previous research that claims the digitalisation level in renovation is still low (Pikas et al., 2021) and points to a compelling opportunity for SBRS to facilitate the adoption of Virtualise actions in building practices.

Exchange

The Exchange principle has the strongest representation amongst SBRS. Switching to renewable energy resources and using alternative low-carbon building materials are two key CE themes present across all SBRS, with *Replacing with renewable energy and material resources (E1) and Using alternative material input (E2)* being the third and fourth most common ReSOLVE actions in SBRS indicators. In LBC, proprietary tools such as the *Red List* were developed to "foster a transparent materials economy free of toxins and harmful chemicals" (ILFI, 2019, p. 53) and the *Declare* label to "support sustainable extraction of materials and transparent labelling of products" (p. 54). In GSB, the Exchange principle is embedded through the promotion of renewable energy production and consumption, the use of advanced technology to support renewable energy transition, passive design, and third-party certifications and labelling for products. Like LBC, GSB has developed its framework, the *Responsible Product Framework*, to assess the responsible selection and sourcing of building materials. Lastly, BASIX integrates the Exchange principle by incentivising the use of renewable energy, materials with lower embodied emissions, advanced monitoring and management systems for energy and water, and passive design as reflected in its Material, Energy, Water and Thermal performance indices.

Figure 2-11 enumerates the second-level indicators from each SBRS that address CE ReSOLVE principles.

Figure 2-11 SBRS second-level indicators addressing ReSOLVE

2.4 Discussion

2.4.1 CE opportunities in SBRS development

The results showed that several principles of CE (Regenerate, Optimise, Exchange) are already strongly represented in existing SBRS, albeit at varying levels and through different approaches. While SBRS have historically focused on improving energy efficiency (Chen et al., 2015; Wen et al., 2020), a gradual shift towards circularity through regenerative principles, resource efficiency, and renewable energy is evident in the current versions of the SBRS. This is a promising result in advancing CE through SBRS and provides an update on previous research indicating that current SBRS are not well prepared to adopt CE (Braulio-Gonzalo et al., 2022).

Conversely, while some CE principles are already present in the select SBRS, there is an opportunity to strengthen other CE principles that are lacking in SBRS, such as Share, Loop, and Virtualise principles. This means integrating the sharing economy (Share), prioritising value recapture in EoL stages of building materials (Loop) and leveraging digital technologies (Virtualise) in SBRS. The Share and Loop principles can be incorporated by adding and prioritising targets for reused, refurbished, or remanufactured building materials usage over recycled materials in SBRS. Furthermore, the Virtualise principle can be embedded by adding indicators that promote circular digital technologies, such as Building and Material passports and Digital Twins, which can also aid the renovation process and contribute to urban mining (Talla and McIlwaine, 2024).

By embedding these weaker CE principles, SBRS has the potential to accelerate the shift away from a material-intensive built environment through augmenting digitalisation in the construction sector and reshaping the labour market (Borms et al., 2023) by prompting the development of labour-intensive markets based on repair, refurbishment, remanufacturing or deconstruction activities with potentially significant socio-economic benefits (Heisel et al., 2023). The potential of this may be higher in the case of market-leading SBRS such as Green Star, LEED and BREEAM and mandatory SBRS such as BASIX, which can have a significant influence on the local building supply chain. Furthermore, by strengthening the Loop principle, SBRS can be more suitable for building renovation projects, and the missing EoL stage credits and whole lifecycle approach in existing SBRS identified in previous research can be addressed (Braulio-Gonzalo et al., 2022; Olanrewaju et al., 2024).

2.4.2 Influence of SBRS on the residential sector

The outcomes of the expert consultations highlighted that the market influence and the level of sustainability standard of SBRS may differentiate their potential to promote CE adoption. On one hand, some SBRS can be pivotal in shifting design thinking amongst professionals but have a smaller market influence. On the other hand, other SBRS are considered as a 'box to tick' but have an apparent greater influence or educational potential. This finding suggests that existing SBRS may facilitate CE adoption in a fragmented approach, and they could have different roles in the CE transition depending on their market influence and level of sustainability standard, among other factors. For instance, BASIX can be an instrumental educational tool as a mandatory SBRS, but its use of minimum targets means that its approach to CE transition remains incremental. Meanwhile, LBC is seen by its users as having a transformational effect amongst industry actors, driving new research and development (R&D) activities, and instigating steep learning curves among professionals. GSB can be both instrumental and educational for the broader industry as the leading voluntary SBRS in Australia. However, GSB and LBC certifications are currently limited to building projects with high potential market value due to the high cost and tedious process of certification, which substantiates previous findings on barriers to SBRS adoption (Darko and Chan, 2017). Despite leading the transition to CE, LBC and GSB can have potential minimal CE influence in the residential sector due to their financial barriers, which could also be the case for other leading but high-cost SBRS in other geographies, such as LEED and BREEAM.

For residential renovation, locally mandated SBRS, which automatically have a greater scope of influence and lower financial costs, may be more suitable for apartment renovation projects and have greater potential in promoting CE. This implies that for geographies without legislated SBRS, SBRS may not provide an accessible implementation pathway for circular renovation. However, a limitation of mandatory SBRS like BASIX is the incremental approach to sustainability and, thus, does not incentivise CE adoption more than minimum standards. To balance these opportunities and barriers and achieve optimal effect, CE adoption in apartment building renovation may benefit from future research exploring a more accessible and unified CE approach among SBRS, conceptually linking minimum standards with aspirational CE initiatives.

2.4.3 CE's conceptual clarity and social dimension

Furthermore, the research revealed two key weaknesses that need to be addressed for a successful CE transition. The first was the difficulty in interpreting ReSOLVE. Although developed as an operational tool for businesses and policymakers, the framework and the definition of its principles and actions are not clear-cut, which may prove to be a challenge in implementing it. The results of this research respond to this challenge by contextualising ReSOLVE in residential SBRS and providing concrete CE actions applicable to apartment building renovation, addressing some of the implementation gaps in CE. Specifically, the SBRS indicators outlined in **Figure 2-11** and their criteria contribute to actionable CE knowledge and provide precedent for other international SBRS that are looking to further integrate CE, which can advance CE standardisation in SBRS. The second weakness is the missing social dimension in ReSOLVE. The findings of the comparative analysis demonstrated that several socially oriented indicators of LBC and GSB were not mapped into ReSOLVE. These include Equity, Beauty, and Health + Happiness imperatives for LBC and Healthy, Places, and People credits for GSB (see **Figure 2-3**, **Figure 2-5**, and **Figure 2-7**). This finding corroborates the critique of the weak social dimension of CE (Murray et al., 2017). It also substantiates previous research recommendations for a more value-based and normative approach to CE (Mies and Gold, 2021) by strengthening its social aspect. The proposed integration of social impact assessment with ReSOLVE by Payne and Kwofie serves as a starting point to improve ReSOLVE's capacity as a practical and analytical tool and promote social value in CE adoption (Payne and Kwofie, 2024). The broader adoption of CE in apartment building renovation through SBRS can also support CE's social pillar, given the strong social agenda in the residential sector. Overall, the research contributes to the growing literature on CE and the ReSOLVE framework and recommends the integration of social objectives in the CE transition as a research priority.

2.4.4 Limitations

There are several limitations to this study. First, the analysis focused on the content of published guidelines of SBRS. However, a review of outcomes of SBRS-certified buildings, which verifies the effectiveness of CE principles 'as built', would provide a critical addition to the content-focused analysis of this study. Understanding which CE-related SBRS indicators building projects have achieved or aim to achieve may provide a better representation of the state of play of CE transition, as driven by existing SBRS. Second, the analysis is limited to three SBRS, albeit two are internationally relevant. Future research may expand the scope to other global and local SBRS to provide a more comprehensive comparative study. Third, the qualitative approach to content analysis precludes the generalisability of the findings to other SBRS. However, given that two of the SBRS included in the study also apply to other building typologies, the findings particularly for LBC and GSB can be extended to typologies other than apartment buildings. Lastly, the expert consultation for this study involved a small sample size. Nevertheless, the experts consulted have first-hand experience with the development or application of the selected SBRS and thus reflect insider insights that provide value to the research and its aims. A larger sample for the expert consultation may provide broader insights for future research.

2.5 Chapter Conclusion

This chapter examined the integration of CE principles in existing SBRS as social artefacts in circular renovation. CE implementation pathways for building projects are still lacking, particularly for apartment building renovation projects. SBRS represent established building sustainability standards for both new builds and renovation projects, serving as a social institutional artefact to this effect. SBRS have grown and evolved since its introduction to adapt to changing sustainability needs, both local and global. Leveraging the evolutionary capacity of SBRS, this study comparatively reviewed how CE is currently integrated into three residential SBRS and can be further integrated to enable circular renovation. Focusing on SBRS applicable to apartment buildings, the study analysed and compared CE presence in Living Building Challenge, Green Star Buildings, and BASIX using the ReSOLVE framework for circularity in the built environment.

The research revealed three key findings. First, the three SBRS already integrate CE principles, albeit to varying extents and with different approaches. Locally mandated SBRS show potential in being more accessible for the residential sector. This suggests that SBRS as social artefacts are progressing towards CE and can potentially support circular renovation. However, the findings imply that not all SBRS have equal or similar influence as social artefacts, indicating further work is needed to understand their effectiveness in the CE transition. Second, the Exchange, Regenerate, and Optimise principles of ReSOLVE have a strong presence, while Share, Loop, and Virtualise principles are underrepresented. This finding points to the opportunity to modify these SBRS to embed these underrepresented principles, increasing SBRS' suitability as social artefacts for circular renovation. Third, there are some potential gaps in ReSOLVE from a social sustainability lens, emphasising that RESOLVE itself as a social artefact of CE requires a stronger social foundation.

While recognising that each SBRS in its current form influence CE adoption differently, the study reveals the opportunity to reform these SBRS to be more accessible for apartment renovation projects and more unified in terms of their CE interpretation and implementation approaches. This can strengthen SBRS's role as an effective social artefact for circular renovation. The findings contribute to both CE and SBRS knowledge, which can establish coherence between the two to enable circular renovation of apartment buildings. The findings provide a starting point for SBRS policymakers and practitioners in reforming SBRS guidelines as well as CE proponents in understanding how SBRS can be leveraged as a social artefact to support the paradigm shift to CE.

CHAPTER 3

3 Circular Economy and the Architectural Profession

Actors in Circular Renovation: Architects' perspectives on their role in a CE

3.1 Chapter Overview

This chapter turns to the second social element of the research scope and focuses on the architectural profession as a *social actor* of circular renovation. It explores the role of architectural professionals in a CE and identifies the barriers and enablers they face in fulfilling this role in apartment building renovation. The study employs phenomenology as the research methodology and presents a thematic analysis of semi-structured interviews of architecture professionals with experience either in CE implementation or apartment building renovation. The chapter addresses Objective 2.2 of the thesis identified in **Section 1.4.**

The chapter commences with a background on CE adoption in the architectural practice, the Australian architectural profession, and research gaps that the study seeks to address. The study's research design is provided in **Section 1.6**. Finally, the results of the thematic analysis are discussed. The research reveals the current CE perceptions and practices of architectural professionals and the factors that influence their role as a CE-oriented social actor. The findings also present a nuanced understanding of the barriers and enablers faced by architectural professionals in adopting CE in apartment building renovation, as well as the potential implications of the broader CE transition to the architectural profession. The research builds on theoretical knowledge in sustainable architectural practice, expands CE scholarship to the architectural domain, and provides empirical evidence to inform policy and practice in support of a just and empowered CE transition in Australia.

3.2 Background

3.2.1 The architectural profession as a social actor in sustainable housing and CE transition

As defined in the introductory chapter, actors are social entities such as individuals, organisations, and institutions that perform or participate in CE actions. Recognising that the social dimension of the CE transition involves a multitude of actors and social groups, the thesis draws attention to the architectural profession as a social group of actors in this setting. The introductory chapter laid out that the architectural profession has a principal function in apartment development and in shaping a circular built environment, which remains underinvestigated and theorised in CE literature. As a social group of actors, architectural professionals share routines, perceptions and other rules (Raven, 2005) and maintain and reproduce these. Therefore, an understanding of these shared routines, perceptions and rules is essential to qualify their role as a social actor in the transition.

As Keena and Friedman (2024, p. 55) describe, “incorporating circular economy into the built environment is fundamentally a design shift.” By implication, the transition towards a CE presents a critical paradigm shift in architectural practice (Dokter et al., 2021). Buildings contribute a significant share of total greenhouse gas emissions and waste (UNEP, 2022), and as principal designers of buildings, architects play a crucial role in the CE transition. Indeed, the development of CE can be traced back to pioneering proponents in the late 20th century who were architects and designers themselves, as in the case of Walter Stahel, whose work on Product-Life Factor (Stahel, 1982) and Performance Economy (Stahel, 2010) developed the product life extension (e.g. repair, refurbishment, etc) and products-as-a-service concepts attributed to CE (Blomsma and Brennan, 2017a; Ellen MacArthur Foundation, 2013; Murray et al., 2017; Stahel, 2020). The conceptualisation of CE reflects its design roots, as the very definition of CE (based on commonly accepted definitions) acknowledges design as a primary tool for implementing CE (Ellen MacArthur Foundation, 2013; Keena and Friedman, 2024). However, it can be argued that a gap between the architecture discipline and CE scholarship is observable. Integration of CE principles remains aspirational rather than normative within the architectural practice, particularly in building renovation (Stoiljković et al., 2023). The same case was observed in Australia's Architecture, Engineering and Construction sector (Shooshtarian et al., 2023).

While CE literature has grown exponentially in recent years, there have been limited theorisation and empirical investigations into the perceptions and practices of architectural professionals regarding CE (Dokter et al., 2021; Kanters, 2020; Warren-Myers et al., 2024). In the words of Kanters (2020, p. 1), "not much is known about the design process of circular buildings and how architects are dealing with translating the principles of the circular economy to the building sector." In response, Kanters empirically analysed the barriers and enablers for a circular building sector from the perspective of architects and building consultants in Europe (Kanters, 2020). Dokter et al. expanded the scope to industrial designers and architects (collectively called design practitioners) to understand how they interpret and implement the CE concept in practice (Dokter et al., 2021). Meanwhile, Sumpter et al. focused on the competencies required for circular design through a qualitative investigation(Sumter et al., 2020). To gain a wider outlook, some studies have covered the architectural profession through systematic literature reviews of barriers and enablers in CE adoption in broader sectors (e.g. Architecture, Engineering and Construction sector), as in the case of Gasparri et al. (2023) and Munaro et al. (2020). The gap has been addressed by others through a more geographically-focused scope of barriers and enablers in CE adoption, for instance, Çetin et al. (2021) in Dutch social housing organisations, Cruz Rios et al. (2021) in the US building sector, Densley Tingley et al. sector (2017) in the UK construction, Stoiljković (2023) in Serbian architectural design studios, and Kozminska (2019) and Hjaltadóttir and Hild (2021) across Europe.

In Australia, research investigating professional perspectives in the Architecture, Engineering and Construction (AEC) industry regarding CE is growing (Hosseini et al., 2024; Shooshtarian et al., 2023). However, similar to international studies, existing research has covered a more general scope of the building actors, such as developers, governments, architects, designers, and planners. While previous research studies have identified barriers and enablers of CE adoption in the Australian built environment, the majority of research to date has employed quantitative or systematic methods that provide a breadth of factors and perspectives (Parry-Husbands et al., 2021; Shooshtarian et al., 2023; Zaman et al., 2023). There remains a limited in-depth understanding of each AEC actor's role in a CE transition and the implications for these professions. In particular, studies that focus on the architect, who often plays the role of lead designer and consultant in building projects, are still lacking, especially within the Australian context. Warren-Myers argues that the architectural practice for climate action remains under-theorised (Warren-Myers et al., 2024). To date, no in-depth studies have focused on architects in the Australian CE transition, to the best of the author's knowledge. As such, this study contributes to existing knowledge through its in-depth investigation of a particular social group of actors (i.e. architectural professionals), generating nuanced insights from a qualitative investigation.

3.2.2 Architectural profession and CE adoption in Australia

For this thesis, the architectural profession is defined to encompass registered architects and design professionals with architectural qualifications (interior architect, graduate architect, building designers, etc), but special attention is given to registered architects, given their professional capacity recognised by law. In Australia, a title registration model is in place for the architectural profession, which means registration is required to lawfully call oneself an 'architect' and/or offer architectural services to the public (Architects Accreditation Council of Australia, 2018).

The Australian architecture industry can be characterised as highly dispersed, dominated by micro-small architectural firms (Architects Accreditation Council of Australia, 2018). Of total architectural businesses in 2017, 98.4% employ less than 20 employees, and the handful of large architectural firms have a market share of less than 2% (Architects Accreditation Council of Australia, 2018). In 2022, there were 15,701 registered architects across Australia, but more than half of the registrations were shared by Victoria (34%) and NSW (28%) (Architects Accreditation Council of Australia, 2023), an increase of 2,134 registrations from 2017 (Architects Accreditation Council of Australia, 2018).

In response to the increasing urgency for climate action in the built environment, efforts have been made to integrate CE into architectural practice in Australia – from industry initiatives and professional peak bodies to government guidelines. In 2019, the industry-led Architects Declare Climate and Biodiversity Emergency (Architects Declare) global initiative was launched locally to mobilise the architectural profession to develop and implement their sustainability action plans with CE-related targets (Association of Consulting Architects Australia, 2020). In 2021, CE capabilities were explicitly added to current standards for architects in Australia. Specifically, the Architects Accreditation Council of Australia (AACA) updated the National Standard of Competency for Architects (NSCA) 2021 to outline the professional capabilities expected of registered architects in Australia. Under *Environmental Practice Capabilities*, NSCA 2021 requires architects to have the ability to minimise carbon impact and to support the transition to a carbon-neutral built environment, including "prioritising design for a circular economy and longevity" (Architects Accreditation Council of Australia, 2021, p. 4). The New South Wales (NSW) Architects Registration Board have enforced this update by requiring architects to take Continuing Professional Development (CPD) courses related to CE under the "Environmental sustainability, life cycle assessment and whole life carbon" umbrella (NSW Architects Registration Board, 2024, p. 1).

In addition, state governments have also developed and implemented built-environment-specific CE guidelines and strategic plans, which may implicate the role of the architectural profession in the built environment sector. For instance, the Australian New South Wales (NSW) Government released Circular Design Guidelines for the Built Environment in 2023 to encourage the industry to adopt CE principles in building, precinct and infrastructure developments (Office of Energy and Climate Change, and NSW Treasury, 2023). In the same year, the Australian Capital Territory (ACT) also published the state's CE strategy and action plan, including the built environment as one of its focus areas (ACT Government, 2023). As the urgency of the CE transition intensifies with the proliferation of CE-related guidance and regulations, in-depth research on the architectural profession's adoption of CE allows for broadening the CE research landscape and deepening the understanding of the actors that actualise the concept of CE – a gap this study aims to bridge.

3.3 Results

Through the thematic analysis, four broad themes were developed: 1) Fragmented understanding and evolving role of the architectural profession in a CE, 2) Different CE practices, 3) Enabling elements to CE adoption, and 4) Multi-dimensional barriers to CE adoption. The result of the thematic analysis is shown in **Figure 3-1.** In phenomenological terms, the first two themes tackle *what* CE adoption is like in the architectural profession by revealing their current understanding, perceptions, and practices of CE. The last two themes relate to *how* CE adoption is experienced by the architectural profession, highlighting the challenges they face and the elements that facilitate CE adoption. Each theme contains several high-level categories, which are comprised of several more categories. The following section discusses each of the four themes and the corresponding high-level categories and categories under them.

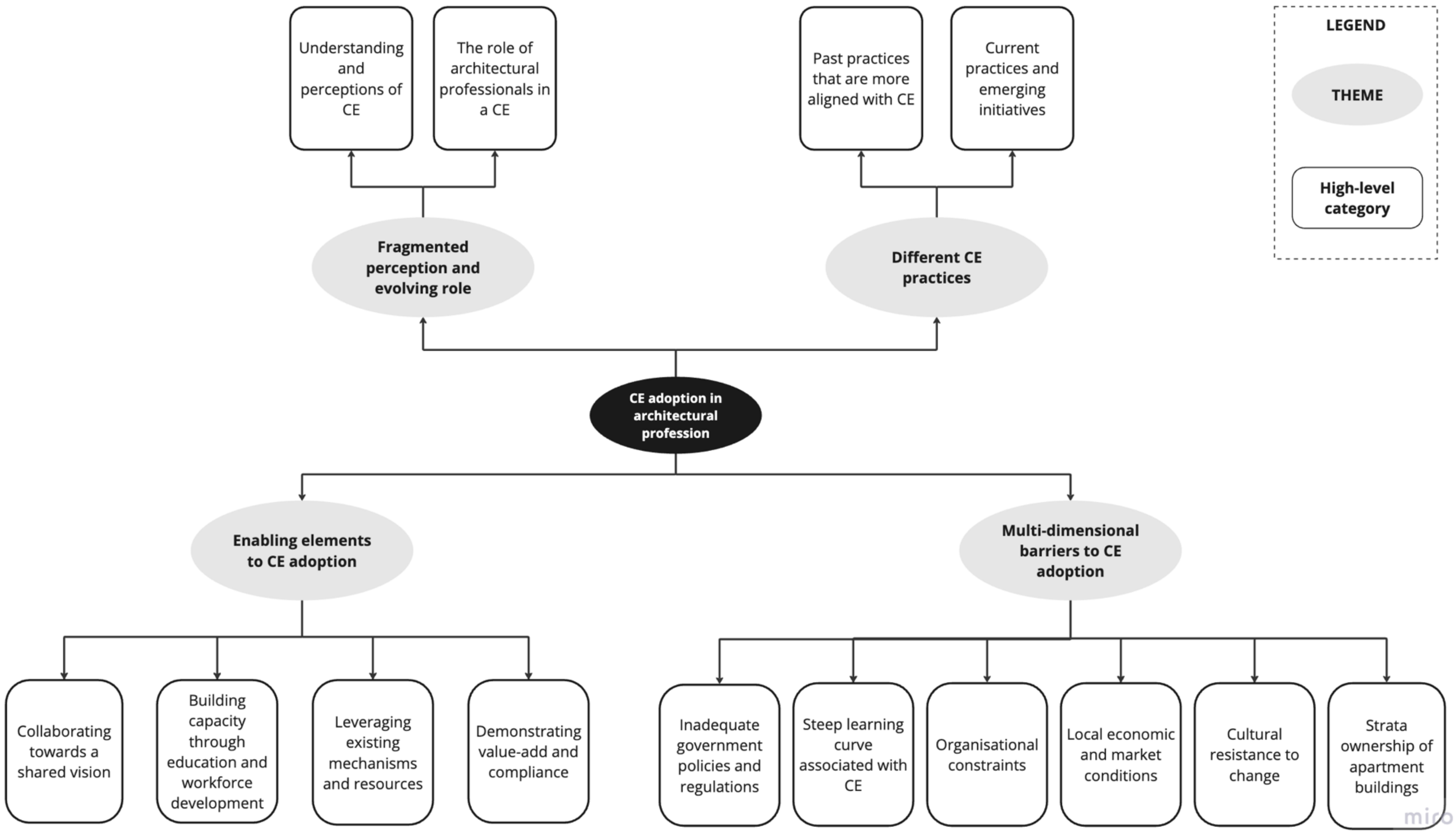

Figure 3-1 Thematic map - overview

3.4 Discussion

This section discusses in detail the four themes from the interviews and tackles their relevance to existing research and broader implications.

3.4.1 Fragmented perception and evolving role

The thematic analysis showed that CE adoption has a fragmented meaning amongst the participants, but there is a shared understanding of its impact in evolving the role of the profession. This theme is explicated by two high-level categories, namely Understanding and perceptions of CE and Role of the architect in a CE, which are described in detail in the following paragraphs. The detailed thematic map for this theme is illustrated below.

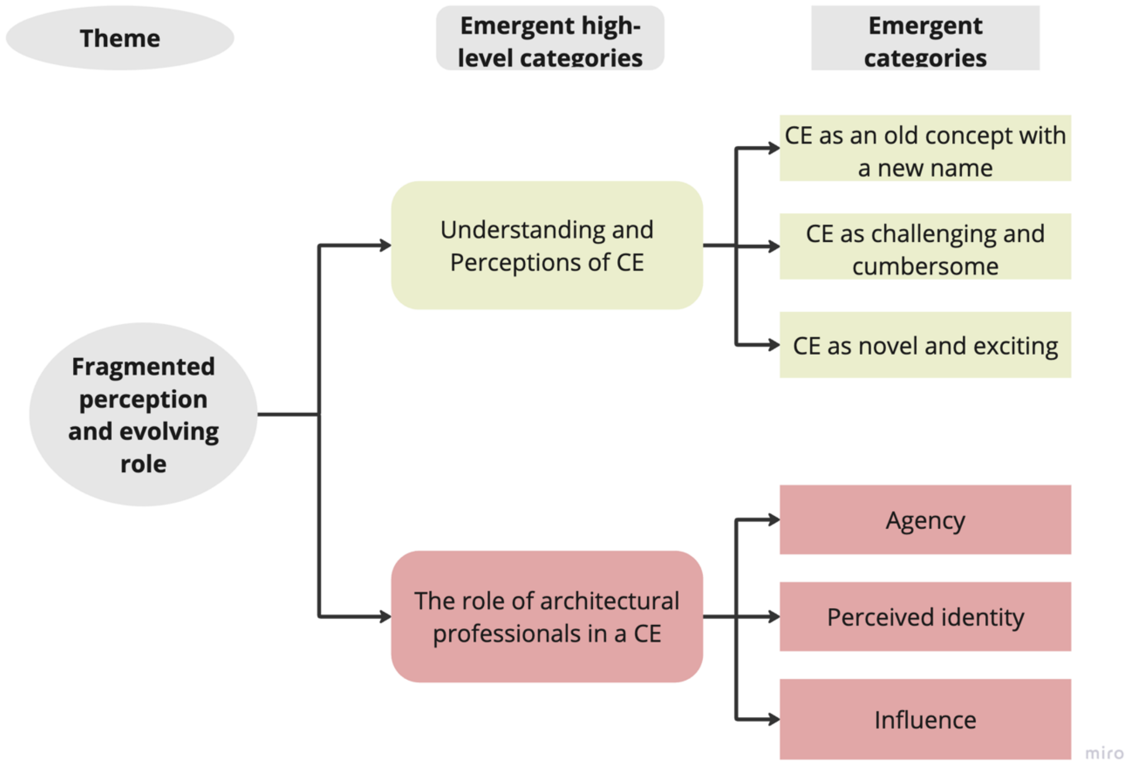

Figure 3-2 Detailed thematic map - Fragmented perception and evolving role

Understanding and perceptions of CE

The thematic analysis indicates that participants assign different meanings to CE and its adoption. Some understand it as an old concept with a new name, some as a challenging and cumbersome design methodology, and others see it as a novel and exciting niche.

CE as an old concept with a new name

Evidence from the interviews indicates that some participants perceive CE as a new terminology for longstanding concepts such as reuse and recycling – a rebranding to some degree for existing propositions. As Participant 1 stated,

> [CE] is just another name for a product that is age-old, I suppose. But, you know, giving it a different name maybe makes people think about it again. Fairly recently, people thought that salvage and reuse of building materials was a new thing. Of course, it's not a new thing; it just has a different name. (Participant 1, 2023)

Supporting Participant 1's assertion, Participant 9 explained that while the term may be new, the principles behind the term itself are already known or practised implicitly. "Circularity, that's not a term that we use, but yes, certainly the idea behind that is things that we do like really strive for" (Participant 9, 2024). Likewise, Participant 6 expressed that "circular economy obviously is not a new concept" but perceived it as an uncommon practice, "Circular economy is definitely a niche, I would say just straight off in the industry. It's not commonplace" (Participant 6, 2023). Participant 1 ascertained that while CE seemed like a rebrand of age-old concepts, a new name would serve in reviving these concepts into practice,: "I certainly think naming it, labelling it, documenting it, and making it a practice would certainly encourage a more active form of recycling and reuse, but certainly always did exist" (Participant 1, 2023).

This finding – that CE is an old concept with a new name – reflects the description of Blomsma and Brennan (2017a) of CE as an "umbrella concept" that encompasses pre-existing ideas and practices and can act as a catalytic and unifying framework. As an umbrella term, CE carries the risk of being an essentially contested concept (Korhonen et al., 2018) with different meanings attached to it that challenge consensus on implementation. This perception of CE points to two potential scenarios: CE as a new sustainability buzzword that could be disregarded for its 'emptiness', as Corvellec et al. (2020) put it, or CE as a new vision for building design and construction as its advocates have proclaimed. For CE adoption to accelerate, harnessing the unifying ability of CE as an umbrella concept by enhancing its conceptual clarity and implementation coherence is needed for the latter case to transpire.

CE as a challenging and cumbersome design methodology

Some participants expressed that CE adoption in architectural design is challenging and cumbersome – it entails a long process that requires a steep learning curve from time-poor professionals. For instance, Participant 9, who is a director in a medium-sized studio, reflected on their challenging experience in implementing CE initiatives such as measuring embodied carbon in one of their projects, “it feels like a constantly, very steep learning curve and trying to understand where the things are that we can do to make an impact” (Participant 9, 2024). Apart from the required technical skills, a major challenge was also attributed to changing established supply chain and procurement processes, which entailed extensive research efforts. Reflecting on their experience in a project with LBC aspirations, Participant 11 highlighted that the research and development requirements to comply with the LBC’s Red List (as covered in **Chapter 2**) were relatively high and further challenged by assessing greenwashing risks in the supply chain:

> I think the supply chain’s lack of knowledge about it has meant that we've had to go on quite a journey on the amount of research. [It’s also] being able to also drill past a lot of greenwash. I suppose that all just takes time, and that's where a lot of the research piece went. It was literally just time spent trying to delve through people's green credentials and see what's what. (Participant 11, 2023)

This perception of CE as a challenging and cumbersome methodology links to a lack of information on how to implement CE, which is one of the most common CE adoption barriers identified in the Australian AEC (Collins et al., 2023; Shooshtarian et al., 2023). The association of CE with resource intensity, particularly in the resource-constrained environment of architectural studios, highlights the sociomaterial realities impeding CE implementation across the profession. **Section 3.4.3** of this chapter expounds on the issues driving perceptions of CE as a challenging task.

CE as a novel and exciting niche

While some perceive CE adoption to be challenging and cumbersome, the interviews revealed positive views towards it. In a professional discipline where technical constraints and problem-solving are inherent aspects, the challenges raised by designing with a CE approach are seen by some participants as an exciting opportunity for a design solution. In particular, amongst participants who were involved in implementing a CE-related framework in their respective studios, a common theme was the positive reception from architects about these novel frameworks. For instance, Participant 5 led the development and implementation of their studio's internal regenerative design framework – demonstrating intent to implement CE through the Regenerate principle – and shared that architects have received the changes positively:

> Generally, people are very inspired about it [Regenerative design framework], but it can be overwhelming as well, because there are many, many things that we need to learn on this. Many things that we have to do differently to apply this. But overall, the reception has been very positive. (Participant 5, 2023)

Similar feedback was observed in Participant 6's studio, wherein educational initiatives were conducted internally to upskill architects about general sustainability and circular economy practices. Reflecting on their experience as part of the organising committee, Participant 6 expressed:

> People [architects and designers] are used to new technologies coming up or new requirements around compliance. So, I don't think that we didn't have any negative feedback at all. As I said, we have been talking about it, telling people it was coming for a while, and we had done a lot of stakeholder engagement in the firm. (Participant 6, 2023)

Likewise, Participant 10, who is a sustainability lead in their studio, noted that new architectural graduates particularly seem to be passionate and motivated to implement sustainability, including CE in practice, "Surprisingly, I think architectural graduates are very motivated and they really want action on sustainability, but don't know how” (Participant 10, 2024). While seen positively as a novel way of doing things, these participant accounts suggest that the meaning of CE adoption is attached to their level of CE knowledge.

Moreover, some participants exhibited a more general understanding of CE principles (e.g. recycling) while other participants demonstrated a broader understanding (e.g. regeneration) and expert technical skills (e.g. life cycle analysis, embodied carbon emissions accounting). Overall, the contrasting perceptions towards CE adoption (i.e. challenging and cumbersome vs. novel and exciting) indicate that the depth of CE understanding varies, despite the shared perception that CE is not entirely new. The findings show that there is growing awareness and willingness to learn about and implement CE among architectural professions, particularly when guidance is provided. By implication, there is also an expanding shared understanding of the changes a CE transition brings to the profession. The next paragraphs discuss this as the next high-level category under this theme.

The role of architectural professionals in a CE

The thematic analysis identified that architectural professionals perceive CE as a part of their professional role and that this role is also changed by it. Among the participants, there is awareness that their work influences and contributes to the environmental impact of buildings and an acknowledgement of the gravity of this issue. Participant 5 emphasised the unique and important role architects play, and the urgency attached to this role:

> Architects are in a very unique place because they're at the beginning of their design process, they have got the relationship with the client and the consultant team. So if they're equipped the right way, they can motivate others. I think they can be an incredibly powerful force of positive change... it's an extra thing on our plate. But it's the most important thing that we need to have on our plate right now. (Participant 5, 2023)

This is supported by another participant who posits that architects carry the responsibility to respond to the climate crisis through their professional practice and to motivate other actors and social groups (e.g clients and contractors) to do the same:

> I think architects have a very important role to play, and in fact, I think it's almost a responsibility of architects to play a role that sets a more positive trajectory for the project, but you know, it's sort of more than a project in many cases, I think. The more that architects advocate and are trusted advisers who have evidence to point to, the more that we're going to see our clients sort of embrace it. (Participant 2, 2023)

Validating that there is awareness amongst architects of their important role, one of the participants identified two ways in which the architect can contribute to the CE transition – first in recapturing the value of existing materials and second in influencing the supply chain towards circular building products.

> To me, the architects got two windows. One is into that deconstruction space, and the other is into the supply chain, properly being able to influence the supply chain about what's valued and what's not, what's important. (Participant 11, 2023)

Although there is evidence of awareness and acknowledgement of the architect's role amongst participants, most of them face challenges in their everyday reality to assume this role and effect change. The thematic analysis revealed that this role, or in phenomenological language, their experience in adopting CE in professional settings, is shaped by and hinges on three interrelated aspects of being an architect: agency, identity, and influence.

Agency of architectural professionals

Agency is generally defined as the capacity of an individual to act independently and freely within their environment. The agency of the architect is central to their role as a driver of sustainability in the built environment and circular buildings:

> We spent a lot of time trying to think about the agency that we have as architects to raise the question of sustainability, but sustainability is not just about windmills and

> solar panels, but economically sustainable, socially sustainable, as well as materially sustainable. (Participant 3, 2023)

Based on the interviews, the agency of the architect to adopt CE is defined by their contractual scope of responsibilities in projects, the resources available to them, and their passion for sustainability. Regarding scope, several participants cited that they are engaged at the wrong time to influence decision-making, thus limiting their scope of responsibility and subsequently, their agency to adopt CE in projects. This aligns with the findings of Warren-Myers et al. (2024) that architects face barriers with regard to climate action in their professional capacity due as their input is not being incorporated at the initial sketch phase when some decisions get locked in.

> A lot of that work [CE initiatives] is usually done early in [the] visibility stage with either project managers or business case management, portfolio management. So sometimes it's already been done too early on, and we get brought in too late to affect some of those decisions. (Participant 6, 2023)

When discussing opportunities for reusing building materials in construction sites, participants have also mentioned that existing practices exclude demolition from the architect's typical scope. Architects are either engaged early on, but not for demolition, or engaged after demolition has occurred, thereby limiting the opportunities to exercise their agency to salvage and reuse building materials before demolition:

> "Where we have an old building, and then we try to go in there and say, can we reuse anything of what we have there at the moment on that site? And that's a short window because often this kind of demolition happens already before we even start designing." (Participant 10, 2024)

When architects do have the remit to influence decision-making in the demolition stage, their resources, such as project budget, determine whether the architect has room to undertake CE research and implement initiatives. One of the participants details the challenges associated with project remit and fees that architects often encounter:

> One of the things that we've been looking at is demolition waste and trying to reuse demolition waste. The roadblock is not really within the architect's purview because we are not engaged for demolition... [the] what and how isn't really yet part of that scope. With all things circular economy or additional research-based pieces, there needs to be [an] additional fee. For the Living Building Challenge project that we're working on, for example, our fee is way higher than it would otherwise normally be, and even then, I think we underestimated the quantum of research necessary to achieve what we're trying to achieve. (Participant 11, 2023)

Moreover, the architectural studio's characteristics (e.g. structure, size, values) emerged as factors that impact their capacity to learn and adopt CE. On one hand, participants from medium to large studios have noted that their company's investment in new roles and internal programs allows architects to advance their CE knowledge and technical skills. One of the participants shared that their position as a sustainability lead has evolved from a part-time role to a full-time role as the studio recognised the need to empower the architects as well as project teams to have a more positive outcome and "become a catalyst for transformation", in the words of Participant 2. Other studios have adapted to the changing demands for architects by establishing sustainability committees in charge of educating the architects about sustainability topics such as CE. One of the participants noted that there is an increasing demand for sustainability lead positions, particularly in big firms, and emphasised the need to have dedicated resources by establishing designated teams to drive circularity outcomes. The organisation changes to adapt to CE are also evident in other geographical contexts such as in Europe. Dokter et al. (2021) found that some architectural and design studios in Europe have established dedicated CE research and design teams to support CE adoption.

> It's a bit of a top-down thing, the company needs to invest in it, and you're starting to see that there are job positions opening in the big firms that are sustainability leads and positions like this that I think will drive that change. But there absolutely needs to be a designated personnel team to drive it. (Participant 7, 2023)

On the other hand, participants from smaller firms were situated in a more resource-constrained environment and relied on project fees or resorted to grants to support their CE research and initiatives on a project basis. However, the interview findings suggest that these opportunities are rare and are highly dependent on the client's willingness to pay:

> We've been lucky enough to find a client who wanted to do a Living Building Challenge project and has been prepared to pay the [price] to do that. Unless you find that client, and they're kind of a Unicorn, it's quite difficult to innovate. (Participant 11, 2023)

Participant 9 from a small studio recounted that, although there is a willingness to learn and implement CE in their projects, employees are limited by their resources to deliver CE initiatives technically and often rely on funding opportunities:

> We were only able to do it [embodied emissions accounting] because we had the funding from doing the competition, and we said we're [going to] spend some money on learning how to do this. (Participant 9, 2024)

Nevertheless, the interviews revealed that the architect's agency may not only be influenced by the resources, either internally or externally available to them, but may also be driven by an inherent passion for sustainability, as evidenced by the accounts of some of the participants. For instance, Participant 3 from a small to medium studio shared that their agency was not defined by project scope or fees but was motivated intrinsically, "It was a huge amount [of research]. It didn't pay for itself. It was a labour of love" (Participant 3, 2023). While some architects have chosen to internally absorb the initial cost of adopting CE or sustainability, *s*ome architects have exercised their agency through volunteer roles specific to CE, but at risk of experiencing volunteer fatigue. Corroborating Participant 3's sentiment, Participant 11 encapsulates what architects who are inherently motivated to adopt CE often experience when assuming volunteer roles related to sustainability: "it's a fairly unrewarding proposition when you're giving your time for free and you're trying to juggle it while you're doing your day job. It's everybody's passion, but nobody's job" (Participant 11, 2023).

The analysis underscores that CE adoption in the architectural profession is not merely influenced by the willingness of the architects but is shaped by their sociomaterial reality, particularly in their professional remit and research and development capital based on their studio's resources. The findings highlight the influence of project delivery norms within architectural studios and building projects, which need to be considered and further examined to maximise the agency of the architect as a CE actor.

Perceived identity of the architectural profession

The perceived identity or sense of self of architectural professionals also shapes their role in the CE transition. Participant 1, who has worked as an architect for over 40+ years, argued that the profession is experiencing an existential crisis, which may preclude them from assuming their role in a CE and to successfully affect change and generate value, "I see it as an existential problem for the profession. We're constantly having to justify our existence and what we do" (Participant 1, 2023). Participant 1 added that this is partly due to the lack of or misunderstanding of what architects can do and the value they can provide. Participant 4 corroborated this and explained that while the architect may be in the best position to address building projects holistically in terms of technical capabilities, they find it difficult without earning traction from clients and contractors because "people do not understand what we [architects] do." He added that this problem is exacerbated by the narrow perception of the architect's capabilities: "Our role has been gradually eroded to a producer of images and anything outside of that is kind of seen as being the domain of other people" (Participant 4, 2023). Participant 10 echoed this sentiment, noting that the other actors they typically deal with such as clients and other contractors, are not aware of the comprehensive technical skillset of the architect that could address CE, stating that their expertise is not often recognised:

> One of the issues is that it's not really on the radar of the client and of the builder to actually talk to the architects about [existing building materials and ask], Look, we've got all this stuff here, is there anything we can do with it? (Participant 10, 2024)

The perceived existential problem architects face extends beyond the sustainability realm and indicates a broader issue of the recognition of the profession. Seconding

Participant 4's sentiments about the decimation of the architect's identity to aesthetic endeavours, Participant 1 pointed out that architects face the predicament of losing their recognition and becoming "modern slaves" once leaving the university, "As soon as an architecture student transitions into being an architect, there's no further discussion. You know, you just do what you're told" (Participant 1, 2023).

Furthermore, the value attached to the architect's work is often questioned or hardly recognised. Participant 4 lamented that the profession is surrounded by scepticism. Participant 11 also commented that he strategic role and the holistic approach that an architect can deliver, which is especially crucial in a CE approach to projects, are not valued enough.

> We also have a portion of what we [architects] do that's about the strategic, about the bigger picture. A mechanical engineer, for example, doesn't have that. An electric engineer doesn't have [it]. A structural engineer doesn't have it. But the really strange thing is that strategy space is not valued. (Participant 11, 2023)

Moreover, the identity of the architect is also impacted by the potential changes in their profession as the transition to CE progresses. There is awareness among participants that the role of the architect would extend beyond technical advisors to becoming advocates and collaborators. As described by Participant 5,

> If you want it to be fully circular, then you start from a different point... This design process changes as well, so it is different. You need to understand who it is that you're talking to and how to start the conversations based on what they care about. So it's really understanding what everyone values and cares about and then framing it from that point of view. (Participant 5, 2023)

Architects recognise that their role and the essential qualities required of them may evolve as CE becomes the norm, which may be challenging given their existing sociomaterial realities. Some participants have noted that adopting CE would entail architects acting as advocates and instigators, which some may find hard or uninteresting, "if the client says that's too expensive, how do you convince people? And that's really a lot of convincing work, and that's not something, many architects are used to, of course, it's hard for many" (Participant 10, 2024). Echoing this point, another participant admitted, "It's a really kind of challenging and engaging design exercise, but not a lot of architects are excited by that. And then the other thing is that you know, architects don't initiate these discussions" (Participant 1, 2023).

Others also acknowledge that a CE approach would modify the design process and subsequently the role the architect fills in. As Participant 5 described it, the architect becomes a mediator and collaborator in a CE rather than the central technical consultant who works in a silo:

> Understanding that the design process is a bit different, that it's more front-loaded, that we need to do a lot more analysis at the start and that it's a very collaborative process. It's not about the architect being the star architect who comes up with a design solution; the design solution sort of evolves from the response to the climate. (Participant 5, 2023)

Even more, some participants foresee that the role of the architect would fundamentally change once CE becomes a norm, from the creator of buildings to carers of buildings, "architects' role will evolve into just caring for things and you know, [refurbishing] and adding life into existing things" (Participant 11, 2023). To be an architect and a CE champion at once is considered a challenging task, an endeavour described by a participant as chancing upon a "unicorn" architect with characteristics that are perceived to be difficult to find in architects nowadays:

> Finding that balance between somebody who's tenacious enough to want to go after it, humble enough to know what they're in control of and what they're not, and at the same time open enough to be able to admit that, yes, what we do causes some harm, and your job is to minimise the amount. (Participant 11, 2023)

While this issue on the profession's identity may be systemic and goes beyond CE adoption, it implies that architects are challenged as CE actors when the profession's identity is perceived to be limited and weakened. These challenges that architects face in demonstrating their value and being recognised may adversely influence the role they play in the CE transition. This suggests that for the architectural profession to be at the forefront of the CE transition, their identity as a 'trusted adviser' (Architects Accreditation Council of Australia, 2018) should be strengthened within the profession and outside of it. Conversely, as the CE transition expands the scope of design (Dokter et al., 2021; Kozminska, 2019), this presents an opportunity for the profession to recalibrate its identity and reputation.

Influence of the architectural profession

CE adoption in the architectural profession also involves influencing others with whom they interact but have no formal control over. Based on the interviews, the architect possesses influential power to effect change in the building process, particularly in the supply chain through material specification. Some of the participants perceive the task of specification as a key positive role of the architect in a CE, which should be leveraged to create ripple effects in the supply chain, as described by Participant 7:

> We have the power; the suppliers work for us. If we really push our suppliers, we tell people we will specify this. If you give me a carbon-neutral certification or if you prove to me that your processes are really good, I will use your product and that pushes them to do the research and dive into it. (Participant 7, 2023)

While recognising the individual capacity of the architect to use their power of specification to influence the supply chain, Participant 5 emphasised the need for collective action by architects to effectively influence the supply chain, "There's no point in having three firms working on three projects that they're asking these questions on. You really want all firms on all projects asking these questions in order to drive the supply chain to shift" (Participant 11, 2023).

However, some of the participants were also sceptical of their influence on the supply chain and the power of specification. Talking about adopting sustainability initiatives in general, some participants shared that there is also potential to be disregarded, despite their formal remit to specify. Participants 1 and 4 shared the same sentiment:

> “I have no power in that game. I could maybe possibly ride it some into the contract [or] into the specifications, but equally, I'm probably just likely to be told to get stuffed. (Participant 4, 2023)
>
> “Architects are a function in what you're talking about. You know, we've all got lots of good ideas, but we pretty quickly get slapped down by the development teams that are put together to come up with these ideas. (Participant 1, 2023)

A lack of influential power of architects on building professionals and clients in the building sector is a recurring frustration among participants and has been found in other studies (Easthope et al., 2023a; Moosavi et al., 2023; Warren-Myers et al., 2024). This perceived limited influence is attributed to the limited perception of the industry about their capabilities, the monetary value attached to their work, the remit they often have, or their timely engagement in projects.

In summary, although architects acknowledge their role and its importance, most of them face challenges in their day-to-day reality to effect change. The interviews reveal that, outside CE adoption, the profession already struggles with various issues as discussed earlier, as well as in other domains such as wellbeing (The Wellbeing of Architects, 2022). With CE adoption entailing an evolving role for the architectural profession, attention must be paid to addressing these existing struggles, along with new ones that may come about with the CE transition. The call for a transition based on justice and equity (Fairbrother and Banks, 2024; Horne et al., 2023; Pál, 2022) is reinforced. This is especially important in a professional industry that is highly dispersed, with 34% being sole practitioners (Architects Accreditation Council of Australia, 2018), and wherein wellbeing issues are prevalent and structural support is immensely desirable. The findings from this thematic analysis contribute to the call to examine the “uneven impact on the nature of work, industry practices, and the consequential impacts on the broader economy and society” for a just transition (Horne et al., 2023, p. 4).

3.4.2 Different CE practices

The thematic analysis identified the different CE practices within the architectural profession as the second theme. Under this theme, the interview revealed that 1) there were past practices that aligned with CE better, and 2) there are emerging, although disparate, CE practices and initiatives. The following sections expound on these two emergent high-level categories. The detailed thematic map is illustrated below.

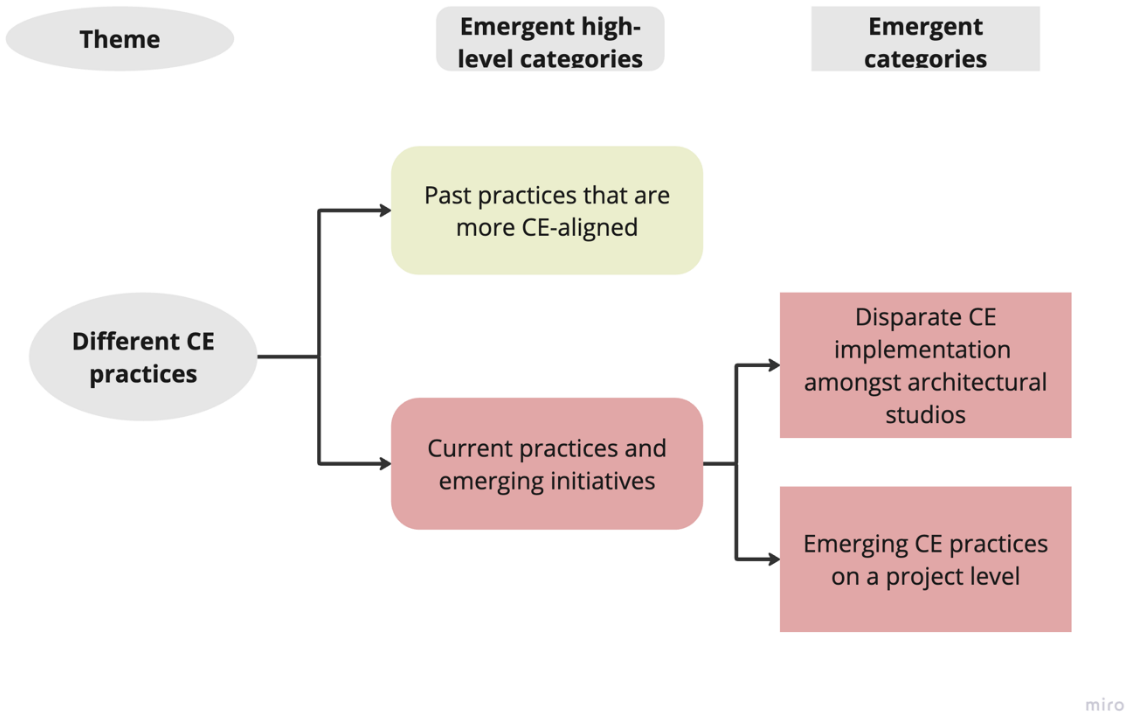

Figure 3-3 Detailed thematic map - Different CE practices

Past practices that are more CE-aligned

An emergent perception from the interviews with long-tenured participants is that previous practices in the building industry had always integrated CE principles such as building deconstruction, reuse and recycling. These CE practices were seen as commonplace in the building process previously. Participant 1, who has professional experience of over 40 years, explained how practices in the past have always been aligned with CE:

> Salvage and reuse, resale of building materials have always been in the building industry...You'd clean all the bricks and stack them up against the back fence, and you'd reuse them, and similarly with the timber in the building. The rafters for the roof

and the joists for the floor, you'd clean those and de-nail them, reuse them so long as the timber was not rotten. So, all of that, all of those sorts of things used to happen in a sort of passive way. It wasn't sort of named and commodified, but people did it as a matter of course. (Participant 1, 2023)

Participants argued that these past practices have embodied the principles of circular building and are reflected in existing century-old buildings that have proved to be durable over time. Participant 4 and Participant 9 evidenced these beliefs through historical examples and existing century-old buildings that have been flexible and durable:

The way it's [building] laid out is really simple, so it can accommodate different uses. It's got good floor-to-floor height, the exterior of the cladding is durable, although it's a timber structure, the external cladding is face brickwork, and that's been more than 100 years old, and it's not going anywhere soon. (Participant 9, 2024)

The government architects in NSW built extraordinary buildings, so from about 1890 to about 1910-15, some of the most sophisticated builds anywhere in the world, and a lot of them don't exist in the city anymore because they've been knocked down and redeveloped. But out in the regions, they're still there, and they still work. (Participant 3, 2023)

However, with the changing of the economic landscape, building practices have favoured new methods of construction that gravitate away from CE principles. Deconstruction and reuse as a default option was replaced by demolish and rebuild as these options became more financially favourable for the industry, as previously discussed in **Section 1.3**. The interviews also revealed that not only did the way architects design and build change, but so did the idea of great architecture – with more emphasis on the physical form and aesthetics rather than the function of the building. Participant 3 perceived that the profession is locked in by the shift towards aesthetic-driven architecture in the late 20th century:

We knew in the 1960s. We knew all of this still, and we were teaching it, and the good architects were building like that... By the time we got to the 90s, it was all about how the building looked. We're still stuck in that, I think. (Participant 3, 2023)

This shared meaning of CE being part of the building practice norms in the past aligns with Stahel's (2020, p. 8) argument that while the linear economy paradigm dominated, the reuse and repair approaches of CE have "remained omnipresent in society, silently and invisibly." It also corroborates Homes et al.'s (2021) statement that there are "hidden places" of CE in everyday life, and the practices of circularity are often invisible but have always and long been a feature in social contexts. It suggests that perhaps broad CE adoption may not necessarily need an overhaul of the entire social economy, as CE practices have been embedded in the past. These practices only remain hidden and invisible because they are not within the purview of the dominant linear economy paradigm and, therefore, not valued properly. The findings indicate that CE practices that modern CE proponents have advocated already exist in some form somewhere, and they are embedded in society, waiting to be reactivated with the proper structures in place.

Current practices and emerging initiatives

Evidence from the interviews indicates emerging CE practices, both done at a studio level and on a project level. On a studio level, approaches to CE adoption seem disparate. On a project level, learnings are starting to emerge regarding the scope of the architectural profession in circular building design.

Disparate CE implementation amongst architectural studios

The interviews showed that CE implementation remains disparate and incremental rather than being approached from a strategic and transformative perspective in the architectural industry. The data revealed that architectural studios' adoption of CE is not yet commonplace, and different approaches exist in incorporating CE principles into their design culture and processes. CE adoption is driven by either top-down or bottom-up initiatives within architectural studios. On one hand, some studios, particularly medium to large practices, have developed and implemented their own internal frameworks (top-down approach) such as Sustainability Action Plans (SAPs), which are advocated by Architects Declare and typically contain CE targets and measures. For instance, Participant 6 from a large studio shared that they have developed a full SAP that projects must comply with and is used as a monitoring and evaluation tool.

> Our SAP outlines all of our targets for carbon, which is just the overall one encompassing all of them, but their energy and water materials are broken down in terms of our projects and we have baseline targets like 50% waste reduction on site by 2025 is a goal and so that then informs every single project has to comply and that's the objective and whether we meet that or not, we're happy to be transparent and say if we couldn't get that across the line but that is at least what we're aspiring to. (Participant 6, 2023)

On the other hand, smaller studios are guided by an informal and unwritten yet deeply ingrained design ethos that is inherently aligned with CE principles. Participant 9 from a small studio explained that while they are signatories to Architects Declare, their lack of resources prevents them from fully developing and implementing their SAP. However, the studio has a longstanding informal rule book containing design philosophies that implicitly integrate CE into everyday design practice, "we've got these little sayings that we use in the office all the time. Things like 'do as much as possible with as little as possible" (Participant 9, 2024).

Some architects are also influenced by their type of practice, such as heritage or community-oriented architecture, and despite not having formal SAPs, their design principles intuitively align with CE principles, such as building conservation and sharing economy – two concepts that align with CE principles such as Optimise and Share as discussed in **Chapter 2**. One of the participants, for instance, distinguished heritage architects from others, suggesting that heritage or conservation architects practice CE by default: "There are architects who like designing and building new buildings, and there are heritage architects who do not like changing anything at all" (Participant 1, 2023). However, a potential drawback of heritage conservation is the trade-off with performance, potentially disagreeing with the Optimise principle of ReSOLVE. The trade-offs between CE principles in this case suggest that CE implementation may become a complex balancing act, requiring a deeper understanding of CE from architects to be able to balance trade-offs and achieve the optimal outcome from a CE perspective. These potential dilemmas of CE adoption in practice require that architectural professionals have a solid conceptual and technical knowledge of CE principles to be able to make informed decisions. Similar insights are echoed by previous studies that architects require more in-depth and extensive knowledge to negotiate between material and stakeholder constraints without compromising good architecture (Kanters, 2020; Kozminska, 2019)

Despite the differences in how architects acquire knowledge and practice CE principles in their design, the findings show that the presence of a circularity-focused design culture or internal framework within a studio potentially influences the design process. Although rather disparate efforts to adopt CE, this finding represents positive strides taken towards the CE transition. Furthermore, the findings of the different approaches to CE adoption by architectural studios point to the opportunity to examine the nuances and effectiveness of these two approaches to determine effective adoption mechanisms that could fundamentally shape the architectural and engender a more normative approach to the transition as put forward by Mies and Gold (2021).

As articulations of CE adoption through customised frameworks continue to emerge in the architectural profession, robust monitoring and measurement mechanisms need to be set in place to ensure accountability and positive outcomes. The SBRS discussed in **Chapter 2** can potentially serve this function in some form, but developing or adopting building-specific CE metrics and industry standards on a project-level may also prove to be instrumental (Nunez Madrigal et al., 2023), which is still lacking for the Australian context (Zaman et al., 2023).

Emerging CE practices on a project level

The thematic analysis identified several CE initiatives taken by the participants to implement CE on a project level. Early engagement with the architect of the client and the project team in these projects emerged as a crucial factor to ensure that CE is, at the very least, considered in the project. Multiple participants strongly expressed this importance, underscoring that engaging in the earlier stages of the building process can maximise the potential to influence CE outcomes in the project. Participant 3 identified that being part of the business case is crucial, while Participant 5 emphasised not only the importance of early engagement but also having alignment as an outcome of that early engagement.

> The broadest reach comes through getting involved during the business case. And if you're not involved in your business case, you can't encourage the big moves to be made as easily. (Participant 3, 2023)
>
> And sometimes that larger team and that client and whoever makes the decision, there are just so many different decision makers that you don't actually get a chance to talk to everybody and bring everybody on board. So, the most important thing is alignment at the start, and if that alignment does not happen, everything can fall apart, really. (Participant 5, 2023)

As a result of these experiences, CE practices have begun to change their internal process to take into account this learning. One of the changes implemented is co-creating a vision with the project team, which means that the early concept stage is becoming more frontloaded, as shared by Participant 5. Participant 2 also shared that they are most successful in implementing CE or any sustainability measures in projects when they engage with the client early on and use this early opportunity to set the trajectory of the project. Similar experience was expressed by Participant 7, who, in their initial engagement meetings, proposed CE initiatives such as salvage and reuse on-site to get the client on board.

> So that's what it's intending to do, and at the beginning of the conversation of the process, it's all about getting the client on board and co-creating a vision of what we want for the project based on the potential of the project. (Participant 5, 2023)
>
> So we encourage our teams to do that from the outset, and that starts the project off on a really solid foundation to embed some of that thinking upfront. Understand how we can advocate to clients, put some, maybe some bold ideas on the table early, because we know that the most success we've had in some of this thinking happens when you can engage your clients early. (Participant 2, 2023)
>
> The initial engagement with the client and you're in that concept design phase, that's where we shared that vision. So, getting the client on board with the idea. Just making sure that we're all on the same page and that they're going to be driving for the same thing as we are. (Participant 7, 2023)

In summary, the thematic analysis found that different CE practices exist in the architectural profession. Some find it in past practices where CE strategies like denailing timber rafters, reusing bricks, and designing for adaptability were simply part of the norm and not commodified. It corroborates previous scholars' conclusions that CE practices have always been embedded in society, although they are often hidden or invisible. This raises a question of whether the CE transition can be framed not just as a business opportunity but also as a revival of past norms. The finding supports the critical approach of Holmes et al. to expand the scope of what is generally regarded as CE interventions and focus on the micro activities of circularity to gain a deeper understanding of the "doing" of circularity (Holmes et al., 2021).

Furthermore, the thematic analysis showed that CE adoption in the architectural profession happens informally through ingrained design philosophies that have preceded the CE movement and formally through codified design frameworks, which were developed in response to growing CE interest. Despite the disparate approaches, the interviews provide evidence of emerging CE practices and initiatives, along with learnings that start to evolve the design practice. Architects are found to have the greatest remit and influence at the initial stage of the project, and this highlights opportunities and implications for project delivery norms and establishes processes. A caveat of early engagement is the risk of failure to follow through with the architectural plans and specifications down the supply chain in the later stages of the project. Kanters (2020) found that successful CE projects were driven by conviction of the client to aim for a circular building. This emphasises that while the architect may play the role of the CE instigator, understanding perspectives of clients and other contractors is also important and warrants further investigation.

3.4.3 Multi-dimensional barriers to CE adoption

The third theme that emerged in the analysis was the multi-dimensional barriers that architects face in adopting CE in their practice and in apartment building renovation. Barriers are defined as factors that hinder or impede the transition towards a CE, creating resistance to change in practice elements and their configurations and reinforcing or stabilising the regimes to overcome challenges from niche spaces. These barriers encompass dimensions of policy, technology, organisation, economy, culture, and strata governance, which identify the many factors that influence how the architectural profession experiences CE adoption within a wider context.

Under this theme, six high-level categories emerged from the interviews: 1) Inadequate government policies, 2) Steep learning curve associated with CE, 3) Organisational constraints, 4) Local economic and market conditions, 5) Cultural resistance to change, and 6) Strata ownership of apartment buildings. The succeeding subsections describe and analyse each of these emergent high-level categories, with the detailed thematic map shown below.

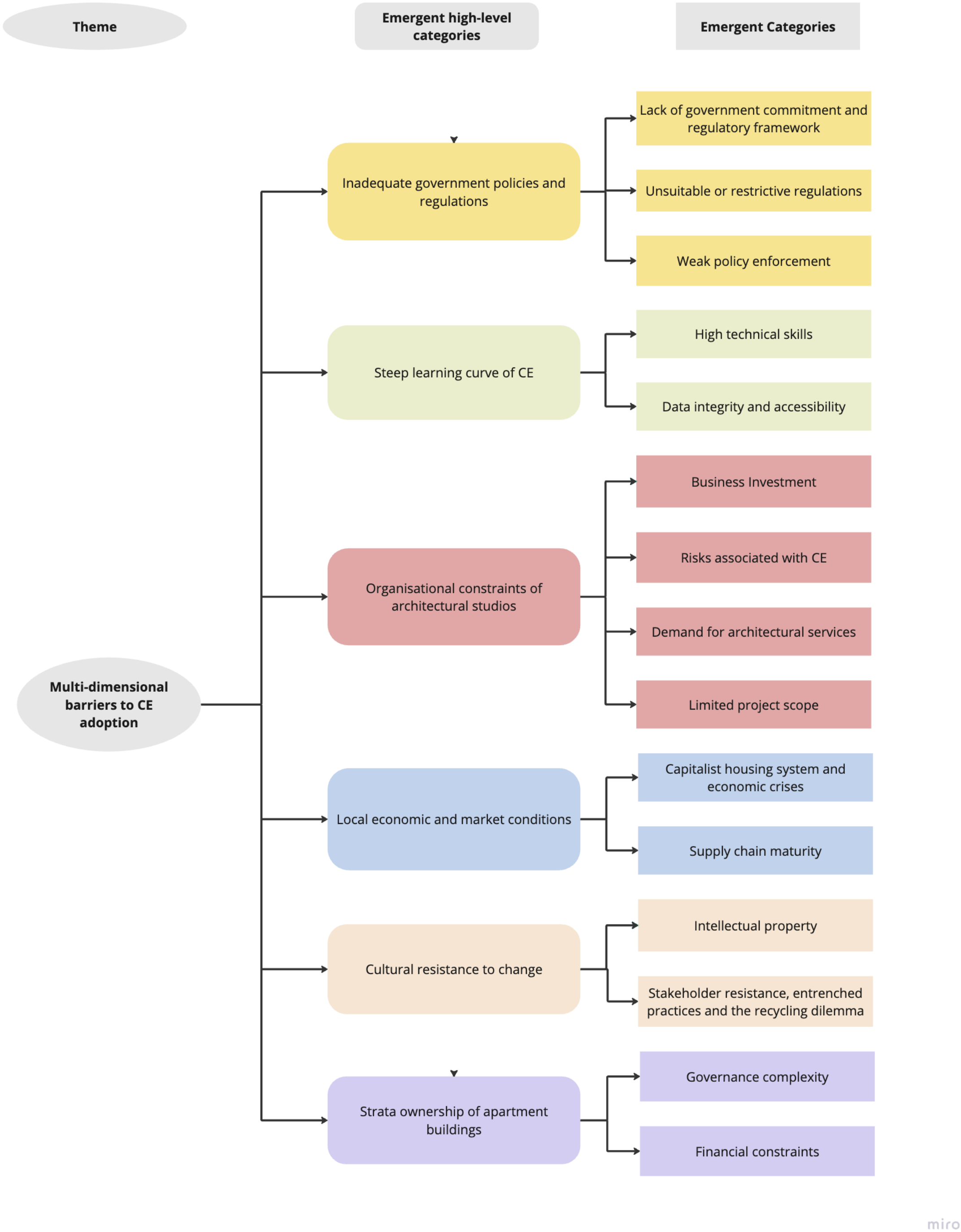

Figure 3-4 Detailed thematic map – Multi-dimensional barriers

Inadequate government policies and regulations

The lack of and unsuitability of current government policies and regulations in Australia emerged as a key barrier. This finding affirms findings from previous research on the Australian built environment, which identified the limited role of the government in supporting climate action amongst architects (Warren-Myers et al., 2024) and a lack of incentives and regulations as primary barriers to CE transition in the AEC industry (Shooshtarian et al., 2023; Zaman et al., 2023). The majority of the participants reasoned that government-led initiatives are critically lacking but necessary to drive CE adoption in the industry. Existing government policies and regulations were viewed by the participants as highly unsupportive of CE adoption. While there are some existing regulatory instruments or policies that may address CE, these were found to be implemented poorly. Furthermore, some existing policies or incentives were deemed to either result in perverse outcomes in relation to CE or implicitly complicate and discourage CE adoption.

Lack of government commitment and regulatory framework

A key barrier identified by multiple participants is the lack of government commitment and a comprehensive regulatory framework that encourages CE activities and outcomes. It is acknowledged that the National Circular Economy was established recently in Australia (DCCEEW, 2024). However, the framework in its current form only serves as a policy statement without detailed sectoral targets for the built environment. The lack of a regulatory framework and specific commitments delays the critical signal to the industry to shift towards CE. Compared to other countries in the Global North and specifically Europe, where a CE-specific strategic framework has been developed and implemented through fiscal, regulatory, financial and policy instruments, Australia's CE initiatives seem inadequate. Without a comprehensive regulatory framework and instruments in place, architects are challenged in convincing clients to adopt CE, hampering industry transition altogether. As Participant 10 voiced out,

> “Unfortunately, we have a political vacuum. There’s no leadership from the governments, and therefore, we have this patchwork of solutions and not all clients are convinced yet, so they can get away with it. (Participant 10, 2024)

Furthermore, this barrier also leads to fragmented regulations and policies in each state, which present geographical implications for architectural studios with a nationwide presence to adopt and implement CE. This finding highlights the need for a unified federal agenda and regulatory framework for CE in Australia. A unified and comprehensive regulatory framework would provide professionals, such as architects, a leverage to drive clients to consider and implement CE. Participant 10, who works in an architectural studio with offices across Australia, discussed in detail the impact of this barrier on their practice:

> The government vacuum creates confusion. Unfortunately, we don't have the regulatory framework really in place, and more importantly, we don't have a unified framework in place. It’s different in every state. It’s totally a challenge for companies like [us], where we have offices in every state, and it's totally different everywhere.” (Participant 10, 2024).

On top of a national CE policy and regulatory framework, participants have also identified the need to upgrade the national building codes and state-level design guidelines to better integrate CE imperatives. This finding is echoed in previous studies of political lock-ins that preclude a circular AEC industry (Hosseini et al., 2024). Integrating CE as part of sustainability requirements in building codes can serve as a regulatory tool – obliging architects, clients and other industry professionals to learn and adopt it.

> Government regulation is something that needs to happen. Obviously construction code should be updated with more sustainability requirements so that architects can invest in learning that because their clients are obliged to do it. (Participant 6, 2023)

Existing building codes and development controls were perceived to not prioritise environmental or circularity performance. Speaking about window design compliance of renovating apartment buildings, Participant metaphorically compared the lack of focus on environmental consideration in building codes and controls to the failure to consider intergenerational environmental justice in building design:

> Ironically, [there's] much more consideration given to the restriction over the window than there is to the environmental performance of them. Because I have to comply with that, I have to make sure kiddies don't plunge to a painful death. But I don't have to do anything about the kiddies' environmental future. (Participant 4, 2023)

Furthermore, the findings also show that existing frameworks lack a particular focus on building renovation, which is a CE strategy in itself. Referring to the recently ratified Design and Building Practitioner's Act (DBPA) in NSW, the same participant whose primary focus is apartment building remediation and renovation, perceived that the DBPA is not suited to the context of existing building renewal:

> It was never meant [for] remediation and upgrade of existing buildings. It was meant for, you know, catastrophes, for one of those top place buildings in [redacted], it's meant to get those guys out of the business, it was never meant for the remediation [of existing buildings]. And so it's a constant battle to then try and understand how the act relates to remediation… but I think the remediation or upgrade side has been sort of left [behind] to a great extent. To have some clarity, having a sort of Design and Building Practitioners Act Part 2 [remediation and upgrade] would be a huge help, I think." (Participant 6, 2023)

The findings reinforce **Chapter 2**'s conclusions and other previous research that existing building frameworks and legislations are not suited to or contextually appropriate for building renovation nor CE. This points to the opportunity for architectural renovation of apartment buildings to be promoted as part of a comprehensive CE policy package for the built environment and for future examination of existing policies that govern the renovation of apartment buildings from a CE perspective.

Unsuitable or restrictive regulations on CE practices

In addition to the lack of a comprehensive regulatory framework, several participants have also noted that some existing policies and regulations conflict with CE imperatives.

For instance, participants expressed those existing incentives favour building new rather than renovating existing buildings. As Participant 5 observed:

> At the moment, there are incentives to build new. So, you get a lot of tax rebates if you're building new, that does not exist if you're refurbishing. So, a lot of things are wrong with planning and legislation that need to change. (Participant 5, 2023)

The potential perverse outcomes of well-intended policies are echoed by other participants, who delved into how the existing policies prevent building upgrades, particularly of ageing apartment buildings, due to perverse financial incentives set out in current housing policies, such as in NSW. Participant 1, whose practice substantially involves apartment building renovations, pointed out thoroughly how existing policies were unsupportive, or even penalising, of CE adoption, which may have long-term repercussions on the quality of housing supply and overall urban fabric. This highlights the opportunity to integrate CE policies and outcomes with those of housing to ensure an environmentally sustainable approach to the housing crisis.

Furthermore, the interviews revealed that current regulations prohibit or challenge the renovation of ageing apartment buildings. In particular, for the state of NSW, the retention and reuse of buildings and components were deemed to be discouraged in the state's apartment design guidelines. As Participant 1 explained in depth, referring to apartment buildings such as the six-pack walk-ups covered in **Chapter 1**,

> The [NSW Housing SEPP 2021] has actually really stopped any of the redevelopment of those types of buildings because more often than not, they're considered to be affordable rental housing. And if you do anything to improve them, you have to pay a massive levy for the loss of that affordable housing unit. So, these well-intended state legislations seem to actually restrict or constrain that type of development. The building owner will be financially penalised for making their building better, so we'll end up having the slums of the mid to late 20th century in no time, because no one can afford to do anything to a building. (Participant 1, 2023)

Existing legislations were also deemed to preclude building material reuse, which is a primary CE strategy under the Loop principle that aims to prolong material lifespan and recapture the value of building materials. Building material reuse involves utilising building materials on- or off-site for the same use without undergoing chemical changes. While there seems to be a desire amongst architects to reuse building materials either from materials salvaged on-site or from somewhere else, many have noted that existing building regulations prevent them from doing so due to material integrity issues. As the industry is already highly regulated, participants found it difficult to specify reused materials in building projects due to compliance requirements and associated risks and liabilities. This aligns with the findings of Hosseini et al. that existing regulatory standards fail to adequately cover the specification for circular materials (e.g. recycled) (Hosseini et al., 2024; Shooshtarian et al., 2023). One participant expounded on this predicament, explaining that while reuse in theory may be easy to implement, it is challenging to do so due to legal concerns. Similar findings were found in a case study of CE implementation in sustainable housing developments in Australia, where material reuse was constrained by structural integrity concerns (Dalton et al., 2023).

> The idea [reuse] that it's somehow simple to implement, like salvage materials, it's not easy to do that at all, and there are a number of reasons for that. It's because there are compliance requirements on us [architects], and we have tried and tested products, [but] we can't say where [salvaged materials] come from. Then you can't satisfy the building surveyor requirements, and we can't satisfy the technical side of architecture... I think that that's there are a lot of realities about that that are often overlooked in terms of legal issues. (Participant 6, 2023)

Weak enforcement of policies that may support CE

Evidence from the interviews indicates that there are existing regulatory instruments and mechanisms already in place that can serve as a lever for circular building practices. One of which is the Site Waste Minimisation and Management Plan (SWMMP), which is a document required when lodging a Development Application. The SWMMP is a document often prepared by the project architect as lead consultants and is typically submitted to the relevant local government Council to obtain a development approval and construction permit. The SWMMP, while it differs across councils, primarily requires architects to address waste during demolition, construction and operation/occupation of the site. A sample SWMMP template, usually available for download online, is shown below in **Figure 3-5**. A typical SWMMP template would require the architects to categorise building materials according to composition or material type, and quantify the volume for on-site and off-site reuse, recycling and disposal during demolition and construction. Some SWMMPs will ask to identify the third-party contractor responsible for the recycling or disposal. Such a document is similar to typical resource recovery plans advocated by CE proponents.

Volume of Waste Table for Demolition to be completed with Construction Certificate Refer 3.1 for objectives regarding demolition waste.

Address of development:____

most favourable ← least favourable

	Reuse	**Recycling**	**Disposal**	
Type of waste generated	Estimate Volume (m3) or Weight (t)	Estimate Volume (m3) or Weight (t)	Estimate Volume (m3) or Weight (t)	Specify method of on site reuse, contractor and recycling outlet and /or waste depot to be used
Excavation material				
Timber (specify)				
Concrete				
Bricks/pavers				
Tiles				
Metal (specify)				
Glass				
Furniture				
Fixtures and fittings				
Floor coverings				
Packaging (used pallets, pallet wrap)				
Garden organics				
Containers (cans, plastic, glass)				
Paper/cardboard				
Residual waste				
Hazardous/special waste e.g. asbestos (specify)				
Other (specify)				

30 Mosman Municipal Council

Figure 3-5 Example of Site Waste Minimisation and Management Plan template (Mosman Municipal Council, 2012)

However, the interview revealed that the enforcement of such plans is often not taken seriously, as there is no monitoring and verification mechanism implemented by the council. As a result, these plans, while well-intended, are often treated as a ‘box-to-tick’ exercise that does not receive proper attention and, in some cases, is given to the most inexperienced architect in the studio. Although part of the DA process, due to the lack of verification and enforcement in place, architects are often not held liable for any discrepancies between the plan and what transpires on site. When asked about

SWMMPs, Participant 1 discussed in-depth the issues with the SWMMP and its lack of enforcement, critically referring to it as “fiction”.

> [It’s] an absolute joke that you have to produce the report, the waste management reports, but the problem with it is entirely in the implementation. I’ve got a project at the moment, $6 million worth, where I have to produce a waste management plan for that, and it has to be signed off by the Certifier and everything, but after that, the builder has no obligation to follow that at all. So, I'm thinking, well, why do I treat this seriously? I know I've been doing this for long enough that there's no follow-through on that, and it becomes just purely a box to be ticked. There’s no mechanism by which the end of that is verified. (Participant 4, 2023)

Another participant, who has worked on apartment building renovation projects, shared a similar experience about the lack of seriousness attached to preparing and implementing SWMMP: “I kind of don't want to say it, but they're bogus often” (Participant 9, 2024). This finding suggests that policy enforcement is crucial, as this sends the signal to industry players of the gravity of the policy intention and builds trust in the government and its processes. As Participant 1 added, “All this stuff is only as good as the process that oversees it. It kind of doesn't matter what the intentions are, if it's not overseen, it's not carried through, then it's only as strong as that” (Participant 1, 2023).

In its current form, SWMPP can be a source of information about CE practices across local councils but poses risks of inaccuracy. While data accuracy is an issue, this also presents an opportunity to leverage existing regulatory instruments, such as the SWMMP, that are already implemented in existing processes and could efficiently influence existing building practices towards CE. Regulatory instruments, such as the SWMMP, assign the local governments an active role in the CE transition through strong enforcement of the SWMMP. Furthermore, this draws attention to the possibility for local councils to update or develop CE plans with a circularity lens rather than from a waste minimisation perspective. The shift to CE perspective in the development and planning process of local governments is evident in other jurisdictions, such as in London, UK, where Circular Economy statements have been required for certain proposals submitted to the Greater London Authority (Greater London Authority, 2022). There is also an opportunity for such plans to be digital and promote the Virtualise principle, assisting with a city-scale resource inventory that bridges materials data gaps to quantify material stocks and flow in residential buildings (Dalton et al., 2023). It can also facilitate urban mining potential and digitalisation of the built environment (Çetin et al., 2022). Lastly, while strong enforcement of instruments such as SWMMP is crucial, the capacity-building and development of third-party contractors, such as builders, demolition contractors, and recycling and reuse facilities, in parallel, are also necessary.

The interviews highlight the influence of macro-level forces such as government regulation on the role of the architect in the CE transition. This finding underscores the importance of political will and the implementation of a unified CE policy package and regulatory framework on all levels of government to provide supportive mechanisms for the architectural profession to be agents of CE. More importantly, it revealed the need to review and rectify existing policies and regulations that may be incompatible with CE imperatives. Lastly, stronger enforcement of policies and implementation mechanisms is necessary to build trust between government and industry and to effectively send a stern signal to shift towards CE. Participant 1 eloquently articulated the common perception of the participants with regard to the inadequate CE policies and regulations, "the circular economy is great, just so long as there's a legislative framework that encourages it. And at the moment, and for a long time, it hasn't. Well, it discourages it. More so, it actually penalises it (Participant 1, 2023).

Steep learning curve associated with CE

The steep learning curve associated with learning and adopting circular building practices emerged as a barrier for the participants. While awareness and general knowledge of CE are growing and evident in the interviews as discussed in the previous chapter, building technical competence to deliver on circular outcomes amongst architects is still needed. This finding is consistent with prior studies that identified a lack of knowledge as a primary barrier to CE adoption in the AEC in Australia (Collins et al., 2023; Shooshtarian et al., 2023; Zaman et al., 2023) but also across the globe (Cruz Rios et al., 2021; Kanters, 2020; Munaro et al., 2020; Stoiljković et al., 2023).

High technical skills

The interviews revealed that among participants who have embarked on the task of implementing formal CE initiatives, challenges were ubiquitous. The steep learning curve is particularly evident in undertaking embodied carbon calculation, as evidenced by the accounts of several participants. The participants acknowledge the need to gain the technical skills required to design for circularity but have expressed the difficulties of doing so. Two pain points emerged for participants who have undergone embodied carbon accounting exercises in their projects: 1) initiating the process and 2) the lack of a trusted source of truth and the inconsistencies in data sources, calculations and results. As recounted by Participant 3, who has completed an embodied energy calculation for a project about a decade and a half ago: “It was really difficult to measure the embodied energy. We knew the right thing to do, but it was very hard to measure” (Participant 3, 2023).

A similar experience remains, as evidenced by the accounts of Participants 9 and 11, who have done embodied carbon calculations less than 5 years ago. Both participants also had to invest substantial resources and recruit a specialist to jumpstart and facilitate the process. As Participant 9 recounted, the process was challenging to commence and required expert input and financial investment from the firm, such as subscription payments to datasets, to be able to train and undertake embodied carbon accounting themselves:

> It was massively challenging. We had no idea how to do it. We had to get a guy who was fantastic on CAD, and he set up like a grasshopper model, so we can measure all the volumes of the different materials. But then, where do we get the figures from? We've now got the subscription to the Green Book, so that's where we're getting the values. But for us, we didn't know where to start. But now we've got basic knowledge, and we can kind of measure what we're doing, but it was hard. (Participant 9, 2024)

Participant 11 added that their experience had been different to their expectations and assumed that embodied carbon calculation would be a straightforward endeavour.

However, their first attempt had been a journey with unexpected outcomes, redirections and more questions:

> We wanted to be able to do it [embodied carbon accounting] on all of our projects, and we therefore thought we were still thinking that an embodied carbon number is an embodied carbon number. And there is one source of truth, and that would be nice and easy. We went away and we had three different data sets… and in looking at all three, the first thing we noticed [is] that they told us three different stories, and then we had to try and figure out why. They told us three different stories, and that whole process was a real learning process for us as to, well, what is this whole black box of embodied carbon? (Participant 11, 2023)

In his reflection, Participant 11 added and metaphorically compared embodied carbon, and the circular economy as a whole, to a "black box", which entails constant unpacking, learning and re-learning through research and experience:

> As soon as you start delving into [circular economy] and you start talking about the difference between recycled and recyclable, and you start talking about where a product is coming from and the material specifications within a product. Your process slows an awful lot because again, the research component of it is quite high. (Participant 11, 2023)

Building on Participant 11's comment on investigating where materials are sourced from, the need to comprehend and interrogate Environmental Product Declaration (EPD) and material life cycle analysis was a recurring participant comment in terms of areas where architects and designers should upskill themselves, as identified by Participants 6 and 8.

> I think the interrogation of suppliers is really important, or even reading their EPD documentation and understanding that, getting the knowledge of how to read those, like section D of life cycle analysis. (Participant 8, 2023)
>
> The technical knowledge of designers could be significantly improved in terms of their understanding of how to read environmental product disclosures. (Participant 6, 2023)

Data integrity and accessibility

Apart from the high degree of technical competence required from architects, a layer of complexity to the already steep learning curve is added due to potential lack of data integrity in existing CE methods or instruments, such as embodied carbon calculations or EPDs were also prevalent. For embodied carbon accounting, Participant 5 explained, and as supported by accounts of Participant 9 and 11, that the process is burdened by 1) access to and proficiency of powerful computing tools of architects, which hinders their daily use in architectural practice, and 2) trusted data sources and standard methodologies, which are still missing, particularly in Australia. Several methodologies are also used for measuring embodied carbon in Australia, which can result in inconsistencies (Tigani et al., 2024). The challenges in data integrity and accuracy, and consistent accounting methodologies entail concerted efforts from the government and industry for standardised methodologies to support CE metrics and benchmarking, which are yet to emerge.

> Still in the embodied carbon field, there are many tools, but there's still a lot of confusion and non-alignment about what to measure. Each tool gives you different results, and so, it's still a very confusing field, and in Australia, we didn't really have a proper materials database that we could trust. (Participant 5, 2023)

In addition to understanding how EPDs can be used, probing product supplier information is also a key activity an architect engages in. For instance, utilising EPDs as part of the material selection and specification process of architects, access to accurate data on building materials and products could be challenged by potential greenwashing, as initially discussed in **Section 3.4.1.**

Furthermore, the findings indicate that technical knowledge as a barrier may be experienced by architects differently, potentially influenced by their background and environment. Participant 6, who had experience in spearheading sustainability education programs in their architectural studio, explained that an architect who has a background in sustainability may not find it difficult to learn the technical aspect of CE; otherwise, acquiring such technical skills may be a key challenge. This finding suggests that general sustainability knowledge should be part of university education and continuing professional development of architects to assist with the CE transition in the architectural practice, and is discussed in more detail in **Section 3.4.4.** However, some participants, such as Participant 4, strongly expressed that willingness to learn is the primary barrier rather than the actual acquisition of technical skills and knowledge about CE.

> This is very complex. You can't learn regenerative design in like 10 one-hour modules, you know, it's something that you do need to implement, and it's like a lifelong process, really. But what I have found is that the barriers are not technical. The main barrier is our willingness, so if the team has the willingness to learn, they will learn. (Participant 5, 2023)

It is important to note that this comment is from a participant from a large architectural studio with appropriate machinery to upskill their designers, suggesting that organisational support is essential to overcome the steep learning curve associated with CE experienced by architects. Themes relating to organisation support and implications are discussed next.

Organisational constraints

Organisational constraints emerged as a barrier to CE adoption in the interviews. These constraints include the high business investment for R&D activities and restructuring or recruitment of CE experts, risks associated with untested and unverified circular products and practices, limited scope and responsibilities of professionals involved, and a lack of consumer demand for architectural services in apartment building renovation.

Business investment

For architectural studios, learning about and implementing CE in practice is a steep learning curve, as discussed above, and requires significant R&D activities. R&D entails extensive resources and business investment. The interview findings suggested that business investment is evident in medium to large companies but is fairly difficult for smaller practices. Business investment was directed to upskilling programs or additional dedicated roles for CE or a combination of both. As discussed in Section 3.4.2 regarding current CE implementation initiatives, some studios, mostly medium to large, have employed dedicated teams for CE research and implementation alone. It is a different story for smaller studios. For instance, Participant 9, who is from a micro-small studio, their studio was able to innovate and conduct embodied carbon studies through design competition funding. Otherwise, innovation happens incrementally on a project-by-project basis if at all.

> If you were a small practice, it would be very difficult [to innovate]. For smaller projects, often they're [clients] looking to us for guidance anyway. I guess on larger projects, you might have a bit more momentum to do more. (Participant 9, 2024)

The business investment required to adopt CE internally is a critical factor for successful CE transition in the built environment. This is because about a third of architectural studios in Australia are operated by sole traders, and 98% are micro and small practices that employ less than 20 employees (Architects Accreditation Council of Australia, 2018). Therefore, there are thousands of studios that are at risk of continuing business as usual because they do not have the capacity or resources (internally or externally funded) to innovate, learn and implement novel CE approaches. Moreover, if and once new CE regulations have been implemented and start to put pressure on these practices to transition, such studios could find themselves in a predicament to follow, which can preclude broad-scale transition. Broadscale CE adoption will require transformational change of these architectural studios in the way they operate due to the fundamentally different ways of working in a CE. This implies massive business transformations and associated costs and investments across different studio sizes, which professional bodies and governments should address to avoid "losers" in the transition (Markard et al., 2020). As Participant 11 expounded, "I think there's definitely a piece there as to how you would make a generic architecture practice more sustainable and give them the time and the capacity to be able to do it, which means money" (Participant 11, 2023).

In addition, SBRS that require some circularity objectives pose unexpected or overhead fees to the architectural studio. Two participants who had experience in getting SBRS certification shared that being part of a project with certification ambitions often results in overhead fees due to the required learning and development activities in order to comply and successfully achieve the certification. Participant 11, who has recently undertaken a Living Building Project, delved into how the architectural fees were significantly higher than business as usual, but were ultimately still underestimated compared to the actual cost incurred by the process:

> Our fee is way higher than it would otherwise normally be, and even then I think we underestimated the quantum of research necessary in order to achieve what we're trying to achieve and that's just to do with having to go the full journey around things like red listing materials and really searching that down, engaging as an architect, engaging with the supply chain in that is oftentimes the first time somebody had a conversation about that with you. So, it is very much breaking new ground. (Participant 11, 2023)

This experience was also recounted by Participant 5, who recounted that, in general, sustainable building rating systems or certifications, which may include some CE indicators, often resulted in overhead costs for the studio. This indicates that while certifications may drive CE-related learning activities for architectural studios, this positive outcome could be limited to studios that are able to absorb the cost of such activities and remain elusive for smaller studios with relatively limited resources.

> It's like an added cost to architects, of course, it's not necessarily part of all the scope of services to do all of these things. We are doing a lot of studies just for free. You know, it's overhead, but that's another thing that needs to change. (Participant 5, 2023)

The findings highlight that CE adoption entails business investment from architectural studios, but there is variation in the capacity to invest based on the studio's resources. This disparity was also evident in a previous study by Warren-Myers et al. (2024), wherein structural issues across the built environment affect architectural studios' capacity to advocate or implement more sustainable design practices. This implies that CE adoption may be more challenging for smaller studios, which form the majority of architectural studios in Australia. A concerted effort from industry and government is required to assist the architectural profession in CE adoption. Furthermore, while high upfront cost was found by Shooshtarian et al. (2023) to rank 8th only amongst other barriers to CE adoption in the Australian AEC, this finding may not extend particularly to the architectural industry and may prove to be more prevalent. Future research may investigate the weight of this barrier to ascertain its real implications and appropriate response.

Risks associated with CE

Another barrier to adoption that emerged through the interviews was the perceived and actual risks associated with some CE actions, corroborating prior evidence found in the Australian context (Dalton et al., 2023; Easthope et al., 2023a; Hosseini et al., 2024). Perceived risks are typically attributed to clients or contractors who avoid risk due to uncommonness, lack of knowledge, experience and verifiable information about CE practices, while actual risks may include business liabilities related to some CE practices. The aversion to perceived risk is particularly prominent in residential projects with stakeholders who tend to be more conservative. In addition, the risk avoidance is perpetuated as there are no existing rewards for residential clients to take a risk on new approaches, such as CE, and initiate or allow innovation in their projects. The risk aversion by clients in residential projects has been observed by multiple participants, such as Participants 8 and 9:

> We are constantly on the lookout for new innovative materials that are great sustainability-wise and circularity-wise, and sometimes we have to take a risk on them because we don't know. Are they going to play out, or if they're going to be suitable for the use? Especially in multi-res, no one likes to take risks. (Participant 8, 2023)
>
> They [clients] don't want to do something that they haven't done before because it's risky. [There is] conservatism and relying on what you've done before from the client side. There's not enough incentive for them to take risks. (Participant 9, 2024)

The interviews revealed that the risk aversion is not only limited amongst clients or architects, but also among other contractors, such as builders, due to liability issues. Participant 8 added that architects or designers may take the risk to innovate or use innovative materials in their design, but are hindered by other contractors in the project, adding evidence to previous findings that innovation is hampered by price penalties placed by contractors due to risk aversion (Dalton et al., 2023).

> We're going into little unknown territory and not trying to just do the status quo of just doing what everyone else is using. Because it's a bit different and it's not commonly done, they don't want to do it... in this climate, there's no builder that wants to take a risk. It's too expensive already. (Participant 8, 2023)

Pushback from other contractors was also shared by other participants, like Participant 12, who shared that compliance remains a big barrier, particularly regarding material integrity and safety.

> For instance, low carbon concretes, a lot of engineers won't sign off on the pressure and the kind of tensile strength of them. [It's] the same move across the board with a lot of different types of materials. Compliance issues with materials are a massive barrier. (Participant 12, 2024)

Some risks may be material, especially for the project consultants who are legally liable for the project. The legal challenges of using circular materials, such as salvaged or reused building materials, without testing or warranty, are often cited as the reason behind risk avoidance and non-adoption of CE in projects. In specifying circular products without being tested, Participant 6 explained that,

> They're going to have to assume responsibility for it. And I would [as the architect] as well. Everyone is then liable. I think that that's there's a lot of realities about that that are often overlooked in terms of legal issues, especially, for example, planning fires, etc. (Participant 6, 2023)

This finding suggests that to reduce the perceived and actual risks as a barrier to the transition to CE, ramping up capabilities for product testing and certification of circular materials, including secondary materials, needs to be prioritised to increase the likelihood of circular material usage and their demonstration of efficacy and safety.

Demand for architectural services

Another organisational barrier to CE adoption in architectural renovation of apartment buildings is the lack of demand for architectural services in this area. While architects may be willing to explore circular renovation of apartment buildings, a barrier to the realisation of such is the low engagement of architects in apartment building renovation projects. If architects do get engaged, the project scope is limited to be able to implement any CE strategy, as detailed by Participant 1:

> I think there's not a lot of demand for architectural services [in apartment building renovation]. Architects don't tend to get involved unless it's a very heavy renovation... The work that you get asked to do in relation to residential flat buildings might be assisting them with a fire order, or they might have a leaking roof, or the driveway might be too steep or something. So, the work the architects get in relation to renovation for flat buildings doesn't often get close to the type of work that you're imagining on that [CE]. (Participant 1, 2023)

Participant 1 added that getting asked by clients to propose ideas beyond what is required at minimum is very rare, "Sometimes somebody corporate might come to you and say, 'oh, you know, we'd like to do something with our building, everybody's on board. Can you put some ideas together?' And that's really good. But that might be one in every 500 buildings" (Participant 1, 2023). This account is supported by Participant 11, who explained that architectural service is not saturated in this sector due to the type of work involved in such projects.

> The reason there aren't very many architects working in that space is that there isn't much of a space. An awful lot of that is about maintenance more than anything else, and decent maintenance of buildings where people live in them is a hard thing. So I think there aren't a lot of Architects because there isn't a lot of volume of propositions out there. (Participant 11, 2023)

This observation was also mentioned by Participant 4, who has specialised in apartment building renovation but still perceives that renovation projects are handled by other players without architect engagement, "The problem is that there are so many more players out [there] and so much of the work, there's no architect involvement anyway" (Participant 4, 2023). The non-involvement of the architect in such projects excludes architectural professionals from the opportunity to provide more strategic advice and to adopt CE. This underscores that while apartment building renovations may occur, there is a possibility of them not engaging an architect and risk failing to address the renovation project more holistically. A circular approach to renovation will entail architect involvement to some degree and thus presents a compelling business opportunity for the architectural industry. Further work is needed to demonstrate the value of architectural renovation in the apartment building sector to drive up the demand for such services.

Limited project scope

The limited decision power and influence of architects in building projects is another organisational barrier that emerged from the interviews. The project contract dictates the scope of the architect. The interviews revealed that some project contracts may not safeguard the outputs of the architect, which include design decisions in general but also encompass any CE initiatives set out by the project architect at the early stages of the project. This issue was also raised by Easthope et al. (2023a), focusing on the shift to D&C contracts in apartment development and its implications for the preservation of design and sustainability features. In D&C contracts, as described in the Introductory Chapter, once the architect is novated to the contractor, design documentation can be altered by the contractor, who is legally responsible for design completion. In 2023, The Australian Institute of Architects surveyed architectural studios across Australia to query 4484 novated design and construct projects from 2009 to 2019 undertaken by member architect practices and found a large proportion of practices perceived that novation negatively impacted quality outcomes particularly on finish and durability, materials selection and sourcing, on aesthetics and design, "the findings also show there are a concerning range of perceived challenges impacting building outcomes and matters that should be of concern for all governments delivering building reform and for end-consumers such as apartments' owners" (Australian Institute of Architects, 2023, p. 3). The survey revealed a major preference for design documentation to be complete (91 to 100%) to be the optimum point of novation. In particular, the survey revealed that practices were only sometimes (42%) or never (32%) included in strategic decision-making processes after novation. For instance, SWMMPs are required during the Development Application (DA) stage of the project and are prepared by the engaged consultant (e.g. architect) prior to any demolition or construction work commencing. However, the SWMMP is only implemented by the demolition or builder contractor after a DA approval has been obtained from the assessing authority. This lag leads to discrepancies between the content of the SWMMP and its actual implementation. Participant 4 explained that in producing SWMMP, “I have no control over it because this has to be produced generally before you’ve engaged a builder”, who then implements the SWMMP.

This finding underscores the fundamental role of professional contracts and the statutory planning process to ensure CE outcomes are achieved as intended. The lack of enforcement and verification mechanisms implies that changes to the Development Approval process overseen by local and state governments need to be reconsidered to strengthen the accurate implementation of CE-related instruments such as the SWMMP. Furthermore, rethinking standard project scopes and professional contracts warrants further investigation to encourage accountability amongst engaged parties and to influence industry practices that facilitate CE adoption. For instance, some CE actions are currently outside the architect’s scope in the current building practices. This suggests that a transition to CE entails changes to industry practices, including project stages and the recommended timeline of engagement of professional consultants and contractors. As Participant 11 recounted,

> One of the things that we've been looking at is demolition waste and trying to reuse demolition, which has been the roadblock. That is not really within the architect’s purview because we are not engaged for demolition by doing a drawing that says, ‘pull that bit down’. What and how isn't really yet part of that scope with all things circular economy. (Participant 11, 2023)

Even while still engaged in the project, architects may still have a limited scope that prevents them from implementing CE actions. Referring to a detailed resource management plan they prepared for a building project as part of their architectural studio's effort to implement CE, Participant 7 described in detail their experience that those plans were not being implemented due to their project remit and multiple actors involved in the process:

> The resources [management plan] that's all sent to the client and the builder, and they have that on site, weren't used. For example, we retained a lot of existing joinery, and so that was like scheduled as a joinery item and then detailed around how to work with what needs to be done. It's mostly detailed in the schedule and then in the documentation. [There were] lots of annotation that all goes to the builder, and then they coordinate with the joiner, and then there's a series of on-site meetings, walking around, saying this is staying, this happens to that, don't touch that, which they still did. [They] removed things that weren't meant to get removed. (Participant 7, 2023)

The findings indicate reconsidering existing contracts and processes to identify the optimal project setup and contract types to be able to plan and deliver circular outcomes in the project. Participant 12 corroborated other participant accounts, noting that CE-driven architects and designers run the risk of downstream contractors failing to follow through. However, they also alluded to collaboration as a potential workaround to this scope barrier without the statutory planning mechanism or professional contract modifications in place. This highlights that other project team members must have the same level of commitment to CE to fully realise the CE plans and visions for the project, emphasising that their perspective must also be investigated to broaden understanding.

> I think finding the willing partners is definitely one and finding the right contractors. But on the design side, it's us actually being in control of that process and having our demolition notes or resource recovery notes absolutely followed to the letter of the law. What happens is we write all, we try to be as diligent as possible, but the contractors just don't follow through. So you need to be on every step of the way, and that's not only us as the project manager, that's the client, partners, all the stakeholders, really, who are a part of those key decision moments. (Participant 12, 2024)

While collaborative approaches may resolve the limited project scope of architects, strong contractual or regulatory mechanisms are needed to ensure that CE plans are implemented as intended. The development and enforcement of such mechanisms will allow for an industry-wide shift, enabling CE innovations to succeed without relying on the agency of the architect. The presence of such mechanisms would also ensure that architects are both empowered as well as held accountable for developing enforceable CE plans when CE is instigated by clients or other consultants.

In addition to ensuring follow-through of CE plans during construction, several participants also highlighted the potential issues of carrying through the intended use of the building and building materials through to operation and the supposed end of life of the building. Participants have the perception that a potential issue with a CE approach, even when well-intended and planned, is information dissemination to building owners and users throughout the building's lifespan. As Participant 6 shared,

> I think the intention is often at the start of the project or during design, but there are a lot of issues in terms of users' ongoing ownership of different buildings, or different people who are managing maintenance, all coming in later and then doing their own projects or fit-outs of different buildings. I feel like there are a lot of barriers in terms of the clients, and then the legacy of the building and changing hands, and, for example, maintenance manuals or design manuals not actually being carried through until the end of life. (Participant 6, 2023)

This finding emphasises the Share principle of CE and highlights the importance of documentation not only during the design and construction stages of the project but also during the operation and maintenance of the building. Ensuring that CE plans are recorded and disseminated to building owners and users for future renovation or deconstruction of the building would be essential to further extend the lifecycle of the building and its materials. Although still an uncommon practice, some accounts demonstrate that architectural studios are beginning to innovate and adopt CE strategies in their projects:

> We can design for disassembly, but of course, we can't decide what happens at the end of the building’s life. So, I'm thinking if you would provide a menu for the building owner, for the client, if you want to disassemble or deconstruct your building, this is how you should do it. (Participant 10, 2024)

Changing the standards of Australian architectural practices to include end-of-life as a project phase was also raised by some participants. Participant 12, who has had international experience in countries where CE transition is more advanced, identified the role of professional peak bodies in leading the promotion of the end-of-life phase at the beginning of each project. This finding points to the opportunity of expanding the project scope of architectural services to include designing for the end-of-life of the building and its materials, whether for disassembly or deconstruction, aligning with the Loop principle of CE. This change entails updating professional capabilities to include this new set of skills required from the architect in a CE (Sumter et al., 2020).

> It's not only the demolition at the first stage of the project, it's also the end of life and the final demolition of [the] building or fit out. We also need to build that in as a project phase on the design side. The RIBA in the UK has been working on that as actually adopting end-of-life as a true project phase. I hope that that is something the AIA will bring into Australia soon. (Participant 12, 2024)

Local economic and market conditions

The wider economic landscape and market conditions emerged as a barrier to CE adoption. In particular, the housing system and cost of living crisis and supply chain issues were found to hamper CE adoption in apartment building renovation and across the residential sector. Evidence from the interviews shows that economic crises preclude CE considerations in projects, while supply chain issues hinder the adoption of CE principles such as Share, Loop, Exchange, and Regenerate.

Capitalist housing system and economic crises

The interviews revealed that the hegemony of the linear economy is perpetuated in the housing system. This is reflected in how housing is produced and how architects are engaged to produce it, which impedes the CE transition. As Participant 1 voiced out, "The economic model and the legislative boundaries of the model conspire against the production of good housing and a circular economy" (Participant 1, 2023). For example, evidence from the interviews suggests that participants perceived competitive fees, which are inherent in a capitalist economic system, were found to stymie housing and architectural innovations in some form. This then precludes the delivery of innovative housing production systems, such as a CE approach to renovation.

> A big part of doing it is the way that we're engaged. If you're engaged on a competitive fee, and you're competing against somebody who's just going to rinse and repeat, then the fee level is really quite low. There's not a lot of headroom to be able to innovate and go and do new research and go and do new thinking in that fee. (Participant 11, 2023)

Some participants hold that the current economic model that underpins the housing system requires fundamental changes to be able to embed CE thinking, such as ensuring the longevity of residential buildings:

> Housing isn't a commodity. It's a human right. And the housing that you've built has to be a certain standard. You have to think 50 to hundred years into the future, and if you're not doing that, then we're failing the society we're trying to house. Whilst we want to produce more housing, we need to shift the paradigm of how we deliver it and why we're delivering it. (Participant 3, 2023)

Furthermore, the housing affordability and cost of living crises came to the foreground at the time of the interviews, which were reported to have financially implicated residential building projects. When considering CE or general sustainability initiatives in building projects, cost is usually the primary factor for residential clients. "In terms of like clients being happy to do it, I think it usually comes down to money" (Participant 1, 2023). Based on the interviews, the housing affordability crisis and cost of living crises are two reinforcing factors that disincentivise CE adoption in apartment building renovation. On one hand, the cost-of-living crisis drives up the cost of building materials, constraining building projects financially. On the other hand, the housing affordability crisis gives landlord investors an unfair advantage as the high demand for housing increases the value even of substandard housing stock, further disincentivising the renovation of these apartment buildings. As Participant 3 noted, “There are so many competing agendas out there. So, if you've had a building that's full of investors or landlords, they're making ridiculous amounts of rent, even if they do nothing…Mortgage repayments have gone through the roof, and the last thing they think about [is] spending money trying to make their building more sustainable” (Participant 3, 2023).

The housing system in its current state – exacerbated by the housing affordability and cost of living crises – does not promote building renovation, more so a CE approach to it. This finding implies that the financial structures must also shift towards CE, along with the technology and cultural norms that comprise and shape the housing system, corroborating previous research and recommendations (Horne et al., 2023).

Supply chain maturity

Currently, the Australian building material supply chain is considered lagging in terms of availability and capability of producing circular building products and services, which impedes the adoption of Share (reuse), Loop (refurbished or recycled), and Regenerate (low carbon and non-toxic materials). Following the definition of Dalton et al. (2023, p. 15), “supply chains are systems in which businesses are located, and facilitate the production, procurement and delivery of products and services.” As Participant 12 elucidated, “[In] Australia, we have major supply chain issues. So we do really need to shore up our own local manufacturing supply chain and really invest in that, and certainly with these circular economy strategies built into that” *(Participant 12, 2024)*. Similar findings were found in prior research by Moosavi et al. (2023).

Supply chain issues, such as the low level of maturity of circular building products and services in the local market, were identified to constrain CE adoption and prevent architects from using circular and secondary materials such as salvaged, recycled, recyclable, and low-carbon materials – a key action of the Loop and Exchange principles. This barrier manifests in the unavailability of materials, lack of price competitiveness of circular products, lack of material testing and treatment to address quality and compliance issues, extensive and time-consuming research and due diligence of suppliers and products, and lack of reverse logistics (e.g. take-back schemes), among others.

> I think until we have a more mature or sophisticated supply chain, I do think time is an issue, because you need time to actually do the work in investigating the kind of right suppliers that can meet some of the expectations and specifications that you set out. (Participant 2, 2023)

Several participants have noted that the underdeveloped supply chain exhibited through the unavailability of desired products locally is a key issue architects face that directly impacts their role in a CE. While resorting to international supply is possible, this issue leads to further predicaments for the architect with a CE mindset, as the emissions from transportation could cancel out the low embodied carbon of the recycled material. As evidenced by Participant 11, "[For example], aluminium curtain wall is all recycled content which you can get to a degree in Europe, but you're having to travel further in order to get something that's greener, which kind of double-edged sword" (Participant 11, 2023). Apart from embodied carbon impacts, the availability of materials hinders architect intentions to use local materials, which is a key CE strategy, and presents financial challenges to the project, "We tried to only use materials that were sourced locally to that site. The material could be cheaper, but you have to bring it from [South Australia] or overseas" (Participant 9, 2024).

The quality of circular and secondary materials is also a factor due to compliance and design requirements. Salvaged materials often require treatment or testing unless the material composition can be safely assumed such as bricks. This means that while salvaged materials may be readily available, their use is subject to compliance requirements and associated costs. As Participant 6 reasoned, "it's really hard to reuse products that you've claimed from site unless you're leaving it in that exact same location or you're not going to touch it at all. You must bring things up into compliance quite often" (Participant 6, 2023). Participant 10 echoes this sentiment and discussed the compliance issue from a financial perspective: "It's very difficult to reuse certain things because they don't meet certain requirements today or they have to be tested. It's just too much money then" (Participant 10, 2024).

Building on the financial issue and supply availability of circular and secondary materials, the lack of platform and standardisation particularly of secondary materials also presents design and project management challenges for the architect. Participant 10 further delved into the issue of 1) sourcing and 2) the varying characteristics of secondary materials, which has implications in the design outcome, process and timeline:

> That's the biggest gap, I suppose, in the circular economy: when you need it, where do you find it? The [project] is almost entirely, except for the concrete slab, made out of recovered materials, mainly timber from bridges and things like that, but it took the builder more than a year to source all these different kinds of beams and columns and so forth out of timber. And then, it was quite an elaborate process, because they are all different sizes, so nothing is standardised, so it is more costly. But on the other hand, for some of the elements, it's the fourth life that they have, and some of the pieces are more than 150 years old, so it's a huge achievement, but it costs more money, and it's difficult, and I think that's one of the biggest hurdles for architects. I would love to reuse something, but either the quality is too low or it's not available. (Participant 10, 2024)

The availability of material testing services and infrastructure in Australia also limits building material reuse in projects. Participant 11 recounted the potential to use salvaged materials in one of their projects but ultimately disregarded the option not due to financial costs but due to the complex logistics of material testing and its impact on total embodied carbon. This implies that while circular materials manufacturing would advance the supply chain, services that support the processing and testing of circular materials should also mature to facilitate CE adoption and encourage higher-order strategies of the Loop principle (refurbish) and Share principle (reuse).

> We looked to build it in a series of different structures, and we did a study on embodied carbon. One of the structures was brick arches with steel, recycled steel and recycled brick. That was the lowest carbon of all of the options. But the reason we didn't go ahead with it was not cost. In that instance, it would have obviously been a lot more expensive, but also, the steel, in order to be used in the structural context, needs to be rated. It therefore needs to be tested, and there's about half a dozen tests that need to be done and not one location can do all those tests. So, we would literally have been shipping steel around the country to get it tested, which kind of defeats the purpose. So, I think there's a lot of maturity still to happen in that space. (Participant 11, 2023)

Furthermore, the interviews showed that the low level of maturity of the supply chain manifests in a lack of knowledge in sustainable building product assessment tools that assist in promoting other CE principles such as Regenerate. Regenerate principle calls for ensuring that environmentally toxic building materials are replaced with non-harmful products in the supply chain. However, the interviews suggest that by leveraging their power of material specification and directly engaging with suppliers, architects have a role in shifting the supply chain.

> There are the materials that you need to be able to build a regenerative building. They [suppliers] said that we have not been demanding that, and it also takes time to develop those things. So, the more we can say that this is important to us and to our design process, the better... We have not achieved 100% circularity yet because of time constraints, budget constraints, and supply chain constraints. But each time we do a new iteration, it becomes better. (Participant 5, 2023)

As evidenced by participant accounts, the interaction between architects and suppliers presents the opportunity for co-education and can be facilitated by the use of SBRS internal frameworks such as LBC’s Red List, as covered in **Chapter 2**. However, the limited scope of the architect may be insufficient to drive changes in the supply chain and underscores the importance of having all stakeholders involved. This aligns with previous research recommending breaking the supply chain lock-in that is presented as a cycle of limited supply and low demand (Hosseini et al., 2024).

> “Being able to get them [suppliers] to commit to searching through for response to parts per million of formaldehyde or anything else is a big ask, unless they have that data to hand, and often we found that as an architect asking those questions where I don't have a check book, I'm not ordering the material, we tend to get brushed off a little bit. (Participant 11, 2023)

In addition, supply-side strategies such as reverse logistics (e.g. take-back programs) were identified to be lacking. This is in line with the findings in **Chapter 2** wherein *Implementing reverse logistics (O3)* were found to be the least integrated CE action in existing SBRS in Australia. Reverse logistics would increase the likelihood of materials being used at their highest value and avoid the risk of downcycling, while simultaneously instigating a cultural shift from the demand side (e.g. contractors) (Mishra et al., 2023). Therefore, this highlights the need to advance reverse logistics to further develop the local supply chain and better support the industry transition to CE.

> Having take-back programmes and communicating that knowledge to the demolition contractor or the builders on site, whoever is kind of undertaking that work to keep that material aside and go, I know I can return that to that supplier and I instead of paying to send that to landfill, I can get better value money back from that. (Participant 8, 2023)

A concerted effort is required to advance the local supply chain towards CE. Architects play a role in driving this shift by engaging with suppliers, interrogating, and demanding CE products through material specification. This can subsequently increase the maturity level of the supply chain to address the demand for circular and secondary building materials. In parallel, direct investments into CE manufacturing and reverse logistics will be needed as well as the supporting services and processes such as testing and treatment of circular and secondary materials to overcome compliance issues of circular and secondary materials.

Cultural resistance to change

The interviews revealed that the adoption of CE in apartment building renovation is also hampered by cultural norms in the building industry. While participants recognise the technical requirements of a shift to CE, they also underscore the importance of culture to the successful adoption of CE across the built environment. Issues surrounding intellectual property rights, stakeholder resistance and deeply entrenched practices across the industry were found to impede the adoption of several CE principles, such as Share, Virtualise (Digitalisation) and Loop.

Intellectual property

The interviews suggest that the notion of intellectual property rights over architectural drawings and data appears to discourage CE adoption by inhibiting the practice of the Share and Virtualise principle. The Share principle, a key imperative of CE, extends to non-material assets and endorses knowledge sharing and open-source information. By adhering to the Share principle, the adoption of new digital technologies such as digital twins and material or building passports that require information sharing can be facilitated, which also embodies the Virtualise principle of CE in the process. However, the interviews revealed that the industry culture currently does not lean towards open-sourcing information.

> "Still, the way that it works here at the moment is there's perceived intellectual property value within the model, which means that sharing it isn't real because people won't share their models. The whole point is that we've got this almost open source, where we can collaborate... Everyone's got their own one that they did themselves. Until we get over that, it's not gonna help. (Participant 3, 2023)

The exclusivity of information is not only apparent in architectural outputs but also in CE-related data, such as carbon intensity information of building materials or construction demolition waste figures. Participant experience highlights accessibility issues concerning waste data from buildings, as well as CE data of building materials that Australia currently lacks (Horne et al., 2023), which must be addressed to enable widespread adoption.

> Information generally tends to be privatised, like I have to subscribe to get that [data]. And I'd apply the same kind of thinking to carbon intensity information. And, I guess, if you're a small architect and you're trying to ask yourself, 'Well, what window system is the most environmentally sustainable, or should it be timber?' I know Greenpeace, even they've done some really good modelling, but why? Why doesn't the Australian government have a reference? (Participant 9, 2024)

The industry culture is reflective of the existing economic model underpinned by competitive advantage, which is deeply established in the dwelling-construction industry (Dalton et al., 2023). However, CE proposes collaborative advantage, which inherently entails the practice of the Share principle. This implies that to successfully shift to CE, a cultural shift must also occur to deviate from existing norms that align with the linear and capitalistic economic model, adding evidence to the influence of culture on CE adoption presented in previous research (Zaman et al., 2023).

Stakeholder resistance, entrenched practices and the recycling dilemma

While architects play a role in initiating CE, collaboration – or at the very least cooperation – of other stakeholders is essential to be able to implement CE initiatives in projects. However, the interviews showed that there is resistance among stakeholders such as clients, builders, and other contractors to adopting new practices and processes based on CE. Entrenched practices such as 'knockdown (demolish) and rebuild' have shaped a wasteful industry culture that is difficult to challenge, based on accounts of several participants. The resistance contributes to an apparent tension between architects and other stakeholders, such as builders and engineers, particularly regarding implementing prepared plans and designs that support circular outcomes. As Participant 12 shared, follow-through of contractors is not guaranteed in practice: "What happens is we write all this [resource recovery information]. We try to be as diligent as possible, but the contractors just don't follow through" (Participant 12, 2024).

In particular, the participants identified stakeholder resistance to CE-driven resource recovery practices such as deconstruction and reuse of building materials, which is core to the Share and Loop principles. Stakeholder resistance to this new form of on-site resource management highlights the cultural aspect of transitioning towards more CE-aligned behaviours. Circular on-site resource management, such as but not limited to building material audit, is radically different to the existing cultural norms, entailing a radically different everyday practice for involved stakeholders or workers. However, this management strategy represents a crucial aspect of a CE approach to renovation as it can enable further CE initiatives in the later stages of the project, embodying several CE principles (i.e. Loop, Optimise, Share, Virtualise). Participants 7 discussed in detail their experience with stakeholder resistance to architect or designer-led CE approaches to resource management in building projects.

> If we're going to retrofit, the biggest push back and the hardest part I had to execute certain important milestones in the project was the builder's lack of awareness, care and consideration. Like in one of our retrofit projects, I went through the site and did an inventory of all the materials and all the waste and provided a schedule of how to deal with it - all the resource management. And they didn't do anything. There are definitely some builders we work with that are incredible, and they do beyond anything that we could specify for resource management. But the general feeling with the builders is that it's too hard and it's too much extra effort. It's like the whole resource management system of, like, recycling or disposal is just really difficult. (Participant 7, 2023)

Furthermore, it is perceived that a lack of education and consideration regarding material value persists in the industry. When asked why building material reuse is not part of the norm, Participant 1 elaborated that reusing building materials has become time-consuming and labour-intensive relative to purchasing brand-new materials, with recycling becoming more prevalent as the more convenient CE option.

> Builders would rather buy a truckload of newly rated and treated material, which is engineered, such as engineered timber, as opposed to 150-year-old Australian hardwood. Engineers would rather specify something that you can buy off the shelf at a hardware shop. Brick [is] cumbersome to move around and restack. And it's much [easier to] get a truck to deliver bricks by the pallet load when you want to use them. Sometimes you know, sometimes it just gets too hard and too boring to tell people to

> reuse stuff, so it's easier to just let the recyclers take it. There is a growing recycling industry, though. There are people who will take timber, and obviously bricks and sand, all of those sorts of things. So long as that's happening, I'm kind of reasonably satisfied that we've met our responsibility. (Participant 1, 2023)

While there are highly durable and reusable materials commonly used in apartment building construction, such as brick and steel, the treatment to bring the material to compliant standards remains costly. The costs associated with reuse and the growing recycling industry are corroborated by other participants, such as Participant 10, who shared that "The only material that is frequently reused, I would say, is brick. And as you know, [there are] lots of problems with that, you have to clean the bricks and that makes it very [hard] and expensive" (Participant 10, 2024). As a result, the default response is to simply recycle building materials to divert from landfills. Participant accounts suggest that landfill diversion through recycling is becoming more common. The growing recycling industry is reflected in the national resource recovery rate for building and demolition materials, which is predominantly recycled, rising from 62% in 2006-2007 to 84% in 2022-2023 (DCCEEW, 2025).

Recycling as a Loop action, however, is regarded as having the lowest circularity potential due to risks of downcycling and lowering the chemical and monetary value of materials, based on the 10-R framework (Potting et al., 2017) as discussed in the Introduction. Furthermore, recycling also presents the opportunity for greenwashing, with improved landfill diversion rates becoming easier to achieve without proper consideration of the building material value. This means that some building materials are being recycled even though they could still be restored to their original or higher quality and reused for the same purpose. Participants acknowledge this recycling dilemma and the associated risk of failing to keep materials at their highest value while in circulation.

> I think recycling construction waste is really positive. We have projects frequently now where you have to divert 90% or more from landfills. But it's usually being downcycled and not actually recycled or reused. That's the problem. So we have to get it up to the next level, I think, to actually have the reuse rather than the recycling kind of effort. (Participant 10, 2024)

> Construction waste on most building sites, even ones not focused on the circular economy, a very, very small percentage of it now goes to landfill. Recent project we've just finished, 96% of all construction waste avoided landfill. So, there's quite a lot that happens, but most of that is downcycling rather than recycling or upcycling. So, your circle is getting kind of larger and less valuable. (Participant 11, 2023)

The growing recycling industry implies that regulations establishing differentiated targets for reuse and recycling are needed and that innovations in technology and services that encourage building material reuse, such as on-site material treatment and testing, should be financially supported to become more economically viable, thereby promoting the Loop principle through higher-order circularity practices such as reuse. Moreover, stakeholder resistance highlights the need to build a culture of material literacy and accountability amongst built environment professionals in implementing CE-related plans. For instance, cultivating a "materials narrative," as suggested by Participant 12, will put CE at the core of building projects and their practices.

However, a more radical position emerged in the interviews, suggesting that radical changes may be needed to disentangle entrenched practices, which ultimately forego the structures of the capitalistic linear economy and commodifying building materials. The concept of material custodianship emerged in the interviews, which underlines a fundamentally opposing proposition of CE to the linear paradigm and reframes materials from being a commodity to a resource. It requires not only the architects but also all stakeholders to look beyond the economic value of materials for resource recovery and emphasises the duty of care to nature and its products for their inherent value. Custodianship, along with collaborative advantage, shifts the focus from material consumption to collective responsibility, entailing a profound cultural shift. This supports recent scholarly works on introducing a Social and Solidarity Economy lens, an alternative model that focuses on social well-being and social cooperation, to CE framing (Pál, 2022). As Participant 12 described,

> It's not about a commodity of material exchange. It's about custodianship. It's about alliances and leases and signing on to behave responsibly. And I just think it is

> absolutely going to be the way of the future when systemically we move towards the value-based economy and away from the capital structure that we have. (Participant 12, 2024)

Strata ownership of apartment buildings

The interviews indicate that the strata ownership of apartment buildings presents as a barrier to CE adoption. The governance complexity and financial constraints associated with strata properties were found to complicate the process of building renovation, leaving less room for innovative approaches such as CE.

Governance complexity

Strata ownership of apartment buildings was perceived as a barrier by participants due to the complexity it adds to renovation projects, due to multiple stakeholder involvement and complicated decision-making processes. Under strata laws, a special resolution (at least 75% approval) is required to undertake major renovations to the common property of the apartment building. From the perspective of the architect, this implies that strata-owned apartment building renovations entail a multitude of perspectives and potentially competing agendas, which may further complicate the renovation process and limit the potential for CE considerations. This added challenge can be considered material, as one of the most prominent challenges that emerged during the interviews was achieving consensus in defining the renovation project scope. As Participant 4 elaborated,

> It's really difficult, and it's probably been the single most difficult thing about the whole [apartment building renovation] sector in that you can have a group of very sensible people who understand that things might really need to be done, but you can then have a [few] people who will quite easily sabotage the whole thing. (Participant 4, 2023)

In a strata-owned apartment building, additional factors, such as tenure, demographic characteristics of owners and location, come into play to achieve an agreement. For instance, tenure becomes a determining factor when a strata scheme with a higher share of investor owners relative to resident owners, as the project may face more difficulties in getting special approval for renovation works. This is because investor owners are likely to have less vested interest in the maintenance and upgrade of the building. Participant 1 elaborated on the challenge of dealing with multiple ownership and varying tenure through a strata scheme:

> The structure of the tenure is difficult… It's difficult to get agreement from the majority of the strata owners. A number of the owners don't actually live in the building, so they don't have a vested interest in [the] building… There's also a certain number of owners who may be elderly or of different economic circumstances than others. The other thing is that while it's been done, they have to be rehoused, and that's difficult. Unless you've got somebody who owns all of the building or a large majority of the building, it's a long and slow process. (Participant 1, 2023)

The interviews revealed that participant experience in renovating strata-owned properties has been an arduous process. Meeting the expectations of the client is fundamental to the success of a project from the architect's point of view. This endeavour becomes more challenging when multiple stakeholders are involved. Multiple ownership is perceived to implicate a CE approach to renovation as it further complicates the already tedious task of renovating strata-owned apartment buildings. Conversely, a different outlook suggests that multiple ownership may increase the chances of finding a CE champion amongst multiple owners. However, this perception was not evident amongst the participants.

CE adoption in the apartment building sector is also seen as a niche in comparison to other building typologies, such as commercial office buildings or single residential projects.

> It is very much breaking new ground. Yeah, it's not common at all in the volume residential market. I would say that circular thinking in terms of existing built stock is much more common in office buildings, in academic buildings, and even in healthcare settings than it is in residential settings. (Participant 11, 2024)

There is a perception that CE adoption is easier in other building typologies due to ownership structure. For instance, engaging with a single owner or client facilitates the process of co-visioning the project, which is a crucial aspect in CE adoption. This is perceived to be difficult to attain in a strata scheme with multiple owners, as the co-visioning and collective decision-making are burdened by many and often competing agendas, serving as a barrier to considering CE.

> That's much easier on a single residential project where you know where someone's coming from within the first couple of meetings, you can gauge that. But if I'm talking to a big strata committee, then it comes to those competing agendas. So, I'm having trouble getting the thing to fly as a whole. (Participant 4, 2023)

Furthermore, there is no external driver, such as industry reputation or government procurement policies, to adopt CE for strata-owned buildings in comparison to commercial or government-owned properties. This missing aspect suggests that architects have less leverage to push for CE. For instance, one of the potential problem areas for CE adoption that emerged in the interviews is client perception surrounding the use of secondary or circular materials. A participant noted that reusing salvaged building materials in residential typologies might be easier, as there are fewer compliance requirements than in other typologies. However, there are consumer expectations of utilising brand-new materials, particularly in the context of apartment building renovation. Residential clients are more likely to have the predisposition that the renovation entails replacing old, existing parts with new building materials. Consequently, the convincing act to use secondary or circular materials as a CE strategy by the architect becomes more challenging with multiple stakeholders and without an external impetus. Participant 4, who has worked in multiple apartment residential projects, posited that there could be resistance to reusing materials in renovation projects.

> The idea that you're remediating and upgrading a building implies sort of fresh and new, [which] might mean that there might be a little bit more resistance to it [reuse or recycled materials], even if the mechanisms were there to actually do it. (Participant 4, 2023)

Participant 10 also referred to this potential barrier but proposed that it may be more likely due to reuse not being a norm in the residential market rather than an actual resistance to it. This implies that the CE opportunities remain underutilised in the residential sector and points to further research.

> In a residential context, when people buy an apartment, there's still a common expectation that everything's brand spanking new, not that stuff's upcycled or recycled or reused, which is probably just because it hasn't been done all that frequently, and, therefore, that's the market norm, rather than I think there being any great resistance to it. (Participant 10, 2024)

Financial constraints

Apartment building renovation projects are often resource-constrained, and sustainability initiatives, including CE measures, were found to be deprioritised first to cut project costs. Sustainability, including CE, is still perceived as a "nice-to-have." This contrasts with the existing regime of a reactionary and minimum compliance approach in renovation projects, wherein the scope of work only addresses the primary issues that triggered the renovation. Several participants covered in detail the low share of apartment building renovation projects that went beyond the required works due to financial constraints.

> It's hard enough to get anything over the line, so the first casualty is the nice stuff. Probably the number of times we've been able to convert the project to go beyond the past booze to actually do any of the Nice to dos or the real value uplift has been fairly small, quite often because of cost, and so the projects will stall. It's very pragmatic, you know, stop my roof from leaking. Stop my windows from leaking, comply with the fire order. The conversion rate to look further into the nice stuff is very low, unfortunately, because construction is so expensive. (Participant 3, 2023)
>
> The capacity for a group of people to agree to spend more money than they absolutely have to is difficult. (Participant 3, 2023)

Furthermore, the interviews suggest that architect engagement in apartment building renovation is low because of the low volume and smaller scope of work for architectural services due to financial constraints often faced by strata-owned apartment buildings.

> For existing buildings it's, it's really got to be some form of strata change government. Government change in terms of how that proposition works to allow buildings to upgrade. The reason there aren't very many architects working in that space is that there isn’t a lot of volume of propositions out there. (Participant 11, 2024)

The findings highlight the need for establishing financial mechanisms to allow the renovation of apartment buildings to occur, with incentives that specifically prioritise CE. By incentivising CE, financing mechanisms for apartment building renovation could offer a more extensive proposition for architects to be involved in the renovation, as projects would require a more strategic and pre-emptive approach rather than undertaking only the minimum requirements for renovation works.

3.4.4 Enabling Elements to CE adoption

Enablers as a theme refer to factors that allow, facilitate, or accelerate the adoption of CE either through instigating change in elements of practice and their configurations or empowering of niches and landscape pressures to overcome regimes, thereby unlocking or enhancing transition pathways. The thematic analysis resulted in four emergent high-level categories that characterise enablers: 1) collaborating towards a shared CE vision, 2) Building capacity, 3) leveraging existing instruments and resources, and 4) demonstrating value and compliance. Each emergent high-level category consists of several categories, as shown in **Figure 3-6** and discussed in detail below.

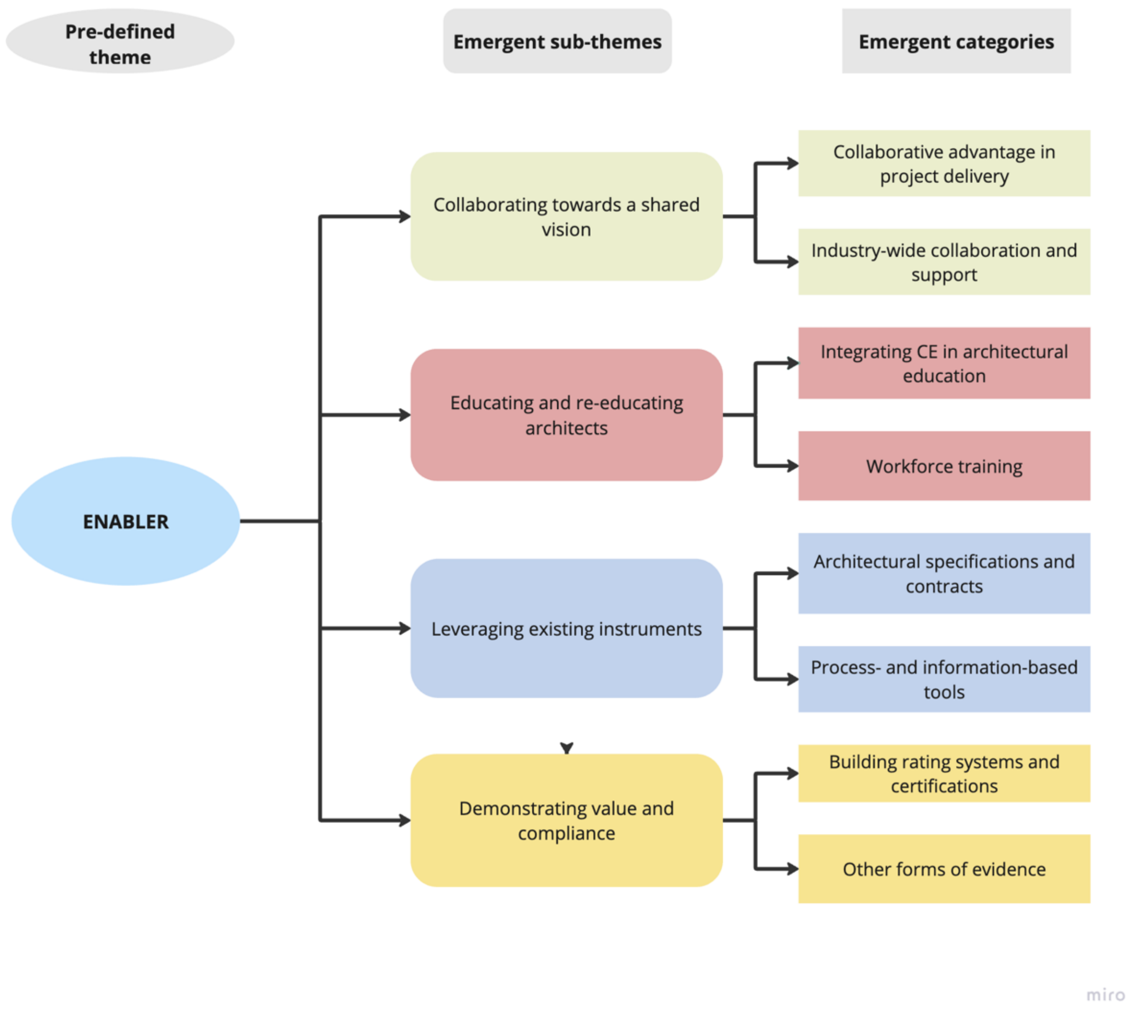

Figure 3-6 Detailed thematic map - Enabling elements to CE adoption

Collaborating towards a shared vision

Collaborating towards a shared vision and understanding of CE is one of the *enabler* sub-themes identified in the interviews. Collaboration largely embodies the Share principle of CE through knowledge sharing and open-source information. This sub-theme is further split into two categories: collaboration in project delivery and collaboration across the industry. In project delivery, early engagement of architects and alignment across the project team is found to maximise opportunities for CE outcomes. Across the industry, collaboration between professionals, studios and industry bodies (as intermediary agents) fosters the creation of a shared CE vision and understanding, thus facilitating learning, agency, and network-building to adopt CE on a broader scale.

Collaborative advantage in project delivery

Early and sustained collaboration throughout the project emerged as an instrumental factor that support CE adoption in building projects. The interview findings highlight that CE actions are difficult to achieve in a silo. On the contrary, collaborative ways of working enable the process of CE visioning and implementation. Based on the accounts of most participants who have had project experience with CE targets, a more collaborative approach than business as usual enabled the project to develop and implement CE strategies. Several participants also emphasised that CE delivery is a responsibility carried not by the architect alone, but hinges on collaboration between architects, clients, and project contractors. The findings suggest that collaboration contributes to a more level playing field by increasing inclusivity and reducing perceived tension between project team members, as there is no single primary professional accountable for delivering CE outcomes.

> It's never down to one kind of professional in the design chain or process... it really does take the whole team being aligned to achieve great results. The architects got a really important role, but if the architect was working in a silo and the client and the engineers, then you just never get there. (Participant 2, 2023)

In a CE-driven project, collaboration is heightened especially at the initial stages – when agreement is achieved between clients and the project team regarding CE targets and strategies. As Participant 5 emphasised, "having everybody on the table and aligning everybody on the same goals, it's really half the [job done]." Other participants not only stressed early engagement but also sustained collaboration throughout the project to ensure that CE plans were implemented as intended. A collaborative approach taken by the project architects strengthens relationships with other professionals, as evidenced by strategies implemented by some of the participants:

> You just hope that it's a collaborative process. We tend to try and get connected with the builder early to meet with them and walk through the site and discuss it to make sure that [information is] shared... It's just about getting a good relationship with the

> builder and trying to get an understanding of give and take, trying to get them on your side. (Participant 7, 2023)

The findings also give insight into how architectural professionals and studios adapt as the industry transitions to a CE. Participant accounts suggest that CE drives architects to be more socially oriented in their role and undertake changes to their typical project delivery process, thereby creating new ways of working and shaping new networks, corroborating findings from Kanters (2020) that leadership skills are essential for architects in a CE. For instance, Participant 5 shared how their design process is becoming more engagement-focused in the initial stage to ensure that all relevant stakeholders are included in the process, whereas Participants 7 and 8 noted that they engage with the builder and rely on their practical experience to advance their knowledge of sustainable materials specification.

> One of the first things that we do is a stakeholder mapping exercise. So, it's understanding who all the stakeholders are who need to be involved in the process. You know, 'who are the decision makers and also is anybody missing from the table?'... You need to understand who it is that you're talking to and how to start the conversations based on what they care about. If you're talking to a finance person, it might be that they're interested in saving money. So it's all about how you can show that this approach will save money in the long term. If the facilities manager, maybe [they'll] be more interested in how the maintenance of this will work. So it's really understanding what everyone values and cares about and then framing it from that point of view. (Participant 5, 2023)

The collaborative efforts taken by participants provide evidence to the argument that collaborative advantage – the benefit achieved from working together rather than working independently - is a key element in a CE. A shift to CE brings forth a new kind of advantage that creates value from collaboration, strengthening the Share principle of CE. Collaborative advantage juxtaposes the linear economy shaped by competitive advantage, which, conversely, puts more value on individual interest. However, as evidenced by participant accounts, actors in CE-driven projects start shifting behaviours and altering practices and relationships to achieve collaborative advantage, as this enables CE implementation.

Industry-wide collaboration and support

Industry-wide collaboration, especially amongst architectural studios, was identified as an enabling factor by several participants. This form of collaboration highlights the collective role of architectural studios in building capacity, demonstrating the Share principle through open-source information and knowledge sharing. Some participants identified that sharing project experience and lessons with the industry helps establish possibilities and instigate industry movement. This enabling factor was also highlighted by architects and designers in European architectural design firms (Dokter et al, 2021). As Participant 5 recounted during a showcase of Living Building Challenge projects, knowledge sharing, especially about innovative approaches, such as CE, drives the willingness of professionals to learn and apply novel approaches. This is supported by Participant 2's comment on the value of sharing to instigate and inspire.

> They showed that it's not [impossible] and it's all about having the willingness to achieve it. And I can see now in the application of projects, even small wins are very contagious. (Participant 5, 2023)
>
> It's how you can share the wins to inspire others [and] see that it's possible. (Participant 2, 2023)

Apart from driving motivation, industry collaboration also expands industry know-how and evidence base for the profession, embodying the Share principle through peer-to-peer sharing of knowledge. Sharing lessons, whether from success stories or challenging projects, was deemed important in the iterative nature of design, as discussed in depth by some participants. Participant 2 emphasised both internal and external collaboration for knowledge sharing, while Participant 11 expounded on the positive impact of industry collaboration in collectively overcoming the steep learning curve associated with CE.

> Whilst maybe the outcome might not be as completely to the vision, we have pushed the boundaries and started to advocate and educate other designers and other builders so they can learn from that and then improve and do better the next time... It's important to share knowledge and solutions both internally and externally. I think big practices like ours have a responsibility to lead by example and showcase our work, and share both the successes and failures. (Participant 2, 2023)
>
> [Architectural studio redacted] on their own can't do it. [We] on our own can't do it. Nobody on their own can do it, only through collaboration. Doing great architecture is more than just the buildings that you do. It's also the output [and] the influence of your practice... No individual architect, through their work alone, can have that much of an influence. But through the influence of their work [and] method, increasingly, [we are] able to circumvent people learning how to do things so that we can all do it quicker. [Then], you can have a much bigger impact, and I think that's really a much more circular economy kind of logic. (Participant 11, 2024)

Furthermore, the analysis indicates that industry leadership and support for CE innovations and initiatives are underutilised enablers for CE adoption. Although industry leadership exist in some form, fragmentation of initiatives remains an issue. Pioneering CE-specific professional guidance or standards with legal grounds or enforceable status is missing in the industry. The findings bring attention to the role of industry peak bodies such as the Australian Institute of Architects (AIA) in leading the CE transition. Some participants compared and identified that the Australian context is missing the strong industry leadership in CE adoption in comparison to the efforts demonstrated by peak bodies in other geographical jurisdictions, such as the Royal Institute of British Architects (RIBA) in the UK.

> The [Australian] Institute of Architects talks about the stages of work. It stops once the building is delivered, whereas if you look at the RIBA stages, that work, it's a circle. [Stage] zero is the business plan, and Stage 7 means the life cycle analysis until it gets either refitted or knocked down. Even though it's unlikely that, as the architect, you're going to be around for [those stages], it means that the next architect would get the job, pick it up at Stage 7, and understand all of that. (Participant 3, 2023)

> The RIBA in London, UK, has been working on actually adopting end of life as a true project phase. I hope that that is something the AIA will bring into Australia soon. (Participant 12, 2024)

Many existing industry initiatives (e.g. Architects Declare) that aim to instigate CE adoption and instil climate advocacy amongst architecture and built environment professionals are voluntary, which challenges their uptake. For instance, Participants 6 and 11 discussed the role of Sustainability Action Plans (SAPs) in prompting industry action as part of the Architects Declare signatory. SAPs are voluntary, architect-led documents that set out goals and targets of architecture studios in response to climate action, including Circular Economy objectives. Depending on the set targets and objectives, SAPs can be influential in how architectural studios conduct business and deliver projects. However, the voluntary nature of the document, inadequate funding support, and lack of monitoring and verification mechanisms challenge industry-wide adoption. Currently, architecture studios are not bound legally to any of these documents and may ultimately withdraw their signatory. Industry support through funding and enforcement is called for to accelerate industry initiatives.

> I think that the SAP is a well-intentioned document. I think, ultimately, not many companies have actually completed [their] SAP. The intention of it remains the same – to be a conversation starter for practices to assess where they are, then try to improve on that. It [does] not necessarily need to be a fully-fledged document. (Participant 6, 2023)
>
> As long as it's fully voluntary, and nobody's getting paid to do it, it's a slow process. So, really, the purpose of looking to get funding is to speed up the effort. (Participant 11, 2024)

It is important to mention that initiatives like Architects Declare exist for other professional groups, such as Engineers Declare, Builders Declare, and Planners Declare. While the foundation of these organisations signals a positive move towards CE in the industry, stronger collaboration amongst these industry advocacy groups can accelerate the transition. Industry collaboration between industry advocacy groups and authoritative professional bodies also shows the potential to create new enforcement pathways. For instance, the AIA recently amended its sustainability awards submission requirements to include an SAP, which has pushed architecture studios to adopt SAP.

> Now that they need it to submit for awards, you watch them do [SAP]. There will be quite a lot of firms that will now do a sustainability action plan. They had good intentions a year and a half ago but didn't do it. (Participant 11, 2024)

However, this enforcement pathway does not encompass all architecture studios and may be limited to those who already can innovate. The finding underscores that industry collaboration can be harnessed as an enabler to find effective enforcement mechanisms and funding opportunities for CE initiatives. It also corroborates the call for an overarching industry-agreed CE vision and actionable plans, established pathways of implementation and monitoring, and funding mechanisms to allow these pathways to be forged.

Building capacity through education and workforce development

Education and workforce development were identified in the interviews as enablers in building the knowledge base and capabilities amongst architectural graduates and professionals to adequately respond to their evolving professional roles in a CE. A two-pronged approach emerged from the interviews: updating the architectural design curricula in universities and professional development through workforce training. First, universities and other tertiary educational institutions play a role in ensuring that the new generation of architectural professionals is equipped with fundamental CE appreciation, knowledge and skills. This entails revising architecture programs and curricula to better suit the evolving job of the architect in a CE. Second, workforce development focuses on existing architectural professionals and involves expanding CE-focused workforce training and Continuing Professional Development (CPD) courses to re-train and upskill architects in practice.

Architectural education

The findings imply that universities and other tertiary institutions are seen by participants as enablers of the CE transition. Specifically, tertiary institutions offering architectural programs contribute to ensuring that upcoming architecture graduates have the foundational CE knowledge and competencies. Several participants stressed the need for CE-aligned architectural education. While it is acknowledged that modernising university curricula to include CE may have lagging temporal effects, its impact on culture and practice would be profound.

However, the interviews reveal that there are conflicting perceptions amongst participants of the efficacy of universities as an enabling factor. On one hand, some participants perceived a disconnect between the educational training that architecture students receive and the competencies required of them in practice to address sustainability issues, including CE. Participants 3 and 10 discussed in detail how universities can enable the CE transition and the current issues that hamper this potential:

> I think that's the most fundamental change you can bring to a company. Every new person you employ, every young person, has a different education standard. Surprisingly, I think architectural graduates are very motivated and they really want action on sustainability, but don't know how. They didn't really get taught at university how you implement what we need to do, so I think there's this disconnect. (Participant 10, 2024)
>
> It starts with the university because we're not teaching students how to design [sustainably]. They do individual courses on passive design and [...] they might even do one [on] ventilation, but when you try and talk to even a master's student now, the students are all really smart, they still think it's solar panels and windmills, and they want to design steel and glass buildings. (Participant 3, 2023)

Some participants also perceive and argue that the legacy of modernism and post-industrial architecture movements in architectural education remains. This legacy is reflected in the current idea of great architecture based solely on form rather than function and content. This points to the opportunity to update curriculum standards set by accreditation bodies and implemented by universities.

> In architecture, the idea of great is largely, not exclusively, but largely an aesthetically driven conversation, not a content conversation... We generally make very quick

> decisions on the basis of how something looks rather than delving into it and understanding it more. (Participant 11, 2024)
>
> We've been stuck in a modernist trope for over 100 years now, where you don't care about what you're actually building. If you're building a building in Sydney, it should be a completely different building than if you're building one in London. We all look at international images and go 'oh, that's how I want it to look rather than this is how I want it to feel, and this is how I want it to be appropriate, and this is going to be culturally connected because it's dealing with this specific climate of this place. (Participant 3, 2023)

On the other hand, some participants recognise advancements in embedding sustainability in architecture curricula. For instance, Participants 6 and 11 held the view that graduate architects are better equipped with CE technical skills in comparison to the majority of architects in practice due to advancements in architectural education regarding sustainability issues:

> Architectural education is improving as well in terms of sustainability. (Participant 6, 2023)
>
> Half the people in my practice wouldn't be able to do what a person coming out of final year uni can do now in terms of knowledge of embodied carbon or knowledge of methodology in terms of how to go about starting to build in a greener fashion. (Participant 11, 2024)

The findings highlight the opportunity to examine and assess the need for a broader refresh of architectural education across tertiary institutions to better equip students with a CE mindset. As discussed in the previous section, the role of the architect in a CE would differ from what it is in the incumbent linear economic and capitalist model. As the transition to CE matures, the architect's work is presumed to no longer commence with vacant land to build on and infinite resources to build with, but with a framework of multiple constraints imposed by the existing environment and available resources. The qualities and skills required or desired from an architect in a CE would also evolve. For instance, resourcefulness, collaboration, and custodianship are values that are prioritised in a CE. Therefore, architectural education should evolve to adequately train architecture students and graduates to address these changing needs. Universities and tertiary educational institutions can enable this by instigating a more profound values shift in architecture education and implementing pedagogical changes to facilitate a more holistic education that equips them with stronger foundational CE knowledge and skills.

Workforce training and professional development

Apart from integrating CE in formal architecture education, the interview findings also underscore the importance of educating practising architects in CE design thinking. Continuing professional education was stressed by some participants, noting that the majority of practising architects do not have formal technical training in architectural design with a CE approach. As Participant 3 noted, “you have the order of architectural professionals who did [the business] in a certain way for 20-30 years, and for them, it is now difficult to rethink”, especially given that CE is fundamentally different from the incumbent design and building practices. With technical knowledge identified as one of the barriers to CE adoption in architectural practice, professional training through in-house workforce training or formal CPD courses was identified as an essential enabler of the CE transition, as this empowers the architectural professionals to build their capacity and better assume their role in a CE. As Participant 2 explained:

> Improving your [architectural] practice on [sustainable] materials and the circular economy will have a bigger impact if you're better educated. You can better explain to the client what your intent is and better explain to the builder what your intent is. (Participant 2, 2023)

As discussed in earlier sections, architectural studios are adapting various approaches to integrating CE into their practice. While some have established formal internal training initiatives (e.g. learning programs, sustainable design guidelines and frameworks), some have relied on project-based learning and development. Based on the interviews, in-house workforce training has enabled architectural professionals to have easy access to CE knowledge and opportunities to apply it in real-world projects. For instance, Participants 2, 6 and 10, who are from large architectural studios, have shared how the various in-house workforce training programs initiated by their architectural studios enable CE adoption.

> In our company, we do it through webinars, through workshops… but I think the most efficient way is probably to do it on the project with that team. (Participant 10, 2023)
>
> We've established a group that meets every week, called Sustainability Champions, and that's where we, as the leadership, present a new topic every week to [the employees]. (Participant 6, 2023)
>
> Our staff have actually been hungry for something to guide them, so there's actually a huge amount of passion and interest in the sustainability framework. (Participant 2, 2023)

A potential drawback of workforce training through in-house training initiatives alone is the onus it puts on architectural studios to implement their own initiatives and risks inconsistent training standards across professionals. This aligns with the organisational barriers to R&D that impact smaller architectural studios, as discussed in the earlier subsection. While innovations such as these in-house workforce training enable CE transition, a more top-down approach to capacity building and knowledge dissemination may prove to be more effective and equitable on a broad scale. As Participant 1 suggests, "a broader education process is required in the industry."

Formal CPD programs offer a potentially effective means of equitably educating the profession about CE. Strengthening CE-specific CPD requirements allows for upskilling the architectural profession across Australia in a standard and regulated manner, as they enable architects to re-educate themselves regardless of the capacity of the architectural studio in which they are employed. Participant 6 explained that "since it became mandated to do the CPD, it's a good opportunity [for architects to learn about CE]. This can facilitate the creation of accessible and authoritative CE references that are still lacking for the profession. Requiring CE-specific CPD programs could promote agency and diminish the steep learning curve associated with CE adoption while facilitating a more aligned knowledge base and streamlined flow of information in the architectural profession, addressing some of the issues of fragmentation and equity discussed under the barrier theme.

Leveraging existing mechanisms and resources

Identifying and leveraging existing mechanisms that may not necessarily be CE-specific but have the potential to assist in implementing CE emerged as an enabling factor amongst participants. These instruments include architectural specification documents, specific types of contracts, and process- or knowledge-based tools. In particular, the interviews indicate that capitalising on the power of architectural specifications and administering effective contractual arrangements enable CE implementation, as these instruments are generally legally binding and thus guarantee enforcement. In addition to contracts, existing process- and knowledge-based tools were identified as helpful instruments to facilitate CE implementation in practice.

Architectural specifications and contracts

Capitalising on the power of architectural specifications enables CE transition by influencing the supply chain and ensuring CE-related specifications are implemented as intended. Architectural specifications are a written legal and contractual document that provides details of the quality and type of building products and their components to be used in building projects. As covered in the earlier section, several participants acknowledged that integrating CE principles in architectural specifications is one of the most direct ways architects can promote CE in their practice. Recognising the importance of specifications, efforts have been taken to facilitate the specification process through further research and developing specification guidelines, as shared by several participants.

> [Our] Material Specification Guide, which is a rudimentary first pass at 'What's the difference between Good Environmental Cause Australia (GECA) certification and global green tech certification? What's the difference between PEFC (Programme for the Endorsement of Forest Certification) and FSC (Forest Stewardship Council)? What is embodied carbon? It's a little document that we give to everybody to [start] their journey. This is the basics. (Participant 11, 2024)

> Materials libraries are a really quite important and incredible resource that we use as designers every day in our working studios. Every architecture and interior design practice has a materials library within its organisation. It's really the first place that you go to find the products that you want to specify, and then you reach out to suppliers and do your research further from there. (Participant 12, 2024)

However, as a key component of contractual documentation, architectural specifications not only provide architects with a practical and technical platform to promote CE but also hold the potential to legally protect CE-related architectural design in the latter stages of building projects (e.g. construction stage), thus ensuring CE implementation. By better understanding the functionality and legality of architectural specifications, their potential as an enabling element of the CE transition can be realised further by the architect, as stressed by Participant 10. Other participants also contemplated the influence of contractual arrangements in projects and how specification documents can be more effectively utilised to safeguard architectural design into construction. For instance, Participant 2 raised the potential issue of not having engaged an architect for a traditional full design and documentation service and the role the specification document plays as a counterbalancing mechanism in such a case.

> It's happening more and more often that projects actually spell out in their contract, even in their design brief, that we have to design utilising the principles of the circular economy. It's probably a bit coming down to the architects in terms of how thoroughly they implement it... It's in our interpretation how we put that in the specifications. (Participant 10, 2024)
>
> In Australia, we have a tendency to go into Design and Construct [contract], but it was actually a traditional full documentation where you [architect] completed the design and specification, and then it was simply just a matter of construction, so there is no design component for the contractor. I think that would make quite a big difference...One of the things that I think we can learn from [our experience] is how we specify things that make it clearer or harder to change further down. (Participant 2, 2023)

The form of engagement and contractual arrangement with architects in building projects also appeared to be influential factors in CE adoption, as they shape the scope of responsibilities and the influence of the architect on projects. The analysis suggests that participants hold the view that some forms of engagement and types of contracts may be better suited to enabling CE outcomes. For instance, Design and Construct (D&C) contracts that allow the novation of the architect to a distinct contractor open the possibility of design changes during the construction, putting potential CE design initiatives at risk should the architect and builder not necessarily be aligned. In contrast, traditional design and documentation contracts – wherein the architect has complete control over the design – allow architects to follow through with the intended design. Moreover, contract administration by the architect – which gives the architect the contractual right to oversee the project during construction – was perceived by a participant as a more suitable contractual arrangement, particularly for apartment renovation, where there is a high plausibility for variations.

> We went into design and construct tender, and we were about 70% through our documentation. So whilst [there] is a great alignment with the client, what that means then is once we go to design and construct, we're novated to the builder or the contractor, and they also need to have the level of alignment, tenacity, and passion to see this through. (Participant 2, 2023)
>
> When you're working with existing structures, the capacity for variations is the norm. But again, it's an unseen advantage in having an architect administer for contracting, that you've at least got somebody who's overseeing the scope and the size and the quantum of variations. Because if you don't have somebody who knows what they're doing overseeing variations, you're really at the mercy of a builder. (Participant 4, 2023)

The account of Participant 7 regarding contractors in interpreting and implementing architectural specifications shows the importance of clear specification documents and effective contractual arrangements that enforce such. This importance is even highlighted when secondary materials are involved, which requires more labour and tenacity from contractors (as discussed in the earlier subsection under *Secondary material barriers*). Ultimately, while contractual arrangements will depend on individual project context, the findings suggest that 1) architectural specification as a legal and contractual document provides architects with a viable instrument to adopt CE and 2) advocating for and utilising suitable contractual arrangements can enable CE implementation.

> There's more labour or there's more consideration that has to happen in the labour. We had to really fight for them, [we] were on site with the joiner, and they have these beautiful louvred solid timber doors on all these old pantries, and we just wanted them cleaned up. And the contractor said, 'We gotta get rid of all of them.' You can't even buy these anymore, and we didn't let them get rid of them, but some of them need to be painted. And they were like, 'This is a nightmare. It's not going to work.' We had to get the client on the contract as well. The client has to obviously sign off, but if the [contractor] is sneaky, I guess they would do it. If you get the client on side, they can really push for decisions. (Participant 7, 2023)

Process- and knowledge-based tools

Another type of instrument that arose as an enabler is the utilisation of tools that help embed CE in the day-to-day architectural practice. The tools can be technical or strategic and either already exist or need to be further developed. Both types of tools were perceived by participants to have enabling effects in implementing CE in building renovation projects, as they facilitate the CE approach to the architectural design process while augmenting CE proficiency amongst professionals.

Technical tools are often digital innovations that are used to measure or validate CE-related aspects of the project, such as embodied carbon calculations or architectural drawings that generate CE evidence for the project. For instance, Participant 2 expounded on how such tools provide them with an evidence base and allow them to engage with clients in a more informed manner regarding CE.

> They're really important in the evidence of the process and making sure that when we say that we're picking low-carbon materials, we can measure that, or when we're designing [for] solar heat gain, we can measure that. So, I think they're really important

in just providing them [the clients] more of an evidence base to the design process. (Participant 2, 2023)

Strategic tools are instruments or methodologies that are often relational (i.e. involving other actors) and help with visioning, planning or monitoring CE-driven projects. As an example, Participant 5 explained that they use existing strategic tools to facilitate collaboration and the development of a shared CE vision for the project. These tools are often not used in the business-as-usual design approach but allow architectural professionals to be equipped with skills essential for a CE approach.

> That's part of this process of education that we're trying to do: show what's possible, show how to do this stakeholder engagement mapping, how to do a visioning exercise, how to do all these things. It's something that we do need to learn as architects. (Participant 5, 2023)

However, several participants also raised accessibility issues associated with these digital innovations that may hamper their enabling effects. It was noted in multiple interviews that one of the key challenges with CE is measuring embodied carbon emissions as part of the design process, as detailed in earlier sections, due to the lack of access to or proficiency in appropriate tools. Some participants, such as Participant 5, elaborated on the current gaps and complexity surrounding digital innovations in the embodied carbon field, identifying data integrity and technical capability as problematic. Nevertheless, some participants recognised the impact of learning about and utilising such tools in incorporating embodied carbon emissions into the design process, as evidenced by Participant 9. This finding suggests that increasing accessibility to these CE innovations is crucial to maximising their potential as an enabler in the CE transition.

> There's still a big gap in that [technical] space to make [it] accessible to the day-to-day architect… the best tools are sort of ladybug tools and grasshopper, and they're more complicated to access. (Participant 5, 2023)
>
> We had a guy who was fantastic on CAD, and he set up a Grasshopper model, so we can measure all the volumes of the different materials… and then we also got help from [redacted]. But for us, we didn't know where to start or how to. But now, and

> obviously, we're not experts on this at all; we've got basic knowledge, and we can kind of measure what we're doing. (Participant 9, 2023)

Furthermore, technical tools that are driven by new technologies emerged as a critical but missing enabler in streamlining CE initiatives in projects such as resource recovery planning, material reuse and material passports. This aligns with the findings in **Chapter 5** that there are opportunities to strengthen the Virtualise principle in the renovation process through these digital innovations. In describing their current resource recovery process, Participants 7 and 8 showed evidence of the low digitalisation rates in building practices, highlighting low awareness and adoption of new technologies that show great potential to digitalise the building process.

> Walking around with my phone, taking photos, writing things down, and then making a schedule of what was available. When looking at joinery that we can reuse, it was a really detailed measuring of everything to figure out how to document around it so that the joiner and builder will integrate it, and [we] thought of everything so that if they face a problem, we know how to fix it. It doesn't work like that always, but that's the goal. (Participant 7, 2023)
>
> We would love it to become a more data-driven system. But we're designers, we're not like tech people. So it's kind of hard. I think that's the gap between the efforts that we do in our schedules and specifications, and design - it's very manual in terms of our entry and ensuring that we share all that knowledge with everyone from the team. (Participant 8, 2023)

Lastly, some digital innovations related to the secondary material marketplace were also identified in the interviews as a potential but missing enabler. These digital marketplaces were perceived to enable architects to 1) salvage and recirculate materials for further use and 2) source and utilise secondary materials. Overall, these findings emphasised the need for stronger incentives not only to increase awareness and adoption of existing tools but also to further develop digital innovations that enable CE activities in building projects.

> Imagine like a Shazam style thing for materiality that understood what it was and then created [a] schedule or banked it directly to partners to talk to or something... You could take a photo of something, identify it as timber, and it connects you to a wider marketplace [for] maybe other designers that want to use it. (Participant 7, 2023)
>
> There is no big Amazon page for second-hand building materials...the biggest gap, I suppose, with architects, is when you need it, where do you find it? (Participant 10, 2024)

Demonstrating value-add and compliance

As revealed through the interviews, demonstrating evidence of economic or social value-add or compliance with sustainability standards of CE initiatives enables their implementation. The relevance of this enabler is more pronounced in the apartment sector, which some participants see as being largely influenced by market conditions compared to other typologies (e.g. commercial, hospital). As Participant 3 noted, "apartments are all about getting the market price right." In comparison to owners of other building typologies (e.g. commercial, health, etc), apartment owners and residents are not subject to corporate social responsibility or high sustainability performance standards. Thus, apartment owners and residents lack this external factor that can inform and influence sustainability aspirations, including a CE approach to renovating their properties. The sector is also perceived to be risk-averse (as discussed under Barriers), with Participant 9 explaining that "clients for these housing projects, they have to be deeply conservative, they don't want to do something that they haven't done before because it's risky". As a result, this conservatism associated with residential clients might challenge the implementation of innovative ideas such as circular renovation without sufficient proof of concept. Combining these two factors, the apartment sector is understood to be generally driven by market forces and thus requires evidence of economic or social value-add to overcome aversion to innovations. Several demonstration pathways were identified in the interviews that can enable CE adoption in apartment building renovation, such as 1) sustainable building rating systems (SBRS) and product certifications and 2) project exemplars and precedents. The following sections discuss these two emergent categories under this sub-theme.

> The focus on sustainability in apartments versus in office buildings is driven very much by who buys it, right? In an office building, it's generally a large corporation that buys it with ESG targets and with goals and aspirations of a business around doing better. It's mum and dad [who] buy apartments, generally speaking, and their focus on that isn't as big. The only real lever I can see to change that is shifting the priority, where if you buy a six-star home rather than a five-star home, you pay slightly less, or you get a rebate. (Participant 11, 2024)

Sustainable building rating systems (SBRS) and certifications

Multiple participants noted that SBRS or certifications enable CE implementation as they provide building projects with direction (e.g. aspirations and targets), a framework to inform design and specifications, and a mechanism for accountability and validation. As Participant 6 expounded, SBRS allow projects to develop criteria, guide decision making and encourage accountability:

> If a building or project needs to be certified, then that will kind of hold the client accountable and also hold the design team accountable and give them a direction. The consultant will be able to stick to those criteria better, and then the design team will know what their objectives are for sustainability. And that will happen early in the project, and that will then inform the targets for the projects and how high the sustainability ambitions are. And then from there, that would be developed through the process, and then obviously checked on site and construction, the building will be held accountable to it. (Participant 6, 2024)

Some existing SBRS were named, such as LBC and BASIX (as thoroughly explored in **Chapter 2**), to be effective in facilitating CE-aligned outcomes. For instance, several participants identified that LBC and its proprietary certifications, such as Red List, have a notable influence on regenerative design and material specifications, as reported in the interview by Participants 11 and 5. This evidence aligns with the findings in **Chapter 2** that LBC instigates normative shifts in design culture and practices, particularly aligning with the Regenerate principle of CE.

> LBC had a really big impact on specifications. So, on our material scheduling, what materials we choose, why we choose and how we choose them and that not that's often we had to develop a bit of a matrix for ourselves to say. Is it the lowest embodied carbon? Is it the most recycled content? Which of these competing questions is actually going to be the thing that drives us? But I guess regardless of where your answer is, if you're asking all of those questions, you're more likely to be doing the right thing than if you're not asking them, which is kind of, I suppose, industry normal practice to not ask most. (Participant 11, 2024)
>
> I developed a regenerative design framework. When I started this process, there wasn't really much out there, but I have been influenced a lot by the Living Building Challenge. (Participant 5, 2023)

BASIX was also identified in the interview, with Participant 9 noting the impact of this SBRS in self-education and self-assessment because the system shows how design can be manipulated to achieve certain sustainability standards.

> I think that [BASIX] is actually a really good example of something positive, because you can pretty much see under the bonnet and understand how it all works through just exploring the BASIX tool. (Participant 9, 2023)

Apart from the benefits of SBRS in learning and adopting new approaches, some participants have also highlighted the role of SBRS in providing the evidence base for the design process and outcomes and demonstrating compliance with set standards or targets that are useful for clients and contractors alike. As an example, the existence of product certifications (e.g. Red List) reduces perceived risks and enables architects to use secondary materials with confidence and less pushback from other actors involved, as experienced by Participant 10.

> [It's] a way to verify that those ambitions have been met is through a certification system... [The] Living Building Challenge is not necessarily a check box. So, even if you don't follow the certification, but you do want that approach, I think it's useful. At the same time, it's incredibly onerous, and it can scare a few people a bit because it's so hard to achieve, So I think they're good because you have verification and you can have accountability that certain goals do get met, not just wishy washy. (Participant 5, 2023)

> Products have to have the proper certification to show the components of those materials and what chemicals have been used, and there are certain materials not used. The Red List [shows] harmful materials or harmful substances with the materials, I think it's a bit related to that because that gives us a performance envelope where we can say we have certain things we have to achieve. (Participant 10, 2024)

However, participants also raised potential issues regarding the current form of SBRS discussed in **Chapter 2**, which may hamper or counter its enabling effects. In particular, the unsuitability of SBRS for building renovation and its influence on the residential sector, given the exorbitant costs and implementation loopholes (e.g. circumvention) associated with them, were noted by multiple participants. There is also a perception amongst participants that some SBRS instigate potentially subversive outcomes, such as rewarding building material consumption over retention and reuse.

> The whole process became this checklist exercise process, where the architects are like, 'Oh, the ESD consultant will deal with that,' and whenever they come on board, what they look at is how you get the maximum number of points at the cheapest price. It's become a bit of a check checklist, a point-chasing exercise. (Participant 5, 2023)
>
> You could fill the thing with some kind of cladding that might have a good star rating, and that will really carry you up in your Green Star rating. Or you could choose to use nothing or use fewer materials, and then you get no stars. (Participant 1, 2023)

These findings highlight the need for existing SBRS to respond better to current demands and priorities in the building industry, such as renovations. The interviews indicate that SBRS, which allows for self-assessment of their design against certain standards, or negotiation between design and sustainability outcomes, may enable CE adoption through influencing normative practices in comparison to point-based or checklist-based systems. Prioritising and rewarding CE activities, such as building material reuse, was also highlighted to better suit renovation activities.

> Rather than being an additive process, you get 100 points if you retain the existing building, then stars keep getting taken away from you as you go further. (Participant 1, 2023)

> I would try away from point systems because point systems like Green Star, you have to understand the justification of certain points, and there's a certain history behind how those points came to be. Versus a Living Building Certification system, which is a dialogue-based system, so it's not this black and white where a person decides you get a point, or you don't get a point. It allows you to kind of exchange bad design for a dollar figure because you can spend something to buy some points. (Participant 10, 2024)

Ultimately, the findings underscore that SBRS's potential as an enabler can be amplified by being able to demonstrate or communicate value, particularly to residential clients such as apartment owners and residents who could encourage CE considerations.

> It would be amazing if they knew they're going to get a huge energy benefit by putting modern windows in the 60s building. But how do you know? It'd be great to be able to say to them, 'Well, this will be then a five-star building or a six-star building.' ...I think that would be super helpful because it would just be good communication. (Participant 9, 2023)
>
> A certification that's kind of polished and able to really articulate value - I think that could work. (Participant 2, 2023)

Project exemplars and precedents

Given the barriers discussed earlier regarding perceived risks associated with CE, the interviews indicate that demonstrating CE's proof of concept and value-add through project exemplars can enable CE adoption. By showcasing that a CE approach is possible and cost-effective, architectural professionals are in a better position to promote CE in building renovation. The findings accentuate the importance of building the evidence base in support of CE as an industry and government priority through catalyst and demonstration projects. As Participant 5 spoke in-depth,

> Showing everybody what's possible made a huge impact on everyone's willingness to achieve this because very often people think, 'Oh, this is just too hard to achieve...' I think something that we need to do more of is show more real examples of what's possible... We need to show what's possible as much as we can implement in real life;

> I think that's going to start moving tidal. That's when those conversations happen with the whole supply chain... So, I think that is really crucial. (Participant 5, 2023)

Moreover, cultivating positive narratives and perceptions about CE was also deemed important to achieve social acceptance of CE-driven building renovation practices, which further enables the CE transition. This aligns with the findings in **Chapter 4**, discussed in the succeeding section, that developing effective narratives plays an important role in convincing actors and promoting the adoption of innovations. As Participant 9 noted, “The big part of it is telling the story.” Other participants also shared extensively their experience of how demonstrating value-add in real-life projects instigates CE adoption amongst potentially sceptical actors, such as Participant 1:

> We've been able to demonstrate an uplift in the value of the building, which people are really interested in – improving the value of their properties. So if you can illustrate that there's real value in doing that. People are interested in it. Those sorts of people are quite open to hearing alternative ideas, so long as they're not going to lose money. They're kind of worried about those sorts of ideas. (Participant 1, 2023)

3.4.5 Limitations, opportunities, and reflections

There are several limitations to this study that need to be addressed. First, the participants are mostly based in the states of New South Wales and Victoria. Insights from participants from other states can further enrich the findings. Second, the analysis did not take into account the differences in the size or specialty of the architectural studio. Although some insights emerged relating to the studio size or specialty, comparison among different studios based on these characteristics can provide further evidence into how the profession can be supported in the CE transition in terms of workforce development. Third, one may also approach the analysis with a spatial lens. As building norms and legislations vary across states, such an approach may lead to interesting findings and inform state-specific interventions. Fourth, the findings are based on accounts of twelve participants. Although this sample is considered sufficient for a phenomenological study, future studies may benefit from a larger sample size for broader insights.

Furthermore, opportunities for future research in related areas were also identified in the interview, such as the nexus between CE, architecture, and Indigenous knowledge in decolonising the built environment. Lastly, on reflections on methodology, the phenomenological in-depth interviews proved to be a profound method for investigating an emerging phenomenon in an underexplored research area. The interviews presented as an avenue for two-way learning for the researcher and the participant, providing the opportunity to raise awareness about the topic and help the participant come out of the interview more informed and interested in the topic. At the end of the interviews, several participants shared that the questions were thought-provoking or incited actions afterwards. In the words of one of the participants, “You've actually helped me today, because I'm going to go and have a look at our waste management plan. It's been constructive.” This experience emphasised that certain methodologies present the opportunity to relay research or, at the very least, its significance to the participants – every interaction becomes a chance to enrich the research process and outcomes, and the understanding and appreciation of each participant about the research topic. Future research on CE, which entails a paradigmatic shift, may benefit from such an approach.

3.5 Chapter Conclusion

This chapter focused on the architectural professionals as social actors in circular renovation and investigated their lived experiences to elucidate their perspective of what a CE entails for their profession and how their profession can contribute to a CE – an area that is critically underexplored in the Australian context. The study sought to broaden the CE discourse and reignite the connection between architectural design and CE, particularly in the context of architectural renovation. The study employed semi-structured interviews with 12 architectural professionals practising in Australia with CE and apartment development experience.

Four themes emerged from the thematic analysis that address what CE adoption is like and how it is experienced in the architectural profession: 1) a fragmented perception of CE and evolving role of the architect, 2) different CE practices, 3) multi-dimensional barriers and 4) enabling elements to CE adoption. The qualitative methodology provided more nuanced and deeper insights into the perceptions of architects about CE and revealed the systemic and context-specific (i.e. apartment renovation) barriers and enablers to CE adoption that they experience. It also illuminates the complex interactions between architects and other actors, and the cultural, economic, and institutional regimes that shape the role of the architect.

The findings reveal that there is growing awareness among participants of the role they play in a CE, which is implicated by a multitude of barriers and enablers. There is also recognition that the role of the architect in the building process is evolving as the CE transition progresses. The transition entails a deeper transformation not only in the current ways of working in architectural practice but also, and more importantly, in the values of the profession that will redefine its essence. The findings reveal areas for government and industry action to facilitate circular renovation of apartment buildings and reinforce calls for a just and empowered framing of and approach to the CE transition. This is critical given the existing challenges in the profession.

By investigating and highlighting the lived experience of architectural professionals with experience in CE adoption and apartment building design, this research contributes to multiple bodies of literature. First, the findings contribute to the highly under-investigated and under-theorised area of architectural practice for climate action. Second, the empirical findings contribute to a broader understanding of Australia's shift to a circular built environment and highlight issues pertinent to the often-overlooked apartment sector.

CHAPTER 4

4 Circular economy and residential buildings

Activities of Circular Renovation: Multiple-case study of circular economy initiatives in residential building projects

4.1 Chapter Overview

This chapter turns to the third element of the research scope – *social activities* – and presents a qualitative case study into demonstrations of CE adoption in residential building projects. The chapter addresses Objective 2.3 of the thesis identified in **Section 1.4** and explores two cases seen as social activities that characterise CE adoption: Case Study 1 (*Coogee Waters*) involved the architectural renovation of a seven-storey apartment building in Sydney, Australia, and Case Study 2 (*Catherine Commons*) involved the deconstruction of a three-storey residential building for material reuse in New York, USA. The case study research methodology is described in **Section 1.6**. First, the chapter provides a thorough description of the case; second, it employs the ReSOLVE framework to analyse the CE initiatives demonstrated in these projects, and third, it presents case themes of lessons learned from these projects. By investigating and comparing these case studies through a qualitative approach, the chapter contributes in three ways: 1) it expands empirical knowledge of CE implementation through documentation and analysis of CE initiatives in practice and 2) it explicates ReSOLVE principles in real life multi-residential projects to extract implementable strategies, and 3) it presents a nuanced understanding of CE adoption in different contexts, thus contributing to knowledge of how CE initiatives emerge as social practices and can be reproduced.

4.2 Background

As defined in the introductory chapter, activities encompass embodied practices by actors that materialise CE in the physical world. By exploring these cases, the social practices that make up CE adoption can be further defined and guide the future circular renovation agenda. This chapter responds to the gaps revealed in the previous chapters in terms of practical knowledge in implementing CE. Lack of actual know-how (Collins et al., 2023; Shooshtarian et al., 2023) is a primary barrier in the Australian AEC. Surveyed AEC stakeholders emphasised that there is a need for more accessible and practical information to support CE adoption and facilitate decision-making (Collins et al., 2023). Furthermore, future research has been recommended to investigate ways to reuse construction and demolition waste, create material hubs, and discover potential uses for urban mining as efforts to dematerialise the housing sector (Miatto et al., 2024).

The 2025 National Waste Report also noted that while waste from large-scale development projects is recycled, waste from smaller projects is often sent to landfill, failing to capture the embodied values from these materials and varied material recovery practices depending on project scale (DCCEEW, 2025). This highlights the opportunity to understand material recovery practices in small-scale projects such as singular apartment building renovations to identify opportunities for diverting waste from landfill and recapturing values from building materials.

In addition, as discussed in earlier chapters, CE scholars have underscored the implementation challenges of CE (Corvellec et al., 2020; Fraser et al., 2024) in understanding the actual "doings and sayings" or the social practice of CE (Holmes et al., 2021; Schulz et al., 2019) to accelerate CE implementation. To enable adoption, Shooshtarian et al. (2023) found that it is crucial to provide evidence for the added value of a CE approach in pilot projects. This case study research, by investigating multi-residential projects from a CE perspective, seeks to bridge these gaps and contribute to actionable insights that can facilitate CE implementation and support CE policymaking in architectural renovation of apartment buildings and beyond.

The case study investigates two multi-residential projects: 1) an architectural renovation of a 1960s apartment building in Australia and 2) a deconstruction project of a 1910 multi-residential building in the USA. The first case was selected for its demonstration of retaining a significant portion of an ageing building and its renewal through architectural design. The second case was selected as a pilot demonstration project that can provide insights regarding material recovery and reuse from ageing residential buildings. Both cases are deemed relevant for understanding how CE adoption in the architectural renovation of an apartment building can be undertaken in real life. An overview of the cases analysed in this study is provided in **Table 4-1** and described in detail in the succeeding sections.

Table 4-1 Case profile

Case Details	**Case Study 1**	**Case Study 2**
Building name	Coogee Waters	Catherine Commons
Building type	Multi-residential building	Multi-residential building
Building use	Private housing (strata-owned)	Student housing
Storeys	7	3
Location	Sydney, New South Wales, Australia	Ithaca, Upstate New York, United States of America
Year built	*1963*	1910
Project timeline	2013-2020	2020-2022

4.2.1 *Coogee Waters* Apartment Building Renovation

Coogee Waters, then known as *Windsor Towers*, is a seven-story apartment building consisting of 28 sole-occupancy, strata-titled units and ground-floor car parking. The building is classified as a Class 2 building (multi-residential flat building) under the Australian National Construction Code. It was originally built in 1963 with a blonde brick façade and cantilevered concrete balconies with metal-framed glass balustrade, which provided each residential unit access to less than 6m^2 of private open space. Cobalt blue-glazed brick spandrel panels accented the building on either edge of the front, left, and right elevations. The building's ground and lower ground levels were unenclosed car parking with bare concrete columns visible from the street. Pedestrian access is from Kurrawa Avenue, while driveway access is from both Carr Street and Kurrawa Avenue. The building frontage is demarcated by a palisade fence. Coogee Waters before and after the renovation are shown below.

Figure 4-1 Coogee Waters pre-renovation, North-facing façade; Source: MWA Architects

Figure 4-2 Coogee Waters post-renovation, North-facing facade; Source: Tom Ferguson

The building falls under the 1950-1970 period of the apartment building construction boom in Sydney. This period is characterised by construction with limited consideration of design quality and driven by economic opportunity (Randwick City Council, 2006). These buildings are also characterised by solid, well-built structures but with minimal and repetitive design features and materials, ground floor level car parks, and narrow and heavy-looking balconies (Randwick City Council, 2006).

Coogee Waters is well-positioned on the corner of Carr Street and Kurrawa Avenue in Coogee, Sydney, Australia. It is approximately 60 meters from Coogee Beach, a famous local beach in the Eastern coastal suburbs of Sydney and is located within the foreshore scenic protection area. It also sits across the Goldstein Reserve, a parkland that serves as a key public open space and community infrastructure in the local area, offering spectacular views of Coogee Bay. The Site also forms part of the southern end of the Coogee business district and is surrounded by a mix of commercial, retail and residential uses. **Figure 4-3** illustrates the Site Map, and **Figure 4-4** shows the view of Coogee Beach and Goldstein Reserve from the Site. *Coogee Waters* is also within 10 kilometres of several famous tourist attractions in Sydney, such as Bondi Beach and Sydney Opera House. **Figure 4-5** shows the broader context map of the Site.

Figure 4-3 Coogee Waters site map; Source: Author, base map from Google Earth

Figure 4-4 View of Goldstein Reserve and Coogee Beach from project site; Source: Google Street Views, February 2025

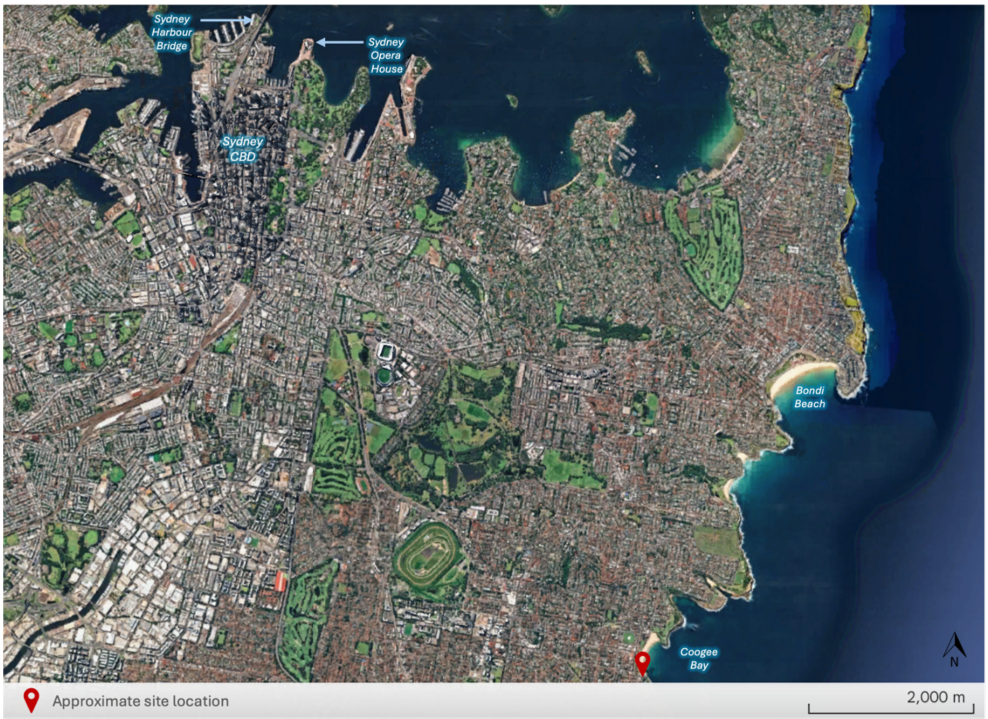

Figure 4-5 Context map; Source: Author, base map from Google Earth

4.2.2 Catherine Commons Deconstruction Project

Pre-deconstruction in 2022, the building at 206 College Avenue *(Catherine Commons)* was a three-storey multi-unit residential building located in the Collegetown neighbourhood of Ithaca within the Finger Lakes region of New York, USA. Catherine Commons was a wood constructed house built in 1910 and was representative of the general housing stock in Ithaca (Heisel et al., 2022). The structural timbers were composed of high-quality Eastern Hemlock. Visibly ageing, the building featured a front gable roof clad with dark grey asphalt shingles. Olive green wood shingles clad the upper portion of the exterior wall. In contrast, the lower portion of the exterior wall was clad in cream-coloured wooden weatherboard. The building's façade was also characterised by a slightly asymmetric layout with green wooden doors, windows with cream-coloured wooden trim, and an elevated covered front porch supported by four simple columns. Internally, the building had cellulose insulation with plaster and lath walls and oak hardwood flooring. The 420-square-meter building contained three apartment units and a total of 13 bedrooms across three storeys (Heisel et al., 2023). **Figure 4-6** and **Figure 4-7** show Catherine Commons pre-deconstruction.

Figure 4-6 Catherine Commons, East-facing façade; Source: Google Street View, July 2018

Figure 4-7 Catherine Commons and adjacent houses along College Avenue featuring similar architectural style; Source: Google Street View, July 2018

Catherine Commons formed part of a row of 20th-century residential buildings along College Avenue in Collegetown, with adjacent residential buildings showcasing a similar style. Situated south of the Cornell University campus, it served as rental accommodation for university students in the area for an extended period. To the West of Collegetown neighbourhood is Downtown Ithaca, the city's retail and commercial hub. To the East of Collegetown lies the historic district of East Hills, which comprises a broad collection of architecturally and historically significant buildings from the 19th to the 20th Century (City of Ithaca, n.d.). **Figure 4-8** and **Figure 4-9** show the site boundaries and the broader context map of Catherine Commons.

Figure 4-8 Catherine Commons Site Map; Source: Author, base map from Google Earth

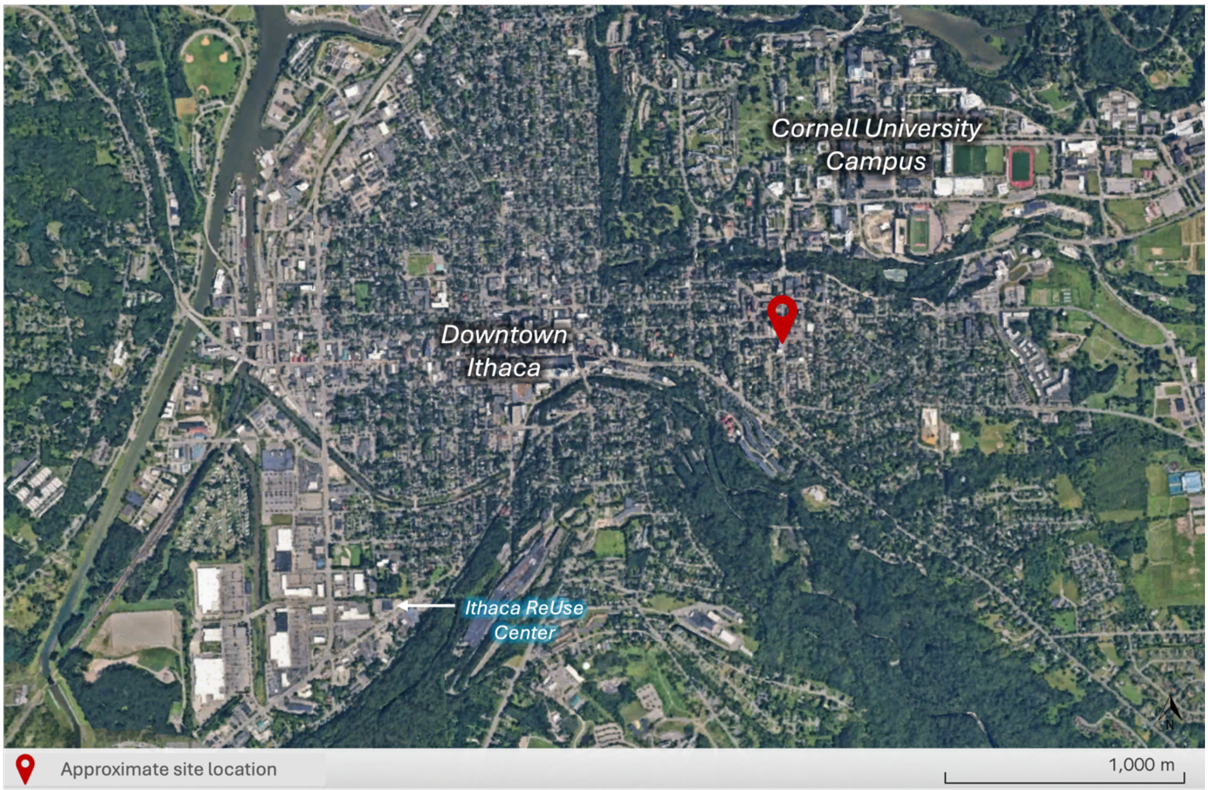

Figure 4-9 Catherine Commons Context Map; Source: Author, base map from Google Earth

4.3 Case Study Analysis

The following sections present the results of the case study. They first provide a thorough case description, which is then followed by CE demonstration and case themes for each of the case study.

4.3.1 Coogee Waters

Case description

Socio-economic context

Coogee is considered one of the affluent suburbs in Greater Sydney and across New South Wales, with a median weekly household income of $2,976 in 2021(Australian Bureau of Statistics, 2022a). In comparison, the median weekly household income across New South Wales for the same year is $1,829. Moreover, the area is known to locals to have higher real estate value due to proximity to coast and prime access to Sydney harbour views. This is reflected in significantly higher median price and weekly rent of residential units. In 2024, the median unit price in Coogee is almost twice as high at 1,450,000 as that of NSW at 752,000 (Heatmaps, n.d.). For the same year, the median weekly rent in Coogee is $750, which is approximately 78.6% higher than the NSW average of $420 (Department of Communities and Justice, n.d.) The stark difference indicates that the Site is in a desirable neighbourhood characterised by residents and households with higher socio-economic status.

Planning context

The Site is zoned as R3 – Medium Density Residential zone within the local government area of Randwick City Council in the state of New South Wales (NSW). R3 zoning allows for a variety of medium-density housing types in the area. While the Site is within the R3 zone, additional use is permitted on the Site granted that the use is for restaurants or cafes, as specified in the Randwick Local Environmental Plan (RLEP) 2012 (Randwick City Council, n.d.)

In NSW, the Local Environmental Plan (LEP) is a key environmental planning instrument and is a part of the statutory planning framework of a local government area. The LEP control "how land is used and sets out provisions for how land can be developed" (Randwick City Council, n.d.) In conjunction with LEPs, Development Control Plans (DCPs) are non-statutory supporting documents that provide detailed design and planning guidelines of proposed developments. Part C – Residential section of the Randwick DCP provides site-specific objectives and controls for the Site. The objective for the permitted additional use on the Site include: "1) to enable ground level small scale neighbourhood shop, restaurant or cafe development whilst protecting the amenity of nearby residents, 2) to ensure any development improves the public domain of Carr Street, 3) to promote pedestrian activity and safety in the public domain, and 4) to encourage high quality design and enhance the street frontage of buildings" (Randwick City Council, 2012, p. 48).

Furthermore, in addition to statutory planning instruments in place that implicate the Site, the Randwick City Council also developed initiatives and guidelines relevant to the apartment building typology. In 2006, Randwick City Council published the "Design Ideas for Rejuvenating Residential Flat Buildings," which is a guide that promotes design excellence in the renovation of ageing apartment building stock (Randwick City Council, 2006). The guide was developed to promote apartment building renovation to meet changing needs and improve the amenity and sustainability of post-war apartment buildings (1950s-1970s), which represent a significant portion of the housing stock in Randwick City. The guide signals the local government's development preference for renovation to demolition and redevelopment of ageing apartment buildings. As prefaced by the then Mayor of the Council, the guide calls for "flat owners and architects to apply these concepts and design principles, to upgrade and extend the life of these buildings and enhance the quality of living for the residents" (Randwick City Council, 2006, p. 1). This initiative provides evidence of strategic alignment of the Coogee Waters apartment building renovation with local government visions.

Scope of Work

The renovation project of *Coogee Waters* was an alteration and addition comprised of three distinct parts: 1) remediation and repair of the existing building fabric including brickwork restoration and replacement of doors and windows, 2) removal of existing balconies and rebuilding of larger and more commodious balconies and 3) creation of a new café/restaurant for commercial tenancy under the first residential level through masking the car parking and enclosing the undercroft areas at the ground floor podium level and sub-basement level. **Figure 4-10** illustrates the rough architectural drawing of the building pre-renovation, while **Figure 4-11** depicts the architectural design changes described above.

Figure 4-10 Coogee Waters pre-renovation architectural drawing; Source: MWA Architects

Figure 4-11 Architectural render of the refurbishment proposal; Source: MWA Architects

The first part of the renovation responded to the deteriorating brick façade due to corrosion from extended exposure to salt air, given the proximity of the Site to the sea. **Figure 4-12** shows the state of the brickwork prior to renovation. The treatment of the brick façade through restoration work and replacement of brick ties served as a long-term maintenance strategy to retain the aesthetic appearance and structural integrity of the building envelope. The brickwork restoration also included the replacement of brick spandrels from single-tone to gradient-tone to modernise the design.

The second part of the renovation addressed the lack of amenities associated with older apartment buildings and compliance with minimum requirements for private open space for residential flat buildings. As evidenced in **Figure 4-13**, the pre-renovation size of the balconies had structural limitations, severely limiting their use. This failed to provide the recommended minimum provision of private space and maximise the amenity afforded by the Site and the plan envelope prescribed by Randwick City Council. The balconies provided less than 6sqm of private open space, which is 2sqm short of the required 8sqm

(Randwick City Council, 2012, p. 11). According to the Project Architect during the case study interview, one of the key points in the project brief is for the residents to have larger balconies, “the thing the residents wanted was bigger balconies. They wanted to have lunch and dinner on their balcony.” **Figure 4-14** up to **Figure 4-17** show the demolition and rebuilding of the balconies.

The third aspect of the renovation is the addition of the café/restaurant along Carr Street, which aimed to provide a more defined and activated building frontage to increase the amenity in the public domain and “to provide a more active use of otherwise ‘dead’ space” (Willana Associates, 2014, p. 13).

Figure 4-12 Worn-out façade (North-facing) pre-renovation; Source: MWA Architects

Figure 4-13 Notice to the resident regarding balcony use; Source: MWA Architects

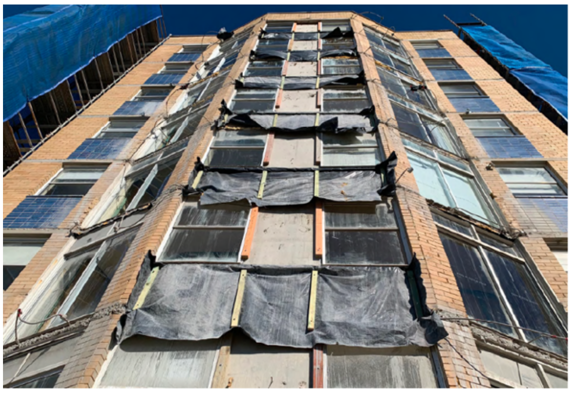

Figure 4-14 Previous balconies sawn off during construction stage, Source: MWA Architects

Figure 4-15 Previous balconies sawn off during construction stage; Source: MWA Architects

Figure 4-16 Rebuilding of new balconies; Source: MWA Architects

Figure 4-17 Rebuilding of new balconies; Source: MWA Architects

Initial proposal

The renovation project spans approximately a decade – from the recorded articulation of the apartment building owners' vision to upgrade the building in 2011 up to project turnover for occupation and use in 2021. In 2011, the Owners Corporation – the legal entity comprising all the owners in the strata scheme of the apartment building – had engaged a different architect for a potential upgrade of the apartment building. The proposed scope of work included the following: 1) enlargement of balconies and replacement of balustrade, 2) enclosure of ground floor level car parking to adaptively reuse for community space, 3) rendering of the external brickwork, and 4) addition of a barrier-free access for "aged and disabled people" along Kurrawa Avenue (Statement of Environmental Effects, 2014, p. 13). **Figure 4-18** illustrates the initial proposal with a rendered façade, circular balcony geometry with rounded column supports, and an enclosed podium with solid masonry elements. A Development Application was lodged in March 2011 following this proposed design. However, based on recorded information, the initial renovation proposal was not approved, and the DA was withdrawn in September 2011.

Figure 4-18 Rendered image of the initial renovation proposal; Source: SEE, 2014

Rezoning of the Site

In 2012, shortly after the DA proposal was withdrawn, the Randwick City Council released the draft Randwick Local Environmental Plan (RLEP) 2012 for public exhibition from February to April 2012. Recorded public submissions identified the rezoning of 58-64 Carr Street Coogee as one of the key issues raised by the community. The additional permitted use of café/restaurant on site is a result of the focused discussion with the Randwick City Council during the community consultation and draft stages of the RLEP 2012 (SEE, 2014). The Draft LEP was amended and put forward for legal drafting in May 2012 and took effect in February 2013.

Renovation project

In April 2013 following the enforcement of the RLEP 2012, the Owners Corporation engaged a new architect (hereinafter referred to as Project Architect) to develop a proposal for the apartment building renovation, including the provision of a ground floor café/restaurant. The Development Application (DA) was then lodged in March 2014 with the proposed plans, as described in the Scope of Work section. The Randwick City Council refused the DA in September 2014 due to non-compliance with Floor Space Ratio standards under RLEP 2012 and objectives and controls specified under RDCP, and adverse impacts on views and amenities of the neighbouring residential flat building. The DA applicants submitted an appeal to the Land and Environmental Court in October 2014, and a hearing was held in January 2015. As a result of the Land and Environmental Court hearing, amendments were made to the plans in February 2015 to respond to issues raised by Randwick City Council. The Project Architect of the DA had a follow-up meeting with Randwick City Council, which led to further amendments to the plan to reduce the impacts on views for the neighbouring residents. The appeal was upheld, and the Development Application was approved through a Land and Environment Court order issued in September 2015. Further amendments were made to the DA to integrate minor design changes, which were approved by the council in August 2018. Detailed design plans were prepared following the Approved DA, and the project issued a Construction tender in March 2017.

The construction phase was divided into two stages: Stage 1 involved the upgrade works including the new café but excluding its fit-out, while Stage 2 covered the works for the café fit-out. During the construction stage of the project, the residents were able to remain in situ, given that the project largely involved external works. Stage 1 commenced in December 2018, followed by Stage 2 in April 2019. The project was completed when the occupation certificate for Stage 2 was issued in March 2021. The café/restaurant tenancy commenced operation in December 2022. **Figure 4-19** illustrates the project timeline.

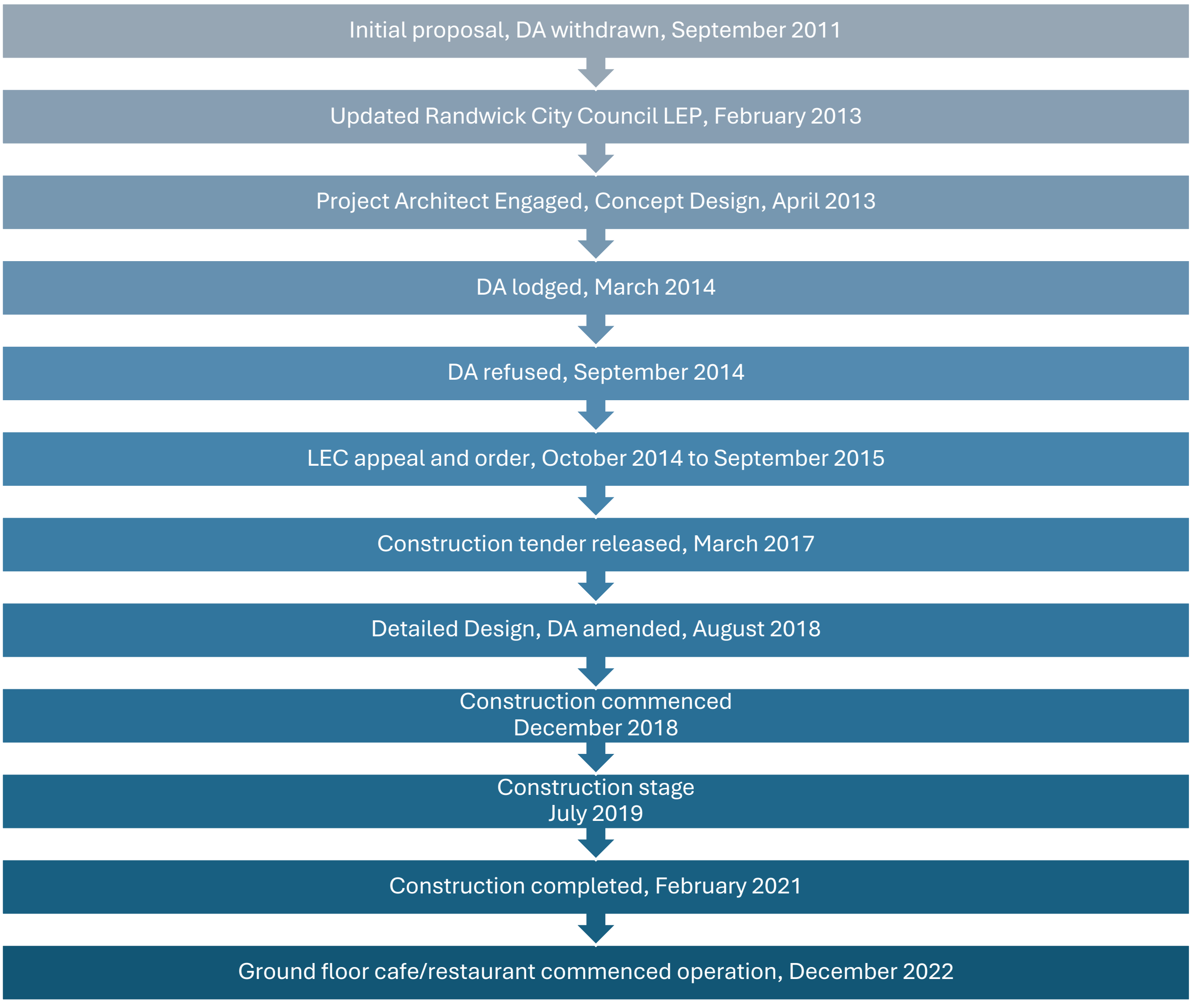

Figure 4-19 Project timeline

Project results and outcomes

The outcomes of the renovation project benefitted both the residents and owners' group as well as the population in the locality. **Figure 4-20** up to **Figure 4-24** show *Coogee Waters* post-renovation. The renovation project resulted in *Coogee Waters* being upgraded and redesigned with modern architectural elements while respecting the original 1960s design. It provided the building residents access to private open space with an area ranging from 13sqm to 31sqm, from less than 6sqm pre-renovation. During construction, residents were permitted to remain on-site, avoiding temporary relocation for existing residents. By retaining and restoring the brick façade, which is representative of apartment buildings of this construction era, the cultural significance and character of the building and the locality is preserved. The café/restaurant operating for seven days a week can serve up to 103 patrons, providing spaces for social interaction for both locals and visitors to the area, while contributing to the local economy through business activities and employment opportunities. The alteration of balconies and addition of the café/restaurant on the ground floor generated social value add by increasing the amenity for the building residents and contributing to urban vibrancy by activating the streetscape, as evidenced in **Figure 4-25** and **Figure 4-26**. The project has been recognised by local government and peak bodies, receiving several awards such as the 2023 Winner of Best Urban Project Randwick Architecture and Urban Design Awards and Highly Commended by the 2021 NSW AIA Award for Heritage Architecture National Trust Awards (Australian Institute of Architects, 2021; Randwick City Council, 2023).

Figure 4-20 Coogee Waters post-renovation, North-West elevation; Source: Anthony Basheer

Figure 4-22 Coogee Waters post-renovation, North-facing facade; Source: Tom Ferguson

Figure 4-21 Coogee Waters post-renovation, West-facing facade and Kurrawa Avenue pedestrian access; Source: Author

Figure 4-23 Outlook from one of the East-facing balconies of Coogee Waters post-renovation; Source: Anthony Basheer

Figure 4-24 Outlook from one of the East-facing balconies of Coogee Waters post-renovation; Source: Participant (Project Architect)

Figure 4-25 Cafe/restaurant overlooking Coogee Bay in operation on the ground floor of Coogee Waters post-renovation; Source: Author

Figure 4-26 Coogee Waters post renovation, North-facing facade and cafe/restaurant in operation showing activated streetscape, Source: Author

CE demonstration

The renovation of *Coogee Waters* exhibited CE principles based on the ReSOLVE framework, although explicit CE targets were not included in the project brief and plans. When the project commenced in 2014, CE adoption in the built environment had not yet gained traction as an industry or policy agenda in Australia and preceded the ReSOLVE framework. However, the analysis revealed that the project succeeded in implementing CE principles through its strategic and sympathetic architectural design. In particular, the principles of Share and Optimise were evident in the project's architectural design decisions. The other ReSOLVE principles were not observed in the project's design and outcomes based on available information. The following sections discuss the implementation evidence and facilitators of Share and Optimise principles such as supportive planning controls and CE-aligned design philosophy. Lastly, it outlines identified opportunities for the unobserved principles in this case.

Share

The Share strategy, *Pooling the usage of assets (S1),* was demonstrated in the project by adding the café/restaurant with landscape views through filling in and masking the common property area in the ground floor level car parking. Enabled by site-specific planning controls and sympathetic architectural design, the project pooled the usage of this previously underutilised common property area and maximised the existing built asset (i.e. apartment building) and intangible assets (i.e. landscape views), as shown in the figures above, to create shared socio-economic value through improved amenity and streetscape. The design was sympathetic to the building's surrounding environment by sharing the coveted outlook of Coogee Bay and reimagining space that benefits the community. The Project Architect was driven by designing buildings that improve not only the amenity of building occupants but also of the urban fabric.

> For us [architects], there are two things that are important. There's the building as an object, but there's also the building as a part of the [urban fabric]. So, the street is almost more important. You can see [pre-renovation], it [the building] has a terrible streetscape. It's very isolated, very detached. (Project Architect, 2024)

As a result of sharing these existing tangible and intangible assets, both the resident group and local community have benefited socially and economically through activated streetscape and improved amenities without adversely impacting the environment, such as clearing land and building separate new structures to provide the same benefits.

Optimise

The project's sympathetic architectural design demonstrated actions that align with the Optimise principle, such as *Prolonging an asset's life (O1)* and *Decreasing resource usage (O2)*. The design respected the building's history by minimising demolition requirements and material usage and preserving the existing structural and aesthetic elements. It is important to note that while both architects who were engaged by the Owners Corporation recognised that the building has good qualities and is in a good condition for its age (Statement of Environmental Effects, 2014) and has architectural merit and urban presence (Fee Proposal, 2014), the sympathetic architectural design of the Project Architect enabled the project to optimise what is already existing on site. The interview revealed that the Project Architect's philosophy was guided by the Burra Charter's preservation, restoration and repair principles: "Changing as much as necessary but as little as possible" (Australia ICOMOS Incorporated, 2013, p. 3). Reflecting on the difference between the design proposal of the initial architect and the approved architectural design, the Project Architect considered that the initial design was not sympathetic enough to the existing building:

> They [initial architect] were trying to change the building fundamentally too much. And so, our approach was to assess the building as it was and to work with it. I guess you could say what we did is to have changes [that are] more strategic and probably more minimal. (Project Architect, 2024)

By adopting the Burra Charter conservation philosophy, the project reduced resource consumption, aligning with the Optimise strategy of *Decreasing resource usage (O2)*, by rejecting the initial architect's proposal to render the brickwork façade. As the Project Architect explained, the initial design could have resulted in higher demand for building materials and higher maintenance costs over the lifespan of the renovated building, "If you render the building, that's a lot more material than you have to paint them and you have to maintain them" (Project Architect, 2024).

With the same philosophy, the project also promoted the longevity and durability of the existing primary face brick fabric through careful maintenance, demonstrating the Optimise strategy *Prolonging an asset's life (O1)*. The scope of work included replacing brick ties to manage corrosion issues and prevent future complications such as cracks or external wall failure. Although the brick ties had to be replaced to maintain the integrity of the external brick wall, the project employed simple, less intrusive building techniques such as manually cleaning the bricks to retain existing materials on site and replacing bricks only as needed. **Figure 4-27** up to **Figure 4-29** show site photos of the brick restoration. The Project Architect described the careful manner by which the existing bricks that characterise the building were restored:

> [There's] very strong, very good, beautiful bricks. So we wash them with hot [water] on every floor. And the brick tie comes from [the] outside [then] through the cavity into the other brick. Then you get the dust from the bricks, you mix that with mortar and you plug the hole. So that was careful to be restored. (Project Architect, 2024)

The sympathetic design also extended to material specification. For instance, the surrounding environment informed the material specification to ensure longevity and durability of the building and its new components. The interviews and architectural documents showed that the material specification considered the severe coastal location of *Coogee Waters*. Some strategies that the project implemented included sealing the concrete, minimising the steel, and paint specification on the steel that reduce material corrosion risk and associated complications.

Figure 4-27 Brick ties being replaced with drill holes visible; Source: Project Architect

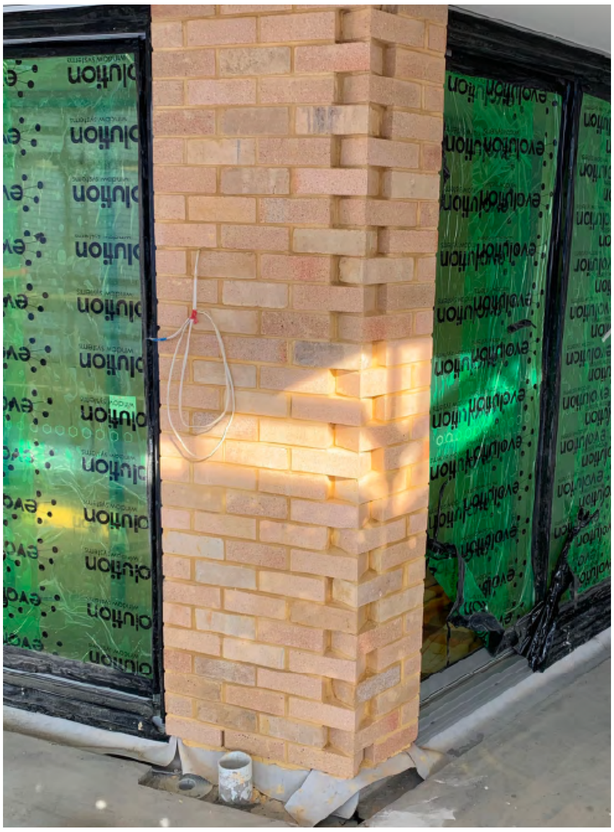

Figure 4-28 Bricks carefully cleaned and restored with brick ties disguised with mortar; Source: Project Architect

Figure 4-29 Artist's board for brick colour matching; Source: Project Architect

Opportunities for Regeneration, Loop, Virtualise, Exchange principles

Several opportunities for other CE principles that, in hindsight, could have been implemented in the case and can point to opportunities for future projects. First, while the renovation enabled further appreciation of nature through better access to open space and landscape views, regenerative design did not appear to be a priority of the project. To render the building more regenerative while keeping the scope within the client's requirements, on-site renewable energy strategy, closed-loop on-site water collection, treatment and use, and biodiversity-positive design could be explored. Regenerative design could also be integrated by identifying design opportunities for Connecting with Country. Second, the Loop principle could be easily realised by a salvage and reuse or recycling strategy from the demolished balconies and bricks to eliminate waste. While there was no indication of salvaging materials for off-site reuse or recycling based on available project information, future renovation projects could integrate an audit of salvageable and recyclable materials and develop a deconstruction plan to ensure 100% landfill diversion of construction waste. Moreover, a Design for Disassembly strategy for the new balconies could also strengthen the Loop principle to allow for easier future balcony upgrades or changes without demolition waste and for disassembly and recovery of materials for remanufacturing or refurbishing, or recycling. The interview revealed openness from the Project Architect's side regarding the deconstruction and reuse of building materials. Referring to the idea of deconstructing the old balconies as part of the specification, the Project Architect admitted: "*We didn't get into that. But you know what, we would do that now.*" Third, the Virtualise principle could be adopted by using the renovation opportunity to create a Digital twin or building passport for future renovations, given the extensive study undertaken for the building. Existing technologies and techniques could also assist the project with life cycle analysis and embodied carbon studies, which promote the Virtualise principle in renovation projects. Lastly, the Exchange principle could be practised by considering alternative materials that are renewable and low carbon or carbon-neutral for the additional elements added to the building and installation of renewable energy resources on site. Existing building frameworks or certifications that prohibit the use of harmful products could be utilised to ensure material specification considers embodied carbon and hazard risk.

Case themes

This section presents several emergent themes that synthesise the lessons learned from this case to strengthen the understanding of the enabling factors of CE implementation and its implications. These themes include the architect's agency, project team collaboration, latency of CE adoption, and the social value of CE practices. The following sections discuss these themes and their implications for future research, practice, and policy.

Agency of the architect and role of design in delivering CE outcomes

The case study revealed the ways in which the architect can exercise agency and play a driving role in facilitating CE adoption in apartment building renovation. This supports the findings from **Chapter 3** that agency influences the role of the architect in a CE. It underscored the impact of the architectural design on project material demand and longevity of the existing building and its components through thoughtful material specification. First, the Project Architect's overarching design philosophy – which profoundly influences and guides their approach to renovation – appeared to be crucial in promoting CE outcomes in the project. Specifically, by aligning with the principles of heritage conservation of the Burra Charter, the Project Architect delivered a sympathetic design and renovation option for the client that allowed the restoration of the existing apartment building and value creation for the residents and the locality. Second, the architect's framing or narrative around the significance of the apartment building and its unique character to the broader urban fabric successfully influenced clients and project contractors to align with their design proposal. The display of agency was evident in the retention of the glazed brick spandrels, which were a key aesthetic feature of the building, but the client no longer deemed desirable. However, by suggesting a minimal design solution such as replacing the single tone glazed spandrels with a gradient tone of the original cobalt blue glaze, the Project Architect enabled the retention of the building's unique design features while meeting client requirements. As the Project Architect explained, "they [Owners Corporation] hated the brick. And we [architectural team] talked them into [the idea of aggradation], so they love that because it seemed a bit more trendy and it's nice. So then, we changed the spandrels, and we worked with the company [glazed brick supplier]." The Project Architect was also able to exercise their agency by creating a narrative around ease of maintenance as a long-term strategy to convince clients to agree with their design proposal, which excludes external brickwork rendering. The Project Architect emphasised, *"We tried not to argue on [aesthetics]. We argue about maintenance... [we've] actually reminded them that they should be washing the steel work"* to avoid salt build-up and care for it to maintain its good condition. Architect agency demonstrated in the case of *Coogee Waters* renovation supports the findings in **Chapter 3** on the role of the architect in the CE transition.

The case study also indicated the importance of contractual arrangements in the project. As the Project Architect explained, *"In this project, we were engaged as architects before the builder and the project manager... We did 90% of the documentation."* This form of engagement afforded the architect the opportunity for in-depth analysis of the building and the Site and an extensive exploration of potential renovation solutions. By having the documentation almost completed before engaging with a builder and a project manager, the project was able to exhaust options and identify the most suitable and feasible solution prior to commencement of any building works. This type of contractual arrangement also allows for safeguarding the architectural design through to construction. The importance of design and engaging the architect as early as possible to minimise cost and maximise value is highlighted, "Carefully, fully Document. Design is much cheaper than building, especially once on site (Project Architect, 2024)." This finding aligns with the results in **Chapter 3**, which emphasises that importance of administering suitable contractual arrangements to enable CE implementation.

Collaboration among project team

While the architect may have played a driving role in unconsciously adopting CE, the analysis revealed that collaboration amongst the broader project team and client remained a key enabling element for a CE-aligned architectural design of the *Coogee Waters* renovation project. In particular, the approved design of the enlarged balconies and ground floor level café/restaurant was a result of a collaborative approach between the Project Architect and a Structural Engineer. The initial fee proposal of the Project Architect demonstrated that there was foresight to engage an engineer: "a preliminary site visit with an engineer to inspect the building will be critical to the formulation of the design." Based on the interview, the architect engaged a structural engineer early on during the Pre-DA stage to assist with the structural requirements of the balcony studies. Post-renovation, the Project Architect reflected on the instrumental role of project Structural Engineer during the design phase, "He was fantastic. I couldn't have done it… [the structure] was a major [element], which influenced the design." This finding corroborates the enablers identified in **Chapter 3** that collaboration within project teams is crucial.

The collaborative approach continued through to the construction stage. Collaboration is highlighted not only for the implementation of CE initiatives but a crucial factor in apartment building renovation. As the experience of the Project Architect reveals, successful renovation of apartment buildings that largely retain existing components of the building entails consistent collaboration and good relationships with the project team to deliver the intended outcomes of the project. The findings corroborate collaboration as an enabler, as identified in **Chapter 3**.

> The foreman was very good. The engineer as very good. I think our documentation was good… After we got the DA, we then engaged an engineer. And we worked with the engineer, services, PCA. Fire access is extremely complex because we were putting a different class, leaving a restaurant between Car Park, which is another class and a residential building, which is another class. So it was so complicated. Anyway, we did 90% of the documentation. Then, we went out to tender to three builders, we then got the project manager to help us with the contract and to help us with assessment of the tenants. (Project Architect, 2024).

Embracing idiosyncrasy - preserving and creating value from the existing

The design intent to preserve and create value from what is already existing – both the physical aspects of the building itself and its surrounding environment – enabled the project to align with CE principles. This intent was evident in the initial fee proposal by the Project Architect, which emphasised that a measured study is necessary. Value preservation and creation were achieved by recognising and embracing these idiosyncrasies of the existing tangible and intangible resources on site.

> The key to this project is to have a proper measured study of the existing building. This study will show the existing floor plans, elevations and sections of the building, as well as some detail at the entry areas. A measured study will allow an appreciation of the building's character and be a sound starting point for the new additional elements. The measured study is also a vital tool for all subsequent stages including construction documentation and so will allow for more resolved details along the way. (Project Architect. 2024)

This finding suggests that circular renovation – as opposed to the business-as-usual renovation – presents a broader proposition for the architectural profession, as existing buildings abound with idiosyncrasies that require deeper analysis and design considerations. This supports the findings in **Chapter 3** that circular renovation provides an opportunity for increased demand for architectural services. Circular renovation would require the architectural profession to have a higher degree of creative yet technical competency due to a more constrained and nuanced environment to address the unique issues and augment the value of existing buildings. Beyond the creative and technical aspects, creating a socially compelling narrative for the building becomes a crucial task for the architect to influence circular outcomes and foster a sense of care and preservation amongst other stakeholders. This corroborates the sub-theme discussed in **Chapter 3** that CE practices drive an evolving role for the architectural profession and substantiates previous research citing that architects will need to be equipped with leadership and communication skills apart from technical knowledge to become pivotal in CE adoption (2020).

> For other projects like [Coogee Waters], you're really dealing with something that's a bit more idiosyncratic, and so there's a limit to what you can do. You try to design things that are simple and durable. I think that's a good start when you're dealing with idiosyncrasy.

Latent adoption and formalisation of CE – making the invisible visible

The case study analysis revealed that CE adoption and its value-add may be latent and require uncovering, corroborating Holmes et al.'s (2021) assertion that there are hidden places that CE may inhabit. During the *Coogee Waters* renovation project from 2013 to 2020, CE was not yet embedded in policy and the industry agenda in Australia. Explicit articulations of CE aspirations in building projects were little to none. Despite having no formal and deliberate articulation of CE visions in the project, the analysis showed that the project was able to implement CE. This aligns with Participant 1's assertion in **Chapter 3** that CE is being practised in some form but remains on the sidelines. Therefore, the formalisation – or the practice of identifying, naming and disseminating - CE implementation strategies is crucial for their wider adoption. Hence, further research on grassroots innovation (Smith et al., 2014), where CE intent and implementation may not be visible but actually flourish, albeit under the radar, is essential to expand the understanding of CE and its practical applications. In addition, metrics and methodologies that allow these projects to be grounded with quantitative evidence (e.g. embodied carbon calculations) are also essential. Future research may focus on retrospective measurement of carbon and the cost of other renovation projects to build empirical evidence of circular renovation. The analysis also uncovered social outcomes arising from a CE approach that are often overlooked. This points to the opportunity to link and further explore the social value generated through a CE approach to broaden its social awareness and acceptance.

Furthermore, the analysis determined that the project was guided by existing design principles and practices that intrinsically align with CE. For example, the Burra Charter principles on Heritage Conservation, while dedicated to heritage buildings, still held influence over the renovation of the apartment building. This finding suggests that principle-led design practice and decision-making may be more effective in promoting CE amongst architects, corroborating **Chapter 2** findings that SBRS presented as a set of design principles can be more pivotal in shifting design thinking than rigid point-based SBRS. For instance, LBC's framing as a philosophy afforded the architects creative freedom with their design while delivering the technical requirements specified by LBC. There is an opportunity to bring these existing CE-aligned design philosophies to the forefront and incentivise their broader adoption to harness their potential in shifting design culture and philosophy towards CE.

4.3.2 Catherine Commons

Case description

Project aims

Catherine Commons Deconstruction Project involved the deconstruction, transport, processing, and recirculation of building materials salvaged from the 1910 residential building at 206 College Avenue. It is considered a pilot demonstration project for local deconstruction and material reuse as an alternative to the business-as-usual practice of building demolition and disposal. Specifically, the project aimed to "investigate the circular potentials of the local built environment by researching and proposing methods for material reuse and recycling, reversible construction, reactivating embodied values, creating green jobs, and reinventing the underlying business models of construction" (Circular Construction Lab, 2022a). The project was organised and financed by the Cornell Construction Lab in collaboration with a broad partner network of industry and non-government organisations (Circular Construction Lab, 2022a). The network consisted of industry partners, university institutions, built environment consultancies and local community organisations including Cornell University Circular Construction Lab, Finger Lakes Reuse (a local reuse facility and organisation based in Ithaca), SC Johnson College of Business, Ithaca Neighbourhood Housing Services (NHS), Cornell

Cooperative Extension, TAITEM Engineering, and Trade Design Build (Circular Construction Lab, 2022a). The project proponents are also members of the advocacy group and collaborative network Circularity, Reuse, Zero-Waste Development (CR0WD) comprised of community leaders, professionals, policymakers researchers advocating for circular built environment across New York State (The Crowd Network, n.d.).

Figure 4-30 Buildings slated for demolition as part of the Planned Unit Development, 206 College Avenue as part of Catherine South Site (TWLA Architects, 2020, p. 19)

Scope of work and project timeline

In November 2020, a Planned Unit Development (PUD) Application was lodged with the City of Ithaca to redevelop parcels of land in Collegetown. A PUD application allows for flexible rezoning of a site typically used for comprehensive mixed-use developments proposals (City of Ithaca, n.d.). The proposed development within the PUD application aggregated 17 parcels of land to form the Collegetown Innovation District with five building sites across the neighbourhood. 206 College Avenue was part of one of the building sites, Catherine South, which was identified in the first phase of the proposed development. In 2022, 206 College Avenue, along with 10 other vacant houses in the area, were slated for demolition to allow for the proposed 440 new rental housing units under Phase 1 of the College Innovation District PUD.

Before the planned demolition of the houses within the Phase 1 Collegetown Innovation District sites, the network proposed to the principal developer of the Collegetown Innovation District to have one of the 11 houses entirely deconstructed rather than demolished as a comparative case study of demolition and deconstruction. The principal developer agreed to the proposal with the condition that the deconstruction process would take no longer than the demolition of the other adjacent houses, which gave a timeline of five (5) working days to complete the deconstruction process (Heisel et al., 2023).

In 2022, a pre-deconstruction site survey was conducted to audit the building. The site survey was conducted by researchers from Circular Construction Lab and students from the Cornell University Department of Architecture (Heisel et al., 2022). A short workshop was held prior to the site visit to train the students regarding the site survey tool. A combination of on-site survey form (i.e. questionnaire requiring quantitative and qualitative data such as material type and dimension through user input) and a Light Detection and Ranging (LiDAR) technology using LiDAR-equipped Apple iPad Pros were used to scan, record and create a digital model of the building (Heisel et al., 2022).

The LiDAR scans taken by the researchers and students were processed using Rhinoceros3D, a CAD modelling software used in the architecture and construction industries, and Grasshopper, a visual programming language that turns Rhinoceros 3D into a parametric design tool. The use of Rhinoceros and Grasshopper plug-in generated an estimated surface model of the building with material estimates based on automated categories (i.e. Floor, Wall, Ceiling, Roof, Stairs). The values for each category are exported into a spreadsheet file and linked to the data from the survey form. The composite data from the survey form and LiDAR scans are referenced against a library of archetype constructions, which then generates a material assessment for the building in volume and mass measures. From the material assessment, further calculations and estimates were made, such as embodied carbon, material intensity, and total material tonnage, that can inform the deconstruction process. The estimated material quantities from the material assessment also served as a baseline to compare the actual quantities of salvaged and processed materials during the deconstruction (Heisel et al., 2023, 2022).

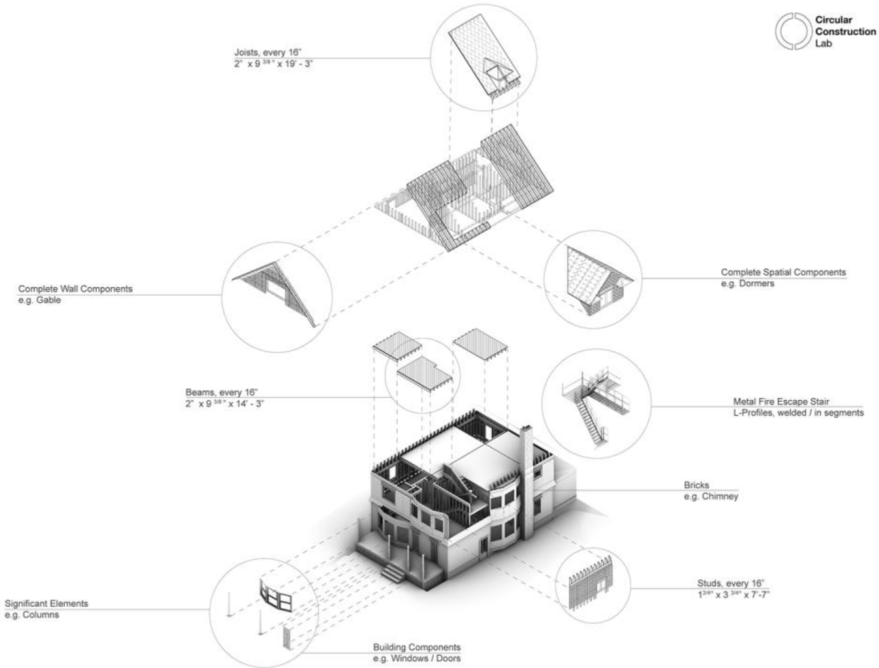

Figure 4-31 206 College Avenue digital model (Circular Construction Lab, 2022a)

The deconstruction process began in January 2022 and was carried out by a crew of 8 workers over the course of 5 working days. The deconstruction team was composed of Cornell University researchers, local workers and apprentices, professional tradespeople, and a deconstruction consultant. The deconstruction consultant, *Building Deconstruction Institute,* played an instrumental role in identifying the appropriate deconstruction method and guiding the deconstruction process on site, including precise cutting and segmenting of the structure to maximise its reuse potential. **Table 4-2** outlines the labour involved in the on-site deconstruction and off-site processing.

Table 4-2 Deconstruction Labour Requirements (Heisel et al., 2023)

Organisation	Description	Number of workers
Finger Lakes Reuse	Local reuse center and charitable organisation	11
Local Laborers 785 (contracted through Finger Lakes Reuse)	Union workers	7
Trade Design Build (contracted through Finger Lakes Reuse)	Architecture and construction consulting firm	3
Building Deconstruction Institute	Deconstruction consulting firm	1

First, soft stripping was undertaken by volunteers from community organisations *Finger Lakes Reuse* and *Historic Ithaca/Significant Elements* to salvage high value elements. Then, the interior plaster, window trims, glazing and other architectural features were removed carefully by local carpenters (*Local Labourers 785*), while the deconstruction of the structural elements were undertaken by building professionals from Trade Design Build, with guidance from the Seattle-based *Building Deconstruction Institute*. The mechanically supported panelised deconstruction process started from the attic working downwards, first removing the exterior walls, followed by interior walls, floors and stairs for each level. The building components were then transported and stored in the local reuse facility. The materials were processed, including de-nailing, cleaning, sorting, and inventorying, before being put up for sale at the local reuse centre. While the deconstruction only employed unionised labour, most of the soft-stripping and de-nailing were carried out through volunteer labour. The scope for deconstruction excluded cast-in-place concrete basement walls and foundations – as they remained in place to stabilise the sloped site. **Figure 4-32** up to **Figure 4-34** show the deconstruction process.

Figure 4-32 Deconstruction in Progress; Source: Felix Heisel (Circular Construction Lab, 2022a)

Figure 4-33 Preparing the building for deconstruction; Source: Joseph McGranahan (Circular Construction Lab, 2022a)

Figure 4-34 Deconstruction panel, Source: Felix Heisel (Circular Construction Lab, 2022a)

Project results and outcomes

Several environmental and socio-economic outcomes were observed and measured from the deconstruction effort. The project provided an indication of the carbon and labour impacts of deconstruction. In comparison to demolition, the deconstruction process resulted in less lifecycle emissions and higher carbon saving potential but entailed higher costs and labour requirements. The analysis showed that the deconstruction pathway had potential knock-on effects on workforce training, higher-order learning opportunities, and built heritage conservation, which are lacking in a demolition pathway.

Based on environmental impact indicators, the project was able to salvage and reuse 1.205 metric tons of concrete, 25.461 metric tons of dimensional lumber, 8.840 metric tons of hardwood flooring and trim and 0.275 metric tons of glazing, totalling 35.506 metric tons of building materials (Heisel et al., 2023). This deconstruction effort translates to 3.793 metric tons CO2E (carbon dioxide equivalent) of carbon emissions from Phase C1-C4, -9.448 metric tons CO2E from carbon storage (Phase C104), -8.243 metric tons CO2E of carbon savings from reuse (Phase D), and -60.771 metric tons CO2E of sequestered carbon from reuse (Phase D). In comparison, demolition resulted in 10.887 metric tons CO2E of carbon emissions from Phase C1-C4, -49.527 metric tons CO2E of carbon storage from Phase C1-C4, and zero carbon savings from reuse (Phase D) (Heisel et al., 2023). The results indicate that the deconstruction pathway resulted in less direct emissions from building removal, transport and landfill operation compared to the demolition pathway. **Figure 4-35** shows the comparison of the environmental and economic impacts of demolition vis-à-vis deconstruction from the case study. Heisel et al. (2023) argues that the environmental impacts of deconstruction in terms of carbon emissions, storage and savings will depend on the construction type of the building. For instance, deconstruction of steel-structured apartment buildings may result in higher carbon savings and storage due to the higher embodied carbon of steel compared to timber-structured buildings as in the case of *Catherine Commons*, but deconstruction involving heavy steel materials may entail higher deconstruction costs (Heisel et al., 2023).

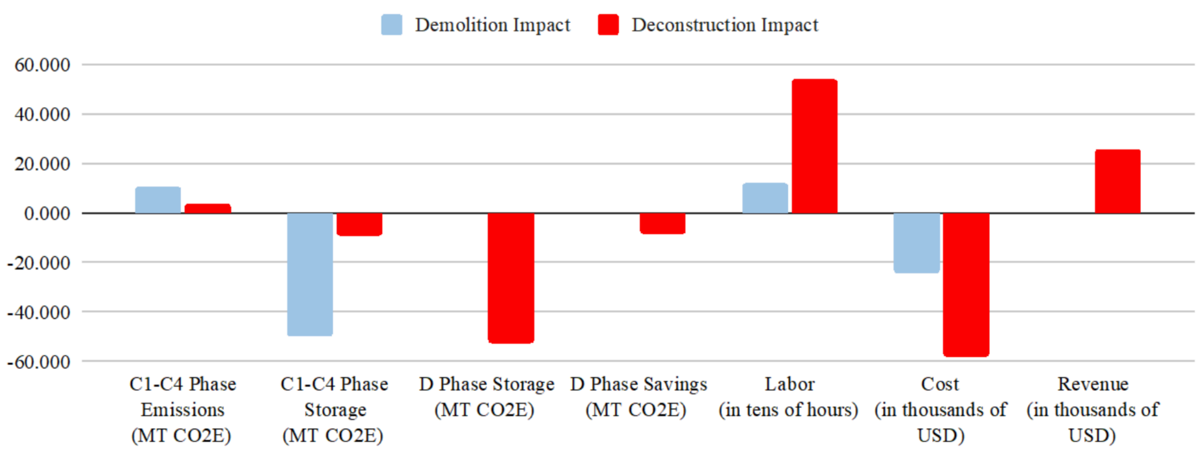

Figure 4-35 Comparison of the Impact between demolition and deconstruction; Image sourced from (Heisel et al., 2023, p. 5)

In socio-economic terms, the project generated 543.5 paid and volunteer labour hours in comparison to demolition, which was allocated only 48 labour hours. (Heisel et al., 2023). While actual sales revenue data from salvaged materials are not fully available yet, the project estimated additional revenue of approximately $26,172 from the sale of salvaged materials for the local reuse centre/charitable organisation (Finger Lakes Reuse) (Heisel et al., 2023). It also facilitated the preservation of architectural elements with historical and cultural value through the sole built heritage preservation organisation in the local area, Historic Ithaca and its non-profit architectural salvage store Significant elements (Historic Ithaca, n.d.). In addition to job creation, revenue generation and historical preservation, the project also contributed to workforce training and development from the diffusion of knowledge of the deconstruction consultant to the local apprentices and tradespeople. It also offered both learning opportunities to Cornell University architecture students and partner networks, as facilitated by CCL researchers through the site survey exercise and Circulating Matters initiative. The initiative directly reused timber elements from the salvage effort, reactivating embodied values from these materials to design and construct an outdoor installation with CE principles as part of an architectural studio course at University of Cornell (Circular Construction Lab, 2022b) **Figure 4-36** shows the salvaged materials in the depot while **Figure 4-37** and **Figure 4-38** show the Ithaca ReUse Center.

Figure 4-36 Material depot; Source: Joseph McGranahan (Circular Construction Lab, 2022a)

Figure 4-37 Ithaca ReUse Center; Source: Author, 2023

Figure 4-38 Salvaged doors for sale at Ithaca ReUse Center; Source: Author, 2023

CE implementation

The Catherine Commons Deconstruction Project exhibited the Share, Loop, Virtualise and Exchange principles of CE. While the Regenerate and Optimise principles were not deliberately implemented, some project outcomes indirectly promote these two principles through carbon savings potential and sequestration from reused materials. The following sections expound on how Share, Loop, Virtualise and Exchange principles were demonstrated in the case and discuss factors that facilitated the implementation, such as community action, expert knowledge, and supportive infrastructure.

Share principle

The Share principle, particularly the *Reusing assets (S2)* strategy, was strongly evident in the project's articulation of aims and outcomes. As mentioned in the Case description, the project explicitly aimed to explore the circular potentials of local building stock and propose methods for local material reuse. Enabled by the mobilisation of community volunteers and guidance of a deconstruction specialist, material reuse was implemented through a two-stage approach: 1) soft-stripping undertaken by volunteers, which involves removing and salvaging non-structural elements on site and 2) panelised deconstruction of the building's structure carried out by building professionals to "preserve as much lumber as possible". As described in the deconstruction methods by Heisel et al., *"An initial salvage effort was conducted by Finger Lakes Reuse and Historic Ithaca/Significant Elements volunteers, taking easily removable high-value elements and transporting them offsite to be de-nailed and/or processed. Following close behind was a team of carpenters from Trade Design Build under the guidance of the Building Deconstruction Institute, making precise cuts into the structure, segmenting the building into panels which could be strapped to a telehandler, tilted and then lifted from the building as components."* (Heisel et al., 2023, p. 2). The careful and methodical deconstruction of each building component ensured that the salvaged materials could be reused to their maximum potential.

Loop principle

Similar to the Share principle, the Loop principle was clearly articulated in the aims of the project and evidenced in its outcomes. The Loop principle, specifically *Remanufacturing and refurbishing products and components (L1)* was demonstrated through processing and repurposing of the salvaged materials for various uses. For instance, a portion of the salvaged timber elements were directly reused as structural members in a Designed for Disassembly spatial folly titled, Circulating Matters, constructed by Circular Construction Lab for the 2022 Cornell Biennale of the Arts (Circular Construction Lab, 2022b).

While data on how each of the salvaged materials was processed remained limited, the refurbishment of the salvaged products was made possible by two enabling factors: 1) community mobilisation and 2) local government infrastructure and support through provision of warehouse facilities to store and process the salvaged materials. First, while the methodical deconstruction was conducted by professional tradespeople under a salary or contract, the soft-stripping process – majority of which involved de-nailing lumber – was undertaken by community volunteers, underscoring that deconstruction is a labour-intensive process. Second, the availability of a warehouse was an essential resource to process and store the salvage the materials for resale. As described by Heisel et al., regarding the processing, "all panels and materials were transported by flatbed truck to a warehouse of Finger Lakes ReUse, where they were stacked, before being processed (cleaned, denailed, sorted, stacked, inventoried) and finally offered for sale at the local ReUse Centers." (Heisel et al., 2023, p. 2) Evidence indicated that the warehouse was secured with the assistance of local government and private donors (Dean, 2022). The key role of local storage and processing facilities, in this case, suggests that localised infrastructure and support are critical to enable material reuse and develop the secondary material market economy. This supports the spatially explicit approach of Tsui et al.(2024) to developing circular built environment by identifying parameters for circular construction lab based on resources, availability, land use, and socio-economic factors to determine future locations of circular construction hubs, which would allow cases like *Catherine Commons* to be easily replicated.

Virtualise and Exchange principle

Alignment with CE principles was observed in the project through the Virtualise principle's *Delivering services remotely (V3)* strategy and the Exchange principle's *Replacing traditional solutions with advanced technology (E3) strategy.* The project's demonstration of these two principles was linked as it promoted both advanced solutions and digitalisation in architectural and construction practices. It adopted an alternative method to site survey and material audit through advanced technology (*E3)* and harnessed digital technology and tools *(V3)* in the alternative method to facilitate the deconstruction process.

The site survey and material audit undertaken before the deconstruction adopted emerging digital technologies that facilitated more advanced modelling and analysis to inform the deconstruction project. While not entirely replacing traditional solutions such as manually documenting tape-measured distances and onsite sketches, the project built on existing solutions and adopted an alternative method, the *ScanR* method, which combines several digital technologies to provide critical information about the harvest of materials and planning of the materials' next use cycle (Heisel et al., 2022). Developed through Circular Construction Lab's expert knowledge and skills in architectural design and computing, *ScanR* involves employing digital survey questionnaires, harnessing easily accessible LiDAR and photogrammetry scanning technology that produces 3D scans of buildings, and integrating 3D architectural modelling applications (i.e. Rhinoceros3D) with an advanced parametric design tool (i.e. Grasshopper), reducing survey time and potential user error. The output of the *ScanR* is a "hybrid Excel spreadsheet of quantitative and qualitative data, initial calculations, and summary metrics and graphs to provide users with an outline for potential material salvage and building deconstruction after as little as 30 minutes of being on-site" (Heisel et al., 2022, p. 4). The *ScanR* method generated a more accurate digital model of the building more efficiently, serving not only the deconstruction project but also as a reference for future practical or educational use. The involvement of Circular Construction Lab as a key university-based proponent of the project facilitated the deployment of *ScanR* as a new method and enabled the implementation of the Virtualise and Exchange principles in the project.

Case Themes

This section discusses several emergent themes from the *Catherine Commons* deconstruction project that provide insights into the enabling factors that influence CE implementation in this context. The themes identified were community-driven CE implementation, top-down facilitation and urban-scale planning implications, and workforce development and business implications. Their research, policy, and practice implications are then explored.

Community-driven CE implementation and social value-add

The *Catherine Commons* deconstruction project showed that CE implementation, including demonstration projects, can be community-led, resembling grassroots innovation (Smith et al., 2014). The coalition of local community organisations as project proponents and the CR0WD network proved to be a driving force in project feasibility and delivery. These community champions and CE advocates – through their network – facilitated the identification of potential deconstruction sites, negotiation with the principal land developer to allow deconstruction, and the subsequent deconstruction, processing, and resale of the salvaged building materials. In addition, the mobilisation of community members provided important volunteer labour for the refurbishment of salvaged materials. This finding highlights the potential of bottom-up initiatives for demonstrating CE and the presence of an engaged community and mission-oriented approach (Schandl et al., 2025) to CE adoption as enabling conditions. The finding corroborates existing research that civil participation and community empowerment are crucial but often overlooked facets of the CE transition (Dyer et al., 2021; Liu, 2024), underscoring the need for a more socially just and empowered approach to the transition.

Moreover, the case study underscores that the labour-intensive nature of a CE approach allows for decoupling building practices from resource and energy intensity, providing evidence to previous research claims (Llorente-González and Vence, 2020). In contrast with demolition, the case study demonstrated that a CE approach can have social value-add through generating green trade jobs and significantly more labour hours from the deconstruction process through to downstream processes (e.g. cleaning and sorting) of secondary materials. However, the case study interview revealed that organisations in the salvage and reuse markets are typically non-profit and face financial and technical barriers in upscaling operations. The interview findings revealed that, while there is market appetite, the limited capacity and resources in operating systems that would facilitate the entire deconstruction to resale process hinder large-scale sorting and storage. This indicates that stronger and concerted government and industry support may be required to build the capacity of local reuse centres and community reuse organisations (Lane and Allen, 2024).

Lastly, the organisational structure of reuse centres indicated potential to augment the social impact of CE through socially responsible business or operational models within the salvage and reuse supply chain. In the case study, the local reuse organisation identifies as community-centred charitable organisation that advocates for waste reduction, material reuse and local sustainable development while providing employment and training opportunities for marginalised local workforce (Ithaca ReUse, n.d.). In addition to CE implementation being community-led, it can also be community-focused through the development of reuse facilities as social hubs and reuse organisations as social enterprises – facilitating capacity building, knowledge sharing, and advocacy for circular building practices among community members that can lead to positive CE narratives and broader cultural shift.

Top-down facilitation and urban-scale planning implications

The case study analysis signalled the role that governments and institutions play in CE adoption. While the case study demonstrated a bottom-up example of CE implementation, top-down facilitation through grant funding and local infrastructure support was fundamental to the delivery of the community-led demonstration project. In the case study, top-down facilitation occurred through the Engage Cornell Grant and the support of the City of Ithaca and Tompkins County to the local reuse organisation. This suggests that although CE implementation may be instigated from the community level, which grants social and cognitive protection to the project, some other form of protection, such as institutional or economic in nature, provide additional short-term support critical to the success of the project.

In the long term, local governments also play an important role to scale these grassroots initiatives up. The case study identified important infrastructure prerequisites for deconstruction and alludes to urban planning implications. In particular, the case study revealed that the availability of local space for a reuse facility allowed the storage and processing of materials not readily resold and recirculated to the market. Without such critical infrastructure, the deconstruction cost would be higher to allow for storage expenses and transport costs, thereby challenging parity with demolition in terms of upfront financial costs. This implies supporting spatially-appropriate infrastructure that are required for secondary materials market to flourish (Tsui et al., 2024). Local governments aiming to transition to an urban or city-scale CE need to consider land requirements for secondary material infrastructure and the location of such to minimise the associated emissions and financial cost of transportation. This finding emphasises that while CE remains a global agenda, CE adoption still requires localised solutions and government action.

Workforce development and business implications

Existing literature, and as discussed in **Chapter 3**, determined that circular practices will require a different set of skills from the workforce and a different set of operational models and insurances for businesses (Fairbrother and Banks, 2024; Sumter et al., 2020). The case study findings expound on the implications of CE implementation to the workforce and local businesses. Different modes of capacity building and business transformation should be explored to empower businesses to pivot to circular business models and to re-skill or upskill workers.

Circular practices imply changes to business operations, but a shift to CE does not necessarily result in business loss. In contrast, CE adoption indicates an opportunity for internal transformation of business models. For instance, deconstruction offers demolition contractors to shift their key services through reskilling of workers, without requiring capital expenditure for deconstruction equipment. Furthermore, specific expert skills were favoured in a CE approach. However, this can be overcome through capacity building, which may occur informally through expert knowledge diffusion in practice, as shown in the case study. For instance, a critical factor to the success of the project was the engagement of a deconstruction specialist. Without such expert input, the deconstruction techniques would be limited, which would affect the quality of the salvaged materials. This implies that a shift to CE may increase demand for certain expert knowledge and services and a steep learning curve for non-experts. However, as knowledge diffusion happens, the steep learning curve and expert demand would decrease. Capacity building may also occur through formal institutional pathways. In the case study, educational institution involvement in the grassroots initiative did not only provide the platform for first-order learning – or technical-focused learning – but also increased opportunity to instigate higher-order learning involving deeper reflection and learning, which could lead to transformative cultural change. This implies that educational institution involvement, particularly in the grassroots model of CE implementation, carries wide impacts on workforce development and capacity building.

4.4 Discussion

The analysis of the two case studies resulted in four key issues that may have implications for future CE demonstration projects and future research in this area. These issues include potentially common drivers of and challenges in apartment building renovation projects, geographical implications of architectural renovation, and the influence of local planning provisions on demonstration projects.

First, Case Study 1 identified the motivators for renovation and challenges with this specific building typology (i.e. medium density apartment building with exposed brick façade) and its locational context (i.e. coastal areas). The findings revealed that the client was mainly driven to renovate by social factors such as the need or desire for better amenity in their building. This social need is reflected in the addition of enlarged balconies with new doors and windows, activated frontage through the addition of café/restaurant, and maintenance measures to the façade to ensure its integrity and resident safety. Furthermore, the case study showed that a typical issue with this building archetype in a coastal location is atmospheric corrosion of building materials that may compromise the building's structural integrity. Future research can build on these findings with a larger case study sample to identify leading drivers for renovation and corresponding circular renovation strategies to address common issues for building archetypes. To scale circular renovation efforts, future research may also attempt to estimate the type and quantum of building materials that are disposed of and required by renovating apartment buildings of this construction archetype to serve as a benchmark for future renovation projects. Moreover, the case analysis also indicated that apartment building renovation projects can be complex and extend for a long period (e.g. 10 years), which could risk CE adoption being deprioritised or falling through during the project. Future case study research may focus on ongoing apartment building renovation projects to monitor and analyse the impact of project duration on CE visioning and implementation.

Second, the analysis suggests potential geographical implications on the scope of work and economic feasibility of the renovation project. For Coogee Waters, the access to coastal views implied higher property value of the building and its units pre- and pos-renovation, which served as a financial enabler for the renovation project. The Project Architect alluded that "if you're building does not have a view, it may be harder to pay for the work." The impact of views and geographical differences on property value may exacerbate existing spatial equity issues with regards to opportunities to renovate existing ageing apartment buildings (Randolph, 2002). Apartment buildings located in areas of lower socio-economic status that lack the desired nature views are not afforded the same socio-economic leverage that coastal apartment buildings have, which may discourage renovation efforts due to limited financial capacity and lead to further deterioration of existing buildings in these areas. Further research is required to ensure future policies, particularly monetary and fiscal instruments for renovation, address these equity issues. Conversely, potential gentrification issues associated with architectural renovation of ageing apartment buildings, particularly in low socio-economic areas should also be examined to ensure a just transition.

Third, local planning provisions were identified as an enabling factor in the case of Coogee Waters and Catherine Commons. For Coogee Waters, the Randwick City Council publicly promoted the design excellence in the renovation of ageing apartment buildings through published manuals and allowed for site-specific additional use in accordance. This highlights that supportive local strategic and statutory planning policies are needed to 1) facilitate renovation projects but also 2) incentivise a CE approach in doing so. A CE policy on a local government level is needed, accompanied by planning-related documents integrated into the Development Application process to ensure an enforcement mechanism. For instance, a combination of a material recovery plan, a deconstruction or disassembly plan, and a building maintenance plan to form an overarching CE statement for the project can replace the poorly enforced Site Waste Minimisation and Management plan critiqued in **Chapter 3**. For Catherine Commons, the City of Ithaca facilitated the deconstruction project through support given to local ReUse centers. This highlights the opportunity for Australia to develop local CE hubs with local government councils to support CE awareness and practices on a local governance level.

Lastly, there are limitations to this study that can inform future research endeavours in this area. First, the interview for each case study was limited to one participant due to practical constraints. Extending the participation to other project members to account for the perspective of various stakeholders, such as owners and other building professionals, can enrich the findings and broaden their significance. Second, the approach to this case analysis was qualitative as it aims to understand how CE initiatives were implemented and the unique factors that influenced their implementation. To extend the study, a quantitative approach that measures the circular outcomes of the projects will be useful to validate the findings of the analysis. Nevertheless, the case studies provided a rich description and analysis of an awarded apartment building renovation project and a pilot demonstration project of deconstruction, which builds the empirical evidence for enabling conditions and implications of CE adoption. This evidence base can then inform practice and policy in housing and CE.

4.5 Chapter Conclusion

This chapter examined two residential building projects that demonstrated CE implementation as social activities that may characterise circular renovation in apartment buildings. The case study involved the architectural renovation of Coogee Waters, a 1960s apartment building in Sydney, Australia and the deconstruction of Catherine Commons, a 1910 residential building in Ithaca, USA. Using a mix of data sources, the cases were examined against the ReSOLVE framework to identify CE activities and thematically analysed to draw out lessons learned and enabling elements for CE demonstration projects.

Coogee Waters in Case Study 1 showed evidence of CE practices in the architectural renovation of a postwar apartment building in Australia, demonstrating implementation of Share and Optimise principles through retaining a significant portion of the building, restoration of existing building components, reducing material usage through sympathetic design, and pooling of existing tangible and intangible assets. The identified enablers include the agency of the architect in proposing CE-aligned design solutions, collaboration among project team members, and supportive local planning provisions to provide mechanisms for apartment upgrades. Case Study 1 also provided evidence that CE practices – the doings and sayings – are already being reproduced by social actors, although they may remain unnoticed if not articulated and strategically recognised. This implies that the formalisation of CE practices in the industry should be prioritised to unify CE understanding and implementation in the building sector. Lastly, geographical implications and potential social equity issues of circular renovation were identified that may be examined in future research.

Case Study 2 provided empirical data on deconstruction as a CE activity, demonstrating implementation of the Share, Loop, Virtualise, and Exchange principles through salvage and reuse, repurposing of building materials and utilizing advanced technologies to digitalise the deconstruction process. The analysis highlighted the enabling effect of digital technology and strong community involvement in CE adoption. The findings reveal implications for workforce development, business transformation, and local economic development and spatial planning. The study provides evidence of how CE demonstration projects can be driven by and instrumental in community development and social empowerment.

Overall, the two case studies revealed favourable regulatory, economic and social conditions in which CE practices emerge and can be reproduced in two distinct geographical contexts. The case study findings underscore the role of local government and communities in the CE transition. Ultimately, the findings broaden knowledge in implementation know-how of CE that is currently lacking , provides real-world insights of the social practices that produce CE adoption, and augments evidence of the value-add of CE.

CHAPTER 5

5 Circular economy and architectural renovation of apartment buildings

A Blueprint for Circular Renovation: CARE Framework, a proposed framework for niche-building practices in the architectural renovation of apartment buildings

5.1 Chapter Overview

This chapter synthesises the findings from the previous chapters in relation to the theoretical underpinning and pragmatic approach of the research. It responds to Objective 3 of the thesis (see **Section 1.4**) by proposing a practical framework for the architectural renovation of apartment buildings that instigates and facilitate a practice of circular renovation as part of the CE transition. The chapter begins with a theoretical discussion of the empirical findings and a methodological note on the development of the framework. It then introduces the *CARE* framework as a pragmatic proposition. Finally, the chapter concludes with a discussion of the framework's implications and limitations in relation to theory and practice, as well as opportunities for future research and action.

5.2 Theoretical Discussion

The empirical findings presented in the preceding chapters benefit from further discussion in relation to the sociological and sustainability transition theories that informed the conceptual framing of this thesis. This discussion enables the findings to be contextualised from multiple perspectives – specifically MLP and SPT – thereby deepening our understanding of how the CE transition is unfolding and how it might be steered through informed interventions, as presented in **Section 5.4**.

First, Chapter 2 revealed how SBRS function as artefacts within practices that resemble niche innovations or regimes. When adopted in renovation projects, these SBRS influence actors' actions that either produce CE niche innovations or reinforce linear economy regimes. Several niche-regime interactions types were evident. For instance, LBC represents a critical niche innovation – presenting itself not only as a building rating system but as a radically different philosophy for building design and construction that largely aligns with CE principles. However, as critical interactions prescribe, LBC remains confined in niche spaces, evidenced by the small number of LBC-certified buildings, emphasising hands-on experimentation to raise awareness, push for different sustainability priorities and address political reality (Smith and Fressoli, 2024). In GSB, co-option was evident through the addition of a Circular Economy Leadership Challenge as a voluntary credit, but hybridisation emerged in their development and implementation of the Responsible Product Framework, which fundamentally affects how other credits are achieved and integrates CE principles more holistically. BASIX, by contrast, demonstrates co-option through its Material Index – a "plug-in module" that incorporates CE without fundamentally altering the index's core values, structure and priorities, reflecting a fit-and-conform dynamic (Smith and Raven, 2012). From an SPT perspective, however, BASIX as a mandatory SBRS shows the greatest potential for reconfiguring practices towards circularity due to its strong recruitment of practice carriers, and, subsequently, continuous reproduction of practice. This is particularly more pronounced in the apartment sector, where voluntary SBRS have yet to become defining elements of renovation. While LBC fosters the formation of new practices through alternative meanings (e.g. buildings as regenerative), competences (e.g. whole life-cycle assessment) and materials (e.g. Declare Red List tools), it faces challenges in recruiting practitioners who can perform and sustain these practices. To accelerate CE transitions, mainstreaming niche artefacts such as LBC or hybridising regime artefacts such as BASIX and, to some extent, GSB to embed niche values and objectives offers viable pathways. In the apartment sector, linking these SBRS with existing renovation elements is essential for forming new practices aligned with CE principles.

Second, Chapter 3 explicated the architectural profession as a social actor in the CE transition. It revealed that CE-related niche innovations exist within the architectural practice but are constrained by incumbent regime structures. Hybridisation is most evident in emerging practices, such as the R&D efforts and organisational structure adjustments by medium- to large-sized architectural studios in order to support CE adoption in their projects. Interviews also highlighted architects' growing engagement with embodied carbon calculations and sustainable material procurement, influencing design processes. These activities reflect hybridisation, as niche methods are integrated into the existing regime, incrementally transforming architectural practice. The accumulation of hybrid interactions contributes to a reconfiguration pathway, as initially discussed in **Section 1.5.**

Interviews further indicate that architects find themselves straddling both regime and niche domains, echoing findings from other geographical contexts (Van Uden et al., 2025). This dual positioning creates tension, as architects navigate conventional systems while experimenting with niche practices. This illustrates the relational nature of transitions (Geels, 2011), where actors simultaneously reproduce regimes and contribute to its transformation through translation and experimentation (Smith and Raven, 2012). Regime pressures persist in the form of apartment strata governance complexity, supply chain limitations, regulatory misalignment, and cultural inertia , which hinder niche practices from diffusing. The interviews also revealed some form of deformation or disappearance of practices that align with CE principles. Some practices aligned with CE principles have even eroded, evidenced by loss of meaning (e.g., architects as material custodians), competence (e.g., salvage and reuse trades), and competition from new materials (e.g. virgin vs secondary materials). While these practices have disappeared as performance, CE as practice-as-entity remains recognised (Schatzki, 2001). For CE to re-emerge, linkages between meanings, competences and materials should be restored. Drawing on SPT, the findings suggest that reconfiguring these elements within architectural and apartment renovation practices is essential for transition. Barriers and enablers identified in Chapter 4 indicate where such reconfigurations are needed for architects to embed niche innovations in everyday work and apartment projects. Such reconfigurations can transform existing regimes and reshape the conditions through which circular renovation practices are reproduced. While early shifts in meanings, competences, and materials are evident based on the chapter findings, they require sustained political and intermediary (such as professional peak bodies) support, consistent with hybridisation dynamics (Smith and Fressoli, 2024). Such support can consolidate and drive lasting transformation in renovation regimes (Keller et al., 2022a).

Third, Chapter 4 presented two case studies that exemplify niche innovations challenging incumbent renovation regimes. When interacting with regimes, differentiation dynamics were evident – more pronounced in Case Study 2 (Catherine Commons) and implicit in Case Study 1 (Coogee Waters). Both cases benefited from various forms of social, economic, and policy protection, substantiating the notion that niches function as "protective spaces" that allow CE innovations to develop through experimentation, learning, and network-building (Smith and Raven, 2012). These protective factors, identified in Chapter 4, offer insights for policy and practice. To diffuse niche innovations, the analysis suggests employing niche policy advancement and critical niche perspectives to stretch and transform existing regimes and to ideologically influence their underlying sustainability values (Smith and Fressoli, 2024). This approach ensures that niche innovations, as illustrated by the case studies, create opportunities to link practice elements and reproduce circular renovation practices (Keller et al., 2022a).

From an SPT lens, Case Study 1 underscores the importance of *meaning elements* for CE adoption, as evidenced by the Burra Charter's influence on renovation values and strategies. It also highlights architects' dual positioning as niche actors advocating for CE and as regime actors operating within incumbent apartment renovation structures. In contrast, Case Study 2 illustrates how deconstruction and demolition practices are competitive and present opportunities for practice substitution, enabling CE to re-emerge as practice-as-entity. Steering such change requires reconfiguring practice elements to support deconstruction: 1) Meaning: elevating its social legitimacy; 2) Competence: disseminating know-how among potential practitioners; 3) Materials: providing spatial, technological, and supply chain infrastructure. Together, these adjustments create conditions for reproducing circular renovation practices and enabling regime transformation.

Overall, the empirical findings point to a reconfiguration pathway for transitions in architectural and apartment renovation practices. This pathway enables incremental incorporation of niche innovations into regime-level practices, with co-option and hybridisation particularly evident in existing practices. While the thesis does not prescribe a certain transition pathway, more critical interactions are needed between these niche and regime elements to engender a more profound transformation. This corroborates earlier calls for a socially-integrated approach to transition, as Liu (2024, p. 481) asserts, "unless the mainstream CE discourse changes its ecological modernisation assumptions and integrates holistic transformation of societal structure..., the requisite social conditions for achieving the closed loop of material circulation at systematic levels may remain elusive in the near future."

Furthermore, although landscape pressures such as supply chain disruptions and global political and health events are moderating, many niche innovations remain underdeveloped. Emerging windows of opportunity could allow CE niche experiments – if adequately supported to flourish – to scale toward a substitution pathway, enabling more radical regime change. The findings emphasise the importance of critical niche developments in steering transitions. The proposed CARE framework operationalises this insight by mobilising social actors through a niche-building artefact that helps reproduce CE practices apartment renovation. Support for these niche developments – through intermediary organisations and policy – is ssential to reconfigure regime practices and facilitate a more fundamental transformation toward a CE.

Employing SPT and MLP to interpret the empirical findings enables a multi-layered analysis of CE transitions in the specific context of architectural apartment renovation. The frameworks complement each other by linking systemic structures with everyday practices, illuminating both macro-level conditions and micro-level processes of change. This dual perspective allows for the identification of multi-level leverage points for circular innovation, as discussed in the preceding sections, while also extending these theories into the emerging CE research field, where applications remain limited and analytical frameworks have largely focused on technological and economic logics (Liu, 2024).

The use of these frameworks also reveals opportunities for further analysis, such as the role of grassroots niches exemplified in the case studies of Chapter 4. Understanding this type of niche spaces – where emergence is driven by social value even within regime logics – offers an exploratory area for MLP and sustainability transitions research to better understand niche development and practice dynamics. While such analyses are more prominent in the energy literature (Seyfang et al., 2014, 2014; Smith et al., 2016, 2014), grassroots niche innovations can be fruitfully expanded to CE contexts. Similarly, the *meaning* element of SPT – encompassing values and aspirations – and the creation of cultural narratives around CE point to a critical focus area for steering practice change and warrant more explicit application in future studies.

Nevertheless, applying these frameworks in this thesis entails limitations related to temporal, geographical, and boundary-scoping factors. Temporally, the theories provide only a snapshot in time, limiting explanations of how practices, niches, and regimes have emerged, evolved, or disappeared over time, which aligns with findings from Van Uden et al. (2024) on the temporal constraints of crossover frameworks. Geographically, both theories offer limited guidance on spatial variation; future work could leverage the MLP landscape level to better capture regional or locational influences on spatialised transitions. Finally, due to ontological differences, the boundaries of practices (SPT) and regimes/niches (MLP) do not align perfectly. Applying these frameworks is therefore challenging and context-dependent, requiring careful consideration of which boundaries to prioritise in future studies.

5.3 Methodological Note

The CARE framework, presented in the succeeding section, was developed through an iterative, evidence-based participatory approach. It is a product of a multi-year process of framework development based on literature review findings, industry consultation outcomes with professionals, and insights from each of the empirical studies. The objective was to propose a practical and heuristic framework that draws on the theoretical underpinning of the research and brings together the empirical findings of this thesis. To ground it in practice, the framework was refined through informal consultations with industry professionals, who specialise in architectural and apartment renovation, during the initial stages of development. The consultation is a critical aspect of the framework development as it discursively bridges the social gap in extant CE research – critiqued substantially earlier in this thesis – and introduces perspectives of social actors in this context. This aligns with the thesis's pragmatic research paradigm, which directs research towards real-world problems and practical outcomes.

The CARE framework is a "how-to" resource that provides actionable strategies and procedural guidelines for circular architectural renovation of apartment buildings. It addresses a gap identified in the empirical studies: the lack of an overarching, practice-based tool to support CE innovations in apartment renovations. The framework enables architects and other building stakeholders (e.g. clients, builders, consultants, project managers, etc.) to systematically integrate CE principles into renovation projects – something existing processes do not currently support. By embedding and "hybridising" the framework into incumbent practices, such as but not limited to client-architect interactions, project brief development, material selection, and operational turnover, it offers a practical means to steer renovation practices toward circularity.

Beyond its practice-based contributions, the framework aligns with the thesis's theoretical framing by integrating key notions from SPT and MLP. It draws on regime practices in architecture and apartment renovation identified through empirical studies and is designed to foster niche development that supports CE transitions in these contexts. By recognising incumbent regime practices and pinpointing emerging niche practices aligned with CE principles, the framework provides a pathway to transform existing practices – specifically through shifts in meanings (values), competences (skills), and material elements (infrastructure and resources) within apartment renovation. In doing so, it stimulates niche innovations and advances CE adoption in architectural renovation. Applied in practice, the framework creates a tangible arena for niche development and offers a platform for further exploration of CE transitions in the built environment.

5.4 CARE framework

"All buildings, like people, need ***care*** over time." (Project Architect, 2024)

Building on the findings from the previous chapters, the thesis defines Circular Architectural Renovation of Existing apartment buildings (CARE) as a renovation approach that employs architectural design aligned with Circular Economy principles to extend the lifespan of apartment buildings and enhance their long-term value. CARE enables future circular renovations or material cascading through deconstruction while contributing to social, economic, and environmental sustainability outcomes across the building's lifecycle. To operationalise this concept, the thesis proposes the *CARE framework*. As a pragmatic proposition, the CARE framework serves a practical and heuristic circular design tool for architectural professionals – a blueprint for CE planning and implementation in apartment building renovation projects. It provides architectural professionals with a reference point for engaging with CE principles and functions as a social artefact for social actors, shaping their reproduction of practices that support niche development and reconfigure regimes towards a CE.

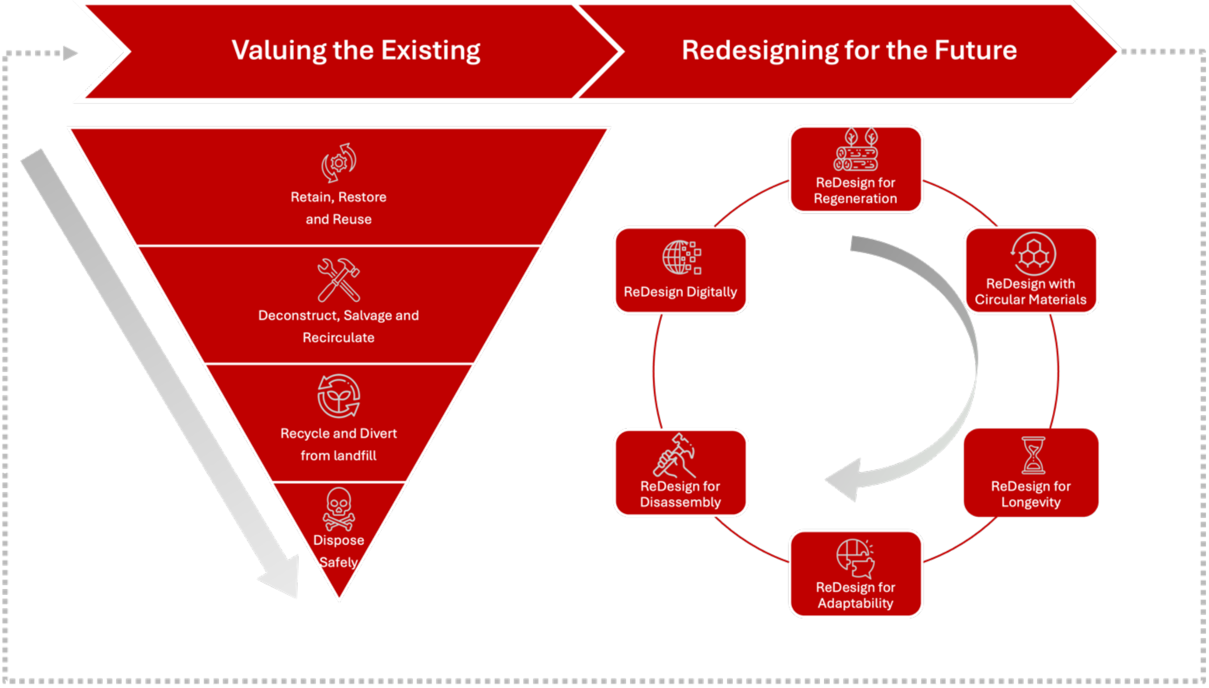

Figure 5-1 CARE Framework

As shown in **Figure 5-1**, the framework is composed of two phases and ten strategies. The first phase, *Valuing the Existing*, underscores the importance of examining the present and looking at the past, allowing for retaining and reactivating embodied values in the actual existing apartment building that contribute to circular outcomes. These values can be material, carbon, cultural, heritage, social, or economic, as the case studies in **Chapter 4** have shown. The first phase is illustrated as an inverted triangle, adopting the hierarchical model of the 10R framework (Potting et al., 2017). It comprises four strategies reflecting different levels of circularity: 1) *Retain, Restore and Reuse, 2) Deconstruct, Salvage, and Recirculate, 3) Recycle and Divert from Landfill, and 4) Dispose Safely*. The level of circularity is highest at the top of the triangle and decreases accordingly. The top of the triangle *(Retain, Restore and Reuse)* has the largest area, denoting that the majority of the existing building materials ideally fall into this strategy. Meanwhile, the bottom of the triangle *(Dispose Safely)* has the smallest area and ideally represents as few building materials from the existing building as possible.

The second phase, *Redesigning for the Future,* turns to the future and asks architectural professionals to redesign with the aim of futureproofing the building through six strategies. The second phase is represented as a circle, signifying that the renovation through these six strategies enables CE implementation far into the future, whether through further renovation activities or deconstruction and material cascading when the former is no longer suitable. This phase consists of six strategies, namely: 1*) Redesign for Regeneration, 2) Redesign with Circular Materials, 3) Redesign for Longevity, 4) Redesign for Adaptability, 5) Redesign for Disassembly,* and *5) Redesign Digitally.* **Table 5-1** outlines the 10 strategies and their strategic aims.

Table 5-1 CARE Framework strategies and aims

Phase	*Strategy*	**Aim**
Valuing the Existing	*Retain, Restore, and Reuse*	Keep building materials and elements in use at their highest value *on site*
	Deconstruct, Salvage, and Recirculate	Keep building materials and elements in use at their highest value *off-site* by deconstructing, salvaging and recirculating them into the market for reuse in other projects
	Recycle and Divert from landfill	Eliminate landfill waste in building projects through recycling or recovery
	Dispose Safely	Protect the natural environment from harmful building materials
Redesigning for the Future	*Redesign for Regeneration*	Redesign proactively contributes to improved biodiversity and regeneration of nature in its own environmental context
	Redesign with Circular Materials	Redesign reduces the need for virgin materials and prioritises use of circular (e.g. reused, recycled, refurbished), bio-based or renewable, and low-carbon materials to reduce embodied carbon

	Redesign for Longevity	Redesign to prolong the lifespan of the building and its components through durable material specification and ease of maintenance
	Redesign for Adaptability	Redesign to allow the building and its elements to be easily adapt to the changing needs of its owners/occupiers
	Redesign for Disassembly	Redesign to facilitate disassembly of building elements for ease of maintenance or deconstruction and reuse in the future
	Redesign Digitally	Redesign process is facilitated by digital technologies and enables digital use in building operation and in future redesign works

The CARE framework can be used in conjunction with other existing frameworks, such as the Shearing Layers proposed by Stewart Brand (Brand, 2007), as Case Study 2 in **Chapter 4** has illustrated. When applied to each strategy, the shearing layers (i.e. site, structure, skin, services, space plan, stuff) turns the framework into a strategic and procedural tool that can assist the design process. The framework also integrates and builds on the CE principles based on the ReSOLVE framework, adopting the CE principles and strategies of ReSOLVE that emerged from the three empirical chapters into actionable design steps in a renovation project. In particular, the CARE framework strengthens the identified weak CE principles in the studied SBRS in **Chapter 2,** namely, Share, Loop and Virtualise. The *Deconstruct, Salvage, and Recirculate* strategy strongly addresses the Share principle. The *Recycle and Divert from landfill* and *Redesign for Disassembly* integrates the Loop principle. The *ReDesign Digitally* explicitly promotes the Virtualise principle.

The CARE framework particularly suits circular renovation as it explicitly accommodates working with an existing building and associated constraints, which other SBRS have not explicitly dealt with, as **Chapter 2** has shown. It partially bridges the gap identified in

Chapters 2 and 3 for a CE-focused accessible framework that allows for creative freedom on the designer's part. It also translates the findings from **Chapters 3 and 4** that the architectural profession can be a social agent for CE adoption. Although their agency is influenced by a multitude of factors, Case Study 1 in **Chapter 4** indicates that there is an opportunity for them to influence design approaches in renovation projects. Furthermore, as a heuristic design tool, it facilitates overcoming the steep learning curve associated with CE adoption, which **Chapter 3** has identified. It also contributes as an educational enabler, as the framework can be adopted both in practice settings and as a pedagogical instrument in architectural courses, following the findings of education as an enabler in **Chapter 3**. The framework was also developed based on the insights from **Chapter 4.** Case Study 1 served as evidence-base for Phase 1 of the framework, while Case Study 2 informed the *ReDesign Digitally* strategy under Phase 2. Responding to Kirchherr's (2023a, p. 7) assertions that a "clearer, more relevant, and more practically actionable conceptualizations of CE can help maintain the connection between CE research and practice", the CARE framework, as a practical and heuristic design tool, helps translate the thesis's empirical findings into practice.

5.5 Limitations and future research areas

There are some limitations to the framework that open possible research areas in the future. Although it addresses some of the practical gaps and integrates key findings from **Chapters 2-4**, the CARE framework is intended to be a pragmatic proposition to the problem of the thesis and hinges on the agency of architectural professionals to adopt and implement it in practice. However, as **Chapters 2-4** have shown, the architect is one actor in the social dimension of circular renovation and their agency and role in a CE are influenced by other social elements. Future research is recommended to examine the other elements in the social dimension (e.g. other actors, artefacts, and activities), investigating the influence of project context in adopting the framework and how the role of the architectural profession in the renovation can be further supported by other elements and vice versa. The proposed practical framework can also benefit from more systematic iteration, testing, and development. For instance, developing suitable metrics for each strategy can also transform the Framework into an evidence base, expanding its relevance in research and practice. There is an opportunity for Participatory Action Research (Baum, 2006), grounding it further in practice, to improve its usability and further enhance its application in the Australian context. Moreover, testing the framework in a live case study would be impactful to assess and enhance its effectiveness. Although developed for the architectural profession and apartment renovation, future research can also attempt to adapt it for various actors in the building construction supply chain and other building typologies or contexts to enhance the framework's transferability. Lastly, as mentioned in the preceding section, the application of the Framework in real-world cases contributes to theory development and provides avenues for testing and expanding social practice and MLP theories within the field of CE.

CHAPTER 6

6 Conclusion

This thesis explored how the emerging and increasingly relevant concept of the Circular Economy can be adopted in the architectural renovation of apartment buildings to support sustainable apartment housing and the CE transition in Australia. Adopting a pragmatic and socially oriented inquiry, the thesis examined three constitutive and interrelated elements – artefacts, actors, activities – within the social dimension of CE and architectural renovation. Specifically, it analysed sustainable building rating systems as social artefacts, architectural professionals as social actors, and real-world residential building projects as social activities that constitute, shape, and influence circular renovation. In doing so, the thesis sheds light on the often-overlooked social aspects of the CE transition in the under-explored domain of apartment housing, gaining a better understanding of the specific challenges and opportunities in this context and their broader implications.

The research addressed the primary question of how a CE approach can be adopted in apartment renovation with a call for a CE transition grounded as a social agenda through: 1) reforming established social artefacts to be accessible, just, and CE-driven; 2) empowering social actors as CE change agents; and 3) recognising and protecting CE activities within and beyond housing and architectural contexts. By focusing on these elements of CE's social dimension, the thesis argues that niche innovations can be developed and nurtured to establish a circular renovation regime in architectural apartment renovation, engendering system reconfigurations that are transformational rather than incremental.

To ground the research, the thesis began with a global outlook by introducing the Anthropocene, in which human activity has an unequivocal influence on climate change. It argued that anthropogenic climate change is largely due to the linear economy paradigm that has, for centuries, underpinned the world economy, including the built environment. Acknowledging the longstanding call for a new economic model that takes into account the ecological environment and reorients itself towards social progress, this thesis explored the concept of CE and its application to the building sector, one of the major contributors to global warming and climate change through resource extraction, emissions, and waste. Shaped by ideas from ecological economics, industrial ecology and environmental economics through several decades of research, CE is understood as a closed-loop economic system that regenerates nature, keeps materials in circulation at their highest value, and eliminates waste and pollution. Interest in CE has grown in industry, policy and research over the last couple of decades due to increasing pressure to substantially reduce global emissions to limit global warming and mitigate anthropogenic climate change, marking a global vision of transitioning towards a CE.

Zooming into the Australian setting, the thesis contextualised the concept of CE and its relevance to the housing sector. The research centred on CE's application to apartment housing stock, given its significance to Australia's urban housing and fabric, and its unique sustainability challenges. As presented in Section 1.3, the growing share of ageing or defective apartment buildings and the increasing demand for apartment housing highlighted the need for an urban-scale renovation agenda. The thesis argued for and focused on the architectural renovation of apartment buildings, asserting that architecture is central to sustainable apartment development and a circular built environment. The nexus between CE, apartment buildings and architectural renovation thus presented a compelling focal point in the investigation, and a primary research question was proposed: How can a Circular Economy approach be adopted in the architectural renovation of apartment buildings?

The thesis adopted a pragmatic philosophical stance, as the research is driven by the urgency to address the impact of buildings on the environment and climate change and primarily aims to contribute actionable knowledge for more sustainable housing and a circular built environment in Australia. The pragmatic positioning enabled flexibility in the research approach, which helped navigate the still emerging and dynamic research field of CE. Informed by the literature review, the research undertook three core empirical studies, which subsequently shaped the development of a practical framework. The succeeding paragraphs revisit the previous chapters' findings in relation to the thesis objectives and discuss their contribution and significance to knowledge and implications for practice, policy and future research.

Responding to Objective 1 – to review relevant literature on CE and apartment building renovation, identify existing gaps and opportunities, and propose research themes – **Chapter 1** established that CE conceptions and scholarship have predominantly focused on techno-economic framing and approaches. Consequently, the social dimension of CE has been neglected, constraining its paradigmatic potential. The thesis attempted to address this gap by designing and conducting a socially oriented inquiry into CE adoption in the architectural renovation of apartment buildings. Drawing concepts from social practice, sociomateriality and multi-level perspective theories in the fields of sociology and sustainability transitions, a conceptual framework is proposed to analyse the social dimension of CE. The conceptual framework, Adaptive Social Perspective Framework for Circular Economy Transitions, is comprised of three distinct but interrelated social elements: artefact, actor and activities, and serves as the basis for the research themes and units of analysis of the three core empirical studies presented in **Chapters 2-4.** The framework provides a broad conceptual framing for future examination of the social dimension of CE in different contexts, thereby bridging the gaps in the sociological underpinning of CE. It also enables context-specific investigations of CE adoption through a social lens. Such an approach can deepen the social and contextual understanding of CE and generate specific actionable insights, which are crucial for local and sectoral CE implementation and policymaking. To further the understanding of CE adoption in apartment building renovation, the thesis perceives value in applying the conceptual framework to map out and analyse different sets of social artefacts, actors and activities in circular renovation. For instance, the framework can be applied to focus on a different set of actors (e.g. owners, builders, local government), artefacts (e.g. digital technologies, building codes, etc.) and activities (e.g. financing, decision-making, governance, etc.) to build on the findings of this thesis and gain more comprehensive insights.

Chapter 2 addressed Objective 2.1 – to investigate the integration of CE principles in existing building frameworks as social artefacts and evaluate their potential to facilitate circular renovation. **Chapter 2** presented a comparative review of three underexplored SBRS (i.e. BASIX, LBC and GSB) as social artefacts that actors in building renovation are guided by, accountable to or integrate into their practice. Employing the ReSOLVE framework for circularity, the comparative review generated empirical evidence of CE integration in these SBRS, indicating varying extents of integration and different interpretations of CE. It showed that the integration of the CE principles Share, Loop and Virtualise was insufficient. This indicates an opportunity to reform these SBRS to embed CE principles more holistically, resulting in a more cohesive CE vision across SBRS. In addition, the study found that SBRS may have a differentiated influence on architectural practice and renovation projects. LBC may be more influential in shifting design thinking, while BASIX is more economically accessible to apartment building renovation projects than others. SBRS that leave room for design solutions or self-education seem more effective in instigating a design paradigm shift. The study revealed that more accessible and renovation-appropriate SBRS, which link minimum standards with aspirational initiatives for CE, are needed to facilitate circular renovation of apartment buildings. This highlights that, for a just transition to transpire, social artefacts must also cater to overlooked sectors and be accessible. The study provides a starting point for SBRS proponents, practitioners and policymakers (in the case of BASIX or other government-mandated SBRS) to ensure balanced integration of various CE principles and to evaluate and enhance the suitability of SBRS for residential building renovation. Further research may broaden the selection of SBRS and endeavour to understand the effectiveness of the different SBRS types as social artefacts for circular renovation. Moreover, research on how existing SBRS can be reformed or developed to be more accessible and capable of instigating broader cultural shifts in design thinking towards CE is recommended.

Chapter 3 tackled Objective 2.2 and explored the role of architectural professionals as social actors in circular renovation, recognising their key function in apartment design and development and in shaping a circular built environment. The phenomenological study generated accounts of the lived experiences of architectural professionals as they navigate the CE transition and tackle apartment building renovations. The thematic analysis findings of the semi-structured interviews point to a fragmented CE understanding and implementation in architectural practice. While the CE concept and their responsibility in applying it in practice are increasingly recognised in the profession, architectural professionals are challenged by their perceived limited agency and confronted by their evolving role as the CE transition progresses. The study found that their agency as CE actors in apartment housing renovation is constrained by barriers that are systemic in nature or specific to apartment building contexts. These barriers include inadequate government policies and regulations, the steep learning curve associated with CE, organisational constraints in a highly fragmented industry, local economic and market conditions, cultural resistance to change and the strata ownership of apartment buildings, which lock them into practices underpinned by the linear economy paradigm.

The study also determined enablers to facilitate circular renovation, which include project and industry collaboration, education and workforce development, leveraging existing mechanisms and resources and value demonstration. The study revealed that a CE transition entails a social transformation for the architectural profession as it fundamentally changes the traditional work of the architect. This implies that CE adoption in architectural practice and, consequently, in architectural renovation may be slow due to entrenched practices and will require broad-scale industry and political support to accelerate. This emphasises that an empowered and just framing of the CE transition is crucial as it implicates the broader workforce. It is recommended that both policy and industry unify CE understanding and standards in architectural practice, ensuring that the profession is ready and well-positioned in the CE transition and that its remit in apartment building renovation is broadened. As Australia grapples with housing issues and its CE policy remains nascent, these findings signal an opportunity to link CE policy with housing and labour policies and outcomes.

Chapter 4 dealt with Objective 2.3 and examined two residential building projects that demonstrated CE implementation as social activities that may characterise circular renovation in apartment buildings. Case Study 1 showed evidence of CE practices in the architectural renovation of a postwar apartment building in Australia, largely aligning with Share and Optimise principles. The case study analysis showed that the proactive role and design philosophy of the project architect, collaboration among project team members and local planning provisions were enabling factors for these CE activities.

Case Study 1 indicated that 1) there may be latent artefacts and activities, such as built heritage and conservation principles, that promote and already align with CE principles, and 2) CE practices may remain implicit if not articulated and recognised. This implies that the formalisation of CE practices in the industry should be prioritised to unify CE understanding and implementation amongst building professionals. Lastly, the case study findings hinted at potential geographical implications and social equity issues of circular renovation that need to be considered in the future.

Case Study 2 provided empirical data on deconstruction as a CE activity and its related environmental, economic and social benefits and implications. The analysis highlighted digital technology and strong community involvement in facilitating CE adoption. The findings also point to implications regarding workforce development, business transformation, local economic development and urban-scale planning for CE infrastructure, indicating the potential of CE activities to become conduits for just work, community building and social development.

Combining the two cases, the research elucidated the regulatory, economic and social conditions in which CE activities have successfully emerged, with respect to two different geographical contexts. Concurrently, it emphasised that while CE is a global agenda, its implementation remains local and will require local solutions and considerations. The case study analysis indicated that the presence of supportive local planning conditions and the harnessing of social movements and the social value generated by CE practices were key factors enabling CE activities. This suggests that architectural renovation of apartment buildings entails the active role of local governments and an approach framing CE activities as opportunities for social development. Future work may focus on socially valuing the impacts of CE activities to support the transition.

Moreover, it underscored the importance of a CE agent to instigate and push the CE transition in micro-scale projects. This points to the potential in future research and policy development to consider an empowerment approach to enable social actors to become CE agents who embed CE activities in social practice. Through the case study description and analysis, the chapter provided an account of CE strategies from these real-world projects to expand practical knowledge of CE, address gaps in the literature and identify the enabling conditions and lessons learned in real-world CE implementation, informing policy and practice. The CE activities described in these cases can be further examined to inform best practice for circular renovations.

Bringing together the findings of the earlier chapters, the thesis developed and proposed the CARE framework in **Chapter 5**, addressing Objective 3. The thesis defines Circular Architectural Renovation of Existing apartment buildings (CARE) as a renovation approach utilising architectural design that aligns with Circular Economy principles to extend apartment building lifespan and enhance their value into the future, enabling future circular renovations or material cascading while contributing to social, economic and environmental sustainability outcomes throughout the building's lifespan.

To facilitate this, the CARE framework is presented as a practical and heuristic design tool for architectural professionals to serve as a blueprint for the circular renovation of apartment buildings. It sits at the intersection of the three social elements of the conceptual framework proposed in this thesis, as it acts as a social artefact for social actors like architectural professionals to guide their social activities in a CE. Keeping consistent with the philosophical positioning of the thesis, the framework serves as the pragmatic response and proposition of the research to the articulated research problem and aims.

The thesis also contributes to theoretical knowledge. By acknowledging the complementary aspects of sociological perspectives, such as social practice and sociomateriality theories, and sustainability transitions perspective, such as the MLP theory, the thesis adds to the limited body of research that recognises their combined merit, despite their ontological differences, to provide a more holistic understanding of the CE transition. While the crossover between SLPT and MLP remains theoretically and empirically emergent, the thesis advances this growing research agenda in a sector (AEC systems) and a context (CE) that are largely underexplored thus far. It does so by investigating the social elements that co-construct practices in architectural apartment renovation and situating these practices within niche and regime levels of systems that steer the CE transition. The interactions between these niche and regime practices, as revealed in the empirical chapters, offer insights into how the transition is currently occurring – how practices are being reconfigured – and how it can be directed and accelerated.

It is important to note the limitations of this research to guide future research directions. First, the thesis mainly focused on architectural professionals, as their central role in a CE and apartment renovation remains under-investigated. However, broadening the set of actors, artefacts or activities in the study can provide a more comprehensive landscape of CE adoption in apartment housing renovation and reveal the dynamics between these social elements.

Second, the thesis was not limited to a specific apartment building typology. As discussed in **Chapter 1**, several apartment typologies exist that vary in scale, ownership and architectural merit. The thesis puts forward that a logical next research step is to undertake focused or comparative investigations of the different typologies, recognising that sociomaterialities can differ for each typology and impose different prerequisites to enable circular renovation.

Third, while the thesis took a socially oriented approach by borrowing relevant concepts from social practice, sociomateriality and socio-technical transitions theories, future studies may benefit from applying or combining more specific theories from these fields, based on the findings from this thesis. For instance, the case study findings could benefit from further research utilising grassroots innovation or strategic niche management theories as analytical lenses, generating insights on how to manage these niche spaces to accelerate the transition.

Fourth, the research focused on the Australian context and considered select international contexts by including globally relevant artefacts (i.e. LBC) and activities (i.e. Case Study 2). As an exploratory study, the thesis was lenient in its geographical boundaries. Future research can benefit from a more defined geographical scope and analysis (e.g. urban vs regional or city-to-city) to reveal geographical differences among actors, artefacts and activities and generate place-based insights.

Lastly, several research themes emerged from the empirical chapters of the thesis that present compelling research opportunities. Questions abound that were outside the scope of this thesis but can guide future research directions. For instance, underscoring the call for an empowered and just CE transition, a matter of particular importance to the Australian context is decolonising the built environment. This raises the question: What is the connection between Indigenous Knowledge and circular architecture? How can circular renovation and the broader CE transition facilitate built environment decolonisation? Conversely, how can Connecting with Country inform CE conceptualisation and implementation in apartment building renovation?

Furthermore, inherent to housing studies are themes of equity and inclusion. Are there social and spatial equity issues arising from circular renovation of apartment housing? How can they be addressed to ensure circular renovation does not undermine social objectives? Moreover, the thesis underscores the spatiality of CE implementation, and this begs the questions: What are the implications of broadscale CARE for state and local planning, infrastructure and communities? How will our cities be reconfigured as the CE transition matures, and what does this mean for the workforce and the community?

These are just some of the starting points that one can reflect on as they engage with the research contained in this thesis. The hope is that the findings instigate critical reflection and investigation on the promise and visions of a CE and ensure that the fundamental purpose – as the Club of Rome put it – of living well in relation to people and the planet remain at the core of these endeavours.

Overall, by focusing on apartment housing, the thesis reorients CE discourse towards a universal social agenda for sustainable urban housing. Furthermore, by adding the layer of architectural renovation as the third element to the research focus, the thesis broadens its implications to climate, housing and social issues. The thesis empirically contributes to CE, housing and architecture bodies of literature and theoretically to sociological and sustainability transitions research fields that can guide future research in these areas. The research informs CE and housing policymaking and the architectural industry alike, providing actionable insights to support sustainable apartment housing and the CE transition in Australia.

In the concluding paragraphs of his magnum opus, The Anthropocene, Paul Crutzen (2006, p. 17) put forward an optimistic scenario for the Anthropocene. He emphasises that humans have the ingenuity to create technological solutions to climate issues but also forebodes the disposition of humankind to self-destruct:

> Hopefully, in the future, the "Anthropocene" will not only be characterised by continued human plundering of Earth's resources and dumping of excessive amounts of waste products in the environment, but also by vastly improved technology and management, wise use of Earth's resources, control of human and domestic animal population, and overall careful manipulation and restoration of the natural environment. There are enormous technological opportunities... Humankind is bound to remain a noticeable geological force, as long as it is not removed by diseases, wars, or continued serious destruction of Earth's life support system, which is so generously provided by nature cost-free.

I conclude this thesis by adding to the dialogue that there are also, if not more, enormous opportunities in the social realm to systemically transform human-made systems to be in harmony with those of the Earth. The thesis lays the foundation for harnessing these opportunities – particularly for the housing and architecture domains – opening up possibilities for a more circular way of living (and building) to paint the Anthropocene in a more hopeful light.

Appendix A Published Manuscript

Building Research & Information

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/rbri20

Towards circular renovation: a comparative review of circular economy integration in sustainable building rating systems

Alysson Nicole Lucas & Sandra Karina Löschke

BUILDING RESEARCH & INFORMATION
https://doi.org/10.1080/09613218.2024.2394470

Routledge
Taylor & Francis Group

RESEARCH ARTICLE

OPEN ACCESS   Check for updates

Towards circular renovation: a comparative review of circular economy integration in sustainable building rating systems

Alysson Nicole Lucas and Sandra Karina Löschke

School of Architecture, Design and Planning, University of Sydney, Darlington, Australia

ABSTRACT
Building renovation is widely considered an effective strategy for reducing the environmental impact of urban housing stock. In recent years, interest in 'circular renovation' – the application of Circular Economy approaches to building renovation – has grown but implementation pathways for circular renovations are still lacking. This study investigates Sustainable Building Rating Systems (SBRS) as an effective method to implement circular renovation by conducting a rigorous comparative analysis of residential SBRS against the established ReSOLVE framework's circularity principles (Regenerate, Share, Optimize, Loop, Virtualize, Exchange). The study focuses on apartment buildings dgiven their importance to urban housing stock and employs a qualitative content analysis on three SBRS (Living Building Challenge, Green Star Buildings, Building Sustainability Index) applicable to renovation. The research revealed that SBRS are progressing towards circularity but to varying extents and with different approaches. While Regenerate, Optimize, and Exchange principles are prominent, Share, Virtualize, and Loop need further integration in SBRS to facilitate circular renovation. The research also highlighted the potential social gaps of ReSOLVE. Although limited to three SBRS, the findings provide valid insights into Circular Economy integration in SBRS, thus synthesizing SBRS and Circular Economy knowledge and its implementation in apartment building renovation and beyond

ARTICLE HISTORY
Received 22 March 2024
Accepted 14 August 2024

KEYWORDS
Circular economy; sustainable building rating systems; ReSOLVE; residential sector; built environment; renovation

Introduction

The residential building sector is responsible for 17% of total global carbon emissions (UNEP, 2022). With the majority of urban residential buildings built before the introduction of building performance standards, this unsustainable housing stock emphasizes the need for renovation to reduce emissions and limit global warming (ClimateWorks Centre, 2023; Metabolic, 2022). Renovation is crucial for complex housing typologies such as apartment buildings (Altmann, 2014; Löschke & Easthope, 2017; Pikas et al., 2021), which house an increasingly significant share of the global urban population (Australian Bureau of Statistics, 2022; Marinova et al., 2020; Rosewall & Shoory, 2017). Therefore, apartment building renovation represents an important strategy to meet sustainable urban housing demand and decarbonize the residential sector (ClimateWorks Centre, 2023; Easthope et al., 2023).

While the global apartment building renovation agenda has focussed on increasing energy efficiency and reducing operational emissions (De Luca et al., 2020; Hamburg et al., 2020), interest in 'circular renovation' – the application of Circular Economy (CE) approaches to building renovation – has grown in recent years for its potential to maximize material efficiency and reduce embodied emissions (De Feijter, 2023; Densley Tingley, 2022; Easthope et al., 2023; EEA, 2022; Nußholz et al., 2023; Sáez-de-Guinoa et al., 2022; UNEP, 2022). In 2022, the European Union recognized that if it were to meet its climate-neutral goals, its green building renovation wave must expand its scope beyond the building performance targets of energy-efficient retrofit schemes towards a circular renovation model (EEA, 2022). Likewise, the planning process in London, UK for building projects including renovations has begun to incorporate Circular Economy Statements in development proposals (Greater London Authority, 2022). Although CE adoption is still considered in its infancy in the Australian building industry (Shooshtarian et al., 2023), it is already reflected in built environment ministerial policies (Australian Government Department of Climate Change, Energy, the Environment and Water, 2022)

CONTACT Alysson Nicole Lucas alysson.lucas@sydney.edu.au
Supplemental data for this article can be accessed online at https://doi.org/10.1080/09613218.2024.2394470.

and endorsed for a more sustainable housing system (Horne et al., 2023). As CE adoption continues to gain momentum in built environment policies including renovation schemes (Yu et al., 2022), its practical implementation in building renovation requires attention to successfully avoid a legacy of waste and reduce the embodied emissions associated with substantial renovation activities (Densley Tingley, 2022).

However, there is still no set standard for CE implementation in building projects paricularly for renovations (Benachio et al., 2020; Ossio et al., 2023; Sáez-de-Guinoa et al., 2022). Incorporating CE in Sustainable Building Rating Systems (SBRS) has been identified as a vital CE driver that can help standardize the concept of CE (Olanrewaju et al., 2024; Wuni, 2023). SBRS, as established frameworks for building sustainability, may provide an effective way to introduce CE principles into apartment building renovation – an opportunity that remains underexplored. To address this gap, this study queries the potential of SBRS for supporting circular renovation through a rigorous review of select SBRS applicable to apartment building renovation from a CE perspective using the ReSOLVE framework's circularity principles (Regenerate, Share, Optimize, Loop, Virtualize, Exchange). The study addresses three research questions: RQ1: How is CE currently reflected in SBRS? RQ2: How do SBRS compare in terms of their coverage of CE and approach to addressing CE? RQ3: What are the opportunities and barriers to further integrating CE principles in SBRS to enable circular renovation?

A background on CE and SBRS is provided in the next section. This is followed by the description of the research methodology and findings of the comparative analysis. Lastly, the implications of the findings for future research and actions as well as the limitations of the study are discussed.

Background

Circular economy in the built environment and the ReSOLVE framework

CE endorses restorative and regenerative systems that operate within the biophysical limits of the natural environment while promoting socio-economic development (Ellen MacArthur Foundation, 2013). It counters the prevailing linear 'take-make-waste' model responsible for the high material and energy consumption and waste generation and instead proposes a close-looped system underpinned by three fundamental principles: (1) Preserving and enhancing natural capital; (2) Keeping products and materials in use; and (3) Regenerating natural systems (Ellen MacArthur Foundation, 2013). In the built environment, CE adoption could potentially reduce emissions by 38% by 2050 through building lifecycle extension, material reuse and recycling, and waste elimination in design and construction (Ellen MacArthur Foundation, 2019). In renovation, a CE approach could translate to lower demand for new construction, reduced costs of construction, operation, and maintenance, increased resource efficiency, and improved local economy and natural environment (EEA, 2022; Marchesi et al., 2020; Rahla et al., 2021). With the potential to contribute to the Sustainable Development Goals, CE has gained significant traction in government, industry, and research in the last decade (Çimen, 2021; Yu et al., 2022), but gaps remain particularly in implementation knowledge for various sectors including the built environment (Antwi-Afari et al., 2021; Shooshtarian et al., 2023).

Considered one of the first attempts to guide CE discourse and adoption in policy and industry, the ReSOLVE Framework was developed by the Ellen Macarthur Foundation (EMF) in 2015 and is now recognized as one of the most prominent CE frameworks (Ellen MacArthur Foundation, 2015a). EMF is the most cited institution in the CE field for its seminal work in promoting CE (Superti et al., 2021). Itproposed the ReSOLVE framework to inform Europe's CE policy for a competitive economy (Ellen MacArthur Foundation, 2015b) and designed it as an operational tool to translate the three fundamental CE principles into six business actions that can be easily implemented across different sectors and scales (Ellen MacArthur Foundation, 2015a). ReSOLVE is acronymous for Regenerate, Share, Optimize, Loop, Virtualize, and Exchange, which are actions that altogether embody a circular economy:

- **Regenerate**: prioritizing restoring and regenerating natural capital
- **Share**: maximizing asset utilization through sharing economy, reuse economy, co-location, and open-source information sharing
- **Optimize**: achieving system efficiency, reduction in material or energy consumption, reverse logistics, longevity, and durability of materials.
- **Loop**: closing the material loop and minimize building material waste sent to landfills by restoring or reprocessing assets and recovering the value of materials
- **Virtualize**: dematerializing through digital technology and virtual products and services
- **Exchange**: exchanging conventional methods and products with alternative and more sustainable or renewable options

With EMF, ARUP expanded and contextualized the ReSOLVE framework specifically for the built environment – the **RESOLVE Framework for Circularity in the Built Environment framework (hereinafter referred to as "ReSOLVE")** (ARUP, 2016). As illustrated in Figure 1, the six main actions are adapted as principles and broken down into 16 more concrete actions to assist building professionals and clients in adopting more circular ways of delivering building projects (ARUP, 2016).

ReSOLVE has been employed in multiple studies as an analytical framework to assess CE developments in different contexts, sectors, scales, and geographies. These include CE research in European policymaking (Mhatre et al., 2021), the agricultural (A. Payne & Kwofie, 2024) and food sectors (Gonçalves & Maximo, 2023; Sehnem et al., 2023), forestry (Tedesco et al., 2022), the water sector (Smol et al., 2023), business management (Lopes de Sousa Jabbour et al., 2019; Marcon et al., 2023), and digital technologies (Aristi Capetillo et al., 2023; Cagno et al., 2021; Ding et al., 2023; Findik et al., 2023; Lopes de Sousa Jabbour et al., 2018; Rusch et al., 2023; Tutore et al., 2024) among others. In the built environment, ReSOLVE has been utilized to analyze the following: CE transition in European Cities (Prendeville et al., 2018), CE challenges and opportunities in the construction sector (Iyer-Raniga, 2019; Torgautov et al., 2021), critical success factors for CE transition in construction industries of developing countries (Koc et al., 2023), CE implementation in the construction value chain (Dewagoda et al., 2022), CE adoption in social housing (Marchesi & Tweed, 2021), and best practice for CE assessments of regions (Van Bueren et al., 2021). ReSOLVE was found to be a relatively comprehensive framework for CE processes (Van Bueren et al., 2021). Over time, ReSOLVE has served a dual purpose – a practical guide for the industry as intended by EMF and an analytical tool for researchers driven by increasing interest in CE adoption (Aubin Payne & Kwofie, 2024). ReSOLVE, as seen in Figure 1, has been adapted in this study for its relevance, practical underpinning, and built-environment-specific elements.

Sustainable Building Rating Systems (SBRS)

SBRS, also referred to as Green Building Rating Systems or Building Certifications, are assessment frameworks that aim to influence building design, construction and operation to reduce the environmental impact of buildings (Ade & Rehm, 2020). They form part of the global decarbonization index to track decarbonization progress in the built environment (UNEP, 2022). SBRS have been developed extensively over the past three decades by a variety of entities ranging from local governments to international organizations (Ming Shan & Hwang, 2018). The first SBRS to be developed was the Building Research Establishment's Environmental Assessment Method (BREEAM) in the UK in 1990, which was initially designed for commercial buildings but has been adopted for different typologies including residential buildings (Ade & Rehm,

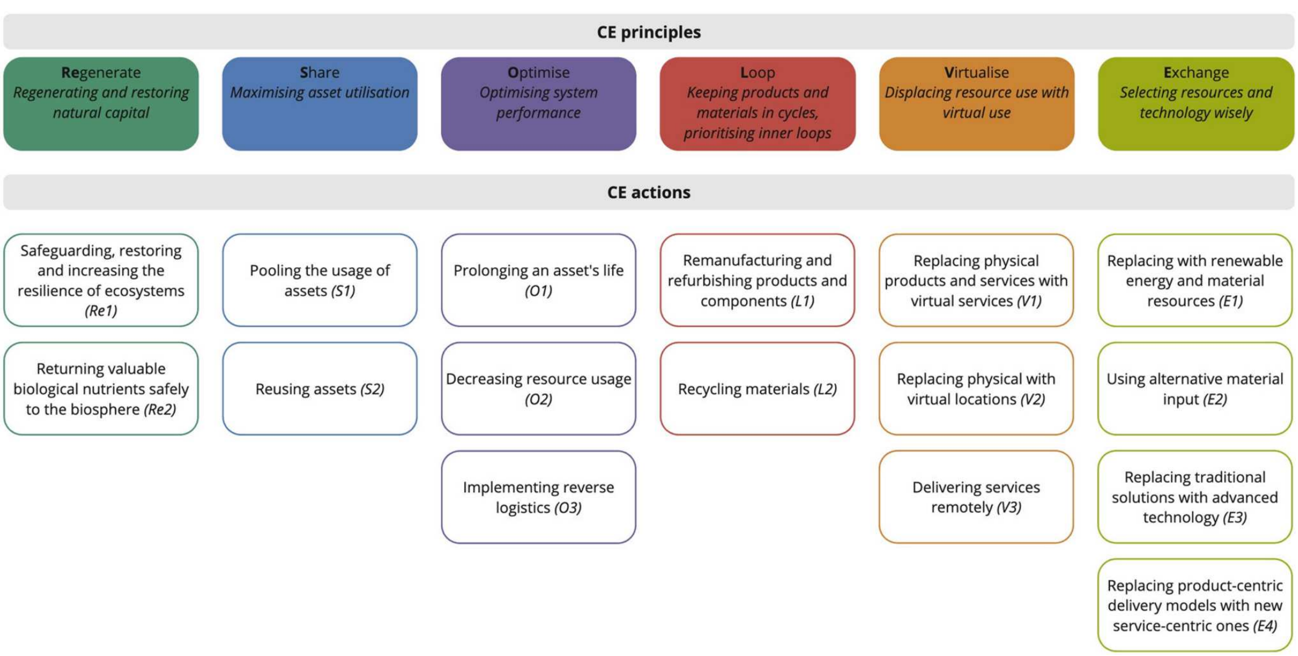

Figure 1. ReSOLVE framework for circularity in the built environment (ReSOLVE) (adapted from ARUP, 2016).

2020). Since then, multiple SBRS that are patterned from BREEAM have been established in different countries and customized to suit local conditions and needs (Lazar & Chithra, 2021; Mattoni et al., 2018; M. Shan & Hwang, 2018). In addition,, SBRS have progressed gradually from being 'green' to adopting the other pillars of sustainability such as social, economic, and governance (Doan et al., 2017; Varma & Palaniappan, 2019). As a result, the complexity and comprehensiveness of SBRS have evolved since their introduction. SBRS can be categorized in multiple ways (Ade & Rehm, 2020) and can differ based on implementation approach (voluntary vs mandatory), coverage (e.g. holistic vs thematic), level of standard (minimum vs aspirational), assessment method (qualitative vs quantitative), and geographic application (local vs global) among other categorizations.

With the proliferation of SBRS, SBRS research has grown subsequently in the last decades (Lazar & Chithra, 2021). Existing literature has covered various methodological studies (Ascione et al., 2022),ranging from bibliometric reviews (Lazar & Chithra, 2021; Zhao et al., 2019), critical comparisons of global SBRS (Doan et al., 2017; Mattinzioli et al., 2021; Mattoni et al., 2018), evolution and research trends (M. Shan & Hwang, 2018; Wang et al., 2024; Wu et al., 2021), to integration of SBRS with other frameworks (Braulio-Gonzalo et al., 2022; Chen et al., 2015; Ferrari et al., 2022; Goubran et al., 2023; Sánchez Cordero et al., 2019; Vitale et al., 2021). SBRS were found to have played a key role in introducing sustainability principles across building industries and influencing sustainable building design and practices (Martek et al., 2019; Ming Shan & Hwang, 2018). However, potential limitations remain including concerns about their influence on residential markets and suitability for renovation. For instance, SBRS adoption rates in the residential sector have been low, mainly due to the high costs associated with certification (Ade & Rehm, 2020; Darko & Chan, 2017). Moreover, existing SBRS are more geared towards planning, design, and construction of new buildings than existing ones (Ade & Rehm, 2020; Jiménez-Pulido et al., 2022), as a majority of SBRS indicators address emissions in the Design, Construction and Use operations, while the End of Life (EoL) stage is poorly approached (Braulio-Gonzalo et al., 2022).

Nevertheless, the multitude of forms and evolution of SBRS indicate that they are often context-specific, evolving to suit local needs, but also globally driven, adapting to worldwide megatrends. SBRS are then positioned to respond to the emerging global shift to CE while remaining effective in the local context. However, the relationship between SBRS and CE has only been investigated by a few in recent years. Current research has generally covered globally prominent SBRS to investigate CE content within them. On a building level, Kubbinga et al. were one of the first to analyze BREEAM New Construction (NC) and Refurbishment and Fit-Out (RFO) and propose a CE strategy framework within these SBRS (68). Likewise, Trubina et al. reviewed four SBRS (BREEAM in the UK, Leadership in Energy and Environmental Design (LEED) in the US, Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) in Germany, and SBToolCZ in Czech Republic), and proposed a single comprehensive rating system that is applicable to office buildings (22). On a neighbourhood scale, Lami et al. qualitatively reviewed BREEAM Communities (C) and LEED Neighbourhood Development (ND) to investigate how SBRS are evolving towards the CE transition within cities (70). To date, research is limited to leading SBRS in Europe and America and has yet to focus on SRBS for residential buildings. Therefore, knowledge of CE integration as the next sustainability pillar in SBRS from other regional perspectives and for the residential sector is underscored to address geographical and typological gaps in the literature.

Using ReSOLVE, this study analyzes and compares three residential SBRS: two internationally comparable SBRS (Living Building Challenge and Green Star) and one local SBRS (Building Sustainability Index) established in Australia (see Figure 2 for overview). These were selected to cover a diverse range of SBRS types based on (1) implementation (voluntary or mandatory), (2) level of sustainability standard (aspirational or minimum), and (3) geographical application (international vs local). This selection allows for a broader understanding of contemporary CE adoption in various residential SBRS in a specific region where SBRS remain the primary mechanism for influencing and assessing the sustainability of buildings such as Australia (Martek et al., 2019).

Living Building Challenge (LBC)

Living Building Challenge is an aspirational and voluntary SBRS first introduced by the International Living Future Institute in 2006 in North America. LBC 4.0 is claimed to be the 'most advanced measure of sustainability in the built environment today' (ILFI, 2019, p. 4). Although less studied than the more prominent SBRS in the American region (i.e. LEED), existing research on LBC has claimed higher sustainability standards compared to LEED and other global SBRS such as BREEAM (Forsberg & De Souza, 2021). Since its introduction, only 105 projects have been certified and over 500 projects have been registered across the globe as of

Figure 2. Overview of LBC, GSB, and BASIX.

2019 (ILFI, 2019, p. 77). In Australia, LBC is considered an emerging SBRS with 21 projects registered. As of October 2023, only one project has achieved a Living Certification and one project has been awarded with a petal certification ('Living Building Projects in Australia', n.d.). The limited number of LBC-certified buildings reflects the high level of aspiration set within LBC.

LBC is an indicator-based SBRS that assesses projects based on the achievement of 20 imperatives (second-level indicators) which are categorized under seven petals (first-level indicators): Place, Water, Energy, Health + Happiness, Materials, Equity and Beauty. LBC can be applied to both new and existing buildings and to a range of building typologies including apartment buildings. Certification is undertaken by an authorised professional using 12-month performance data, and outcomes vary depending on which imperatives were achieved by the project.

Green Star Buildings (GSB)

Green Star is one of the leading voluntary SBRS in Australia established by the Green Building Council of Australia in 2003. Green Star is considered one the most prominent global SBRS and was intended to be an internationally comparable SBRS after being patterned from the pioneer SBRS, BREEAM (Ade & Rehm, 2020). Green Star is considered a market-leading SBRS in Australia, similar to the UK's BREEAM and USA's LEED rating systems (Varma & Palaniappan, 2019). After its establishment in Australia, Green Star has been adopted in other geographical locations such as Green Star South Africa (SA) and Green Star New Zealand (NZ) (Mattoni et al., 2018). Similarly, Green Star SA and Green Star NZ have become the primary SBRS in their respective countries (Doan et al., 2021; GhaffarianHoseini et al., 2017; Hoffman et al., 2020). Green Star offers multiple rating tools including Green Star Buildings (GSB) for new building construction and renovation. GSB and its previous iterations have certified over 300 buildings since 2015 including major refurbishments as of October 2023 (Green Building Council of Australia, n.d.), indicating its wider sphere of influence in Australia than that of LBC.

Similar to LBC, GSB is described as a rating tool with 'aspirational benchmarks for design, construction, and operational performance' (Green Building Council of Australia, 2021, p. 9). It assesses projects based on the requirements of its 41 credits (second-level indicators) which sit under 8 categories (first-level indicators), namely Responsible, Healthy, Resilient, Positive, Places, People, Nature, and Leadership. Each GSB certification comes with a star rating based on the accumulated points from achieving a set of credits, assessed and calculated by an accredited professional.

Building Sustainability Index (BASIX)

Building Sustainability Index is a mandatory SBRS introduced by the Australian New South Wales (NSW) Government in 2004 as part of its development approval process for any new single or multi-unit dwelling, including alterations or additions (e.g. renovation). As a regulatory tool, it sets minimum sustainability targets for energy and water use as well as minimum performance levels for thermal comfort using benchmarks. In contrast with LBC and GSB which require an accredited professional in its certification process, the BASIX platform can be accessed by the public and the certification process can be facilitated by non-professionals.

BASIX is composed of 15 assessment elements (second-level indicators) organized under four indices (first-level indicators), with each index having a specific target score that must be met to obtain a certificate. Unlike GSB and LBC, which measure the performance of buildings based on a suite of indicators after practical completion or post-occupancy, BASIX assesses the sustainability of projects based on estimated savings from energy, water, and thermal efficiency measures at the design stage. The project's savings are compared to 2003 state-wide benchmarks (before BASIX was introduced) and certification is awarded if minimum standards are achieved (NSW Department of Planning and Environment, 2023, p. 7). The targets evolve and are based on local climate and housing typology, hence there is no fixed one-size-fits-all target.

Methodology

This research was designed around a four-step methodology (see Figure 3), adapted from previous studies that examined the alignment of SBRS with various emerging and leading sustainability frameworks (Braulio-Gonzalo et al., 2022; Ferrari et al., 2022; Goubran et al., 2023).

Review of SBRS and ReSOLVE texts

The published guidelines of each SBRS (see Table 1) were reviewed to understand the scope, structure, and assessment approach of each SBRS. For CE, authoritative sources on ReSOLVE (ARUP, 2016; Ellen MacArthur Foundation, 2015a) were reviewed to determine the structure, intent, definitions, and practical applications of ReSOLVE.

Comparative analysis

The review of SBRS guidelines and ReSOLVE texts informed the formulation of a comparative framework. As shown in Figure 4, ReSOLVE and the three SBRS have a two-level hierarchical structure, consisting of

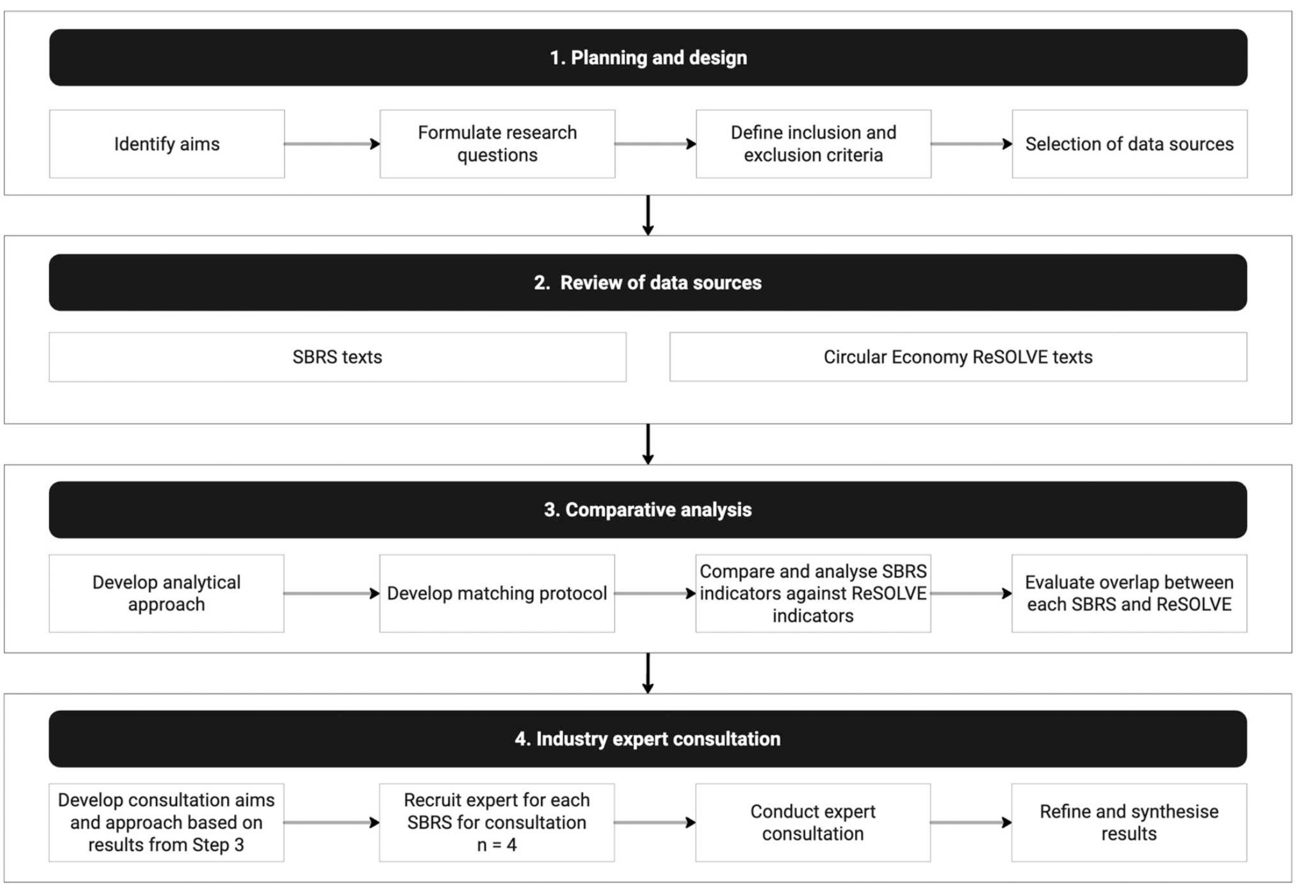

Figure 3. Research Methodology.

Table 1. Data sources for SBRS.

SBRS	Living Building Challenge	Green Star Buildings	BASIX
Developer	International Living Future Institute	Green Building Council of Australia	New South Wales Government
Implementation	Voluntary	Voluntary	Mandatory
Geographical Scope	Australia / Global	Australia / Globally-comparable	New South Wales, Australia
Versions	2006, 2008, 2009, 2012, 2014, 2016, 2019	2014, 2015, 2017, 2020	2004, 2017, 2023
Version reviewed	Living Building Challenge 4.0 (June 2019) (ILFI, 2019)	Green Star Buildings Version 1 Revision B (December 2021) (Green Building Council of Australia, 2021)	A comprehensive guide to BASIX (September 2023) (NSW Department of Planning and Environment, 2023); About BASIX (September 2023) (NSW Government, n.d.)

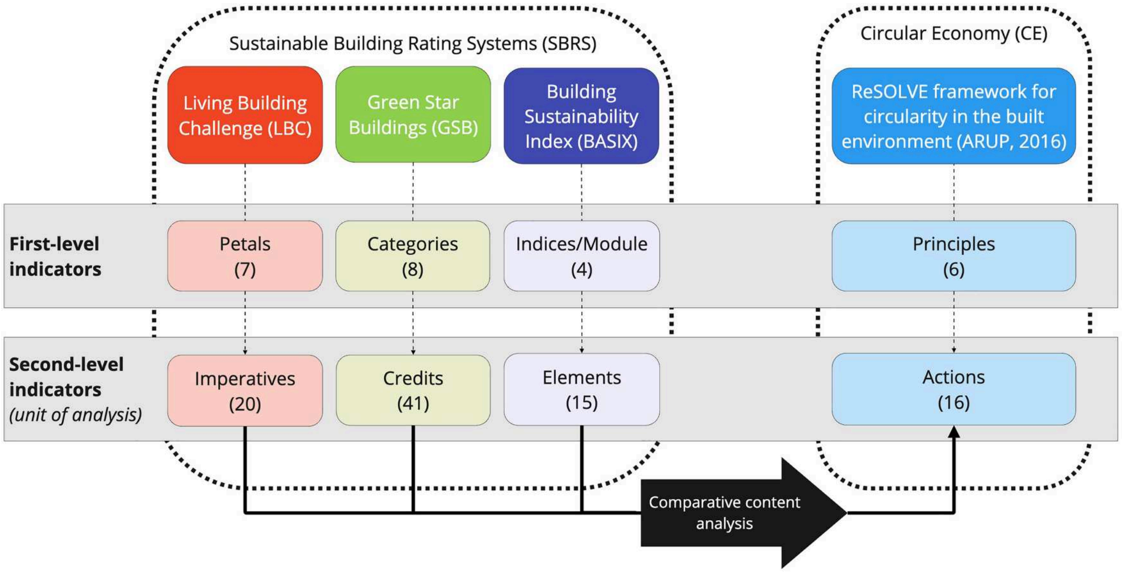

Figure 4. Schematic diagram of comparative framework.

first- and second-level indicators which are referred to using various terms (e.g. petal, credit, index, etc.). The comparative framework uses the second-level indicators as the unit of analysis, enabling a uniform and consistent comparison across the three SBRSs against ReSOLVE.

The comparative content analysis employs a mixed-method approach wherein text description of each SBRS second-level indicator was extracted, qualitatively analyzed and compared against ReSOLVE second-level indicators, and then matches are encoded into quantitative data to evaluate the findings. The qualitative content analysis was guided by a matching protocol and the quantitative analysis was aided by an evaluation matrix (see Appendix 1 – Evaluation Matrix). In the matching protocol, as detailed in Figure 5, second-level indicators of each SBRS were first compared and mapped into the 16 actions of ReSOLVE for the built environment (ARUP, 2016). If the results were deemed ambiguous, then the SBRS data was reviewed for a second round against the more general principles of ReSOLVE initially defined by EMF (Ellen MacArthur Foundation, 2015a). The authors independently reviewed each SBRS against ReSOLVE. When the reviews diverged or remained ambiguous, the indicators were reviewed for a third round by both authors and an industry expert was consulted. After all possible rounds, each SBRS indicator was either successfully matched with at least one of the 16 ReSOLVE actions or marked as no match. Based on a binary approach, matches are accounted for in the evaluation matrix, with 1 representing a match and 0 representing a no-match. The matches are summed in the evaluation matrix and used as an indicator of alignment between the SBRS and CE.

This mixed-method approach of qualitative analysis followed by quantification of findings has been employed in previous research comparing SBRS against notable sustainability frameworks (Braulio-Gonzalo et al., 2022; Vitale et al., 2021; Wen et al., 2020). More importantly, the qualitative approach used in the content analysis addresses limitations in a similar previous

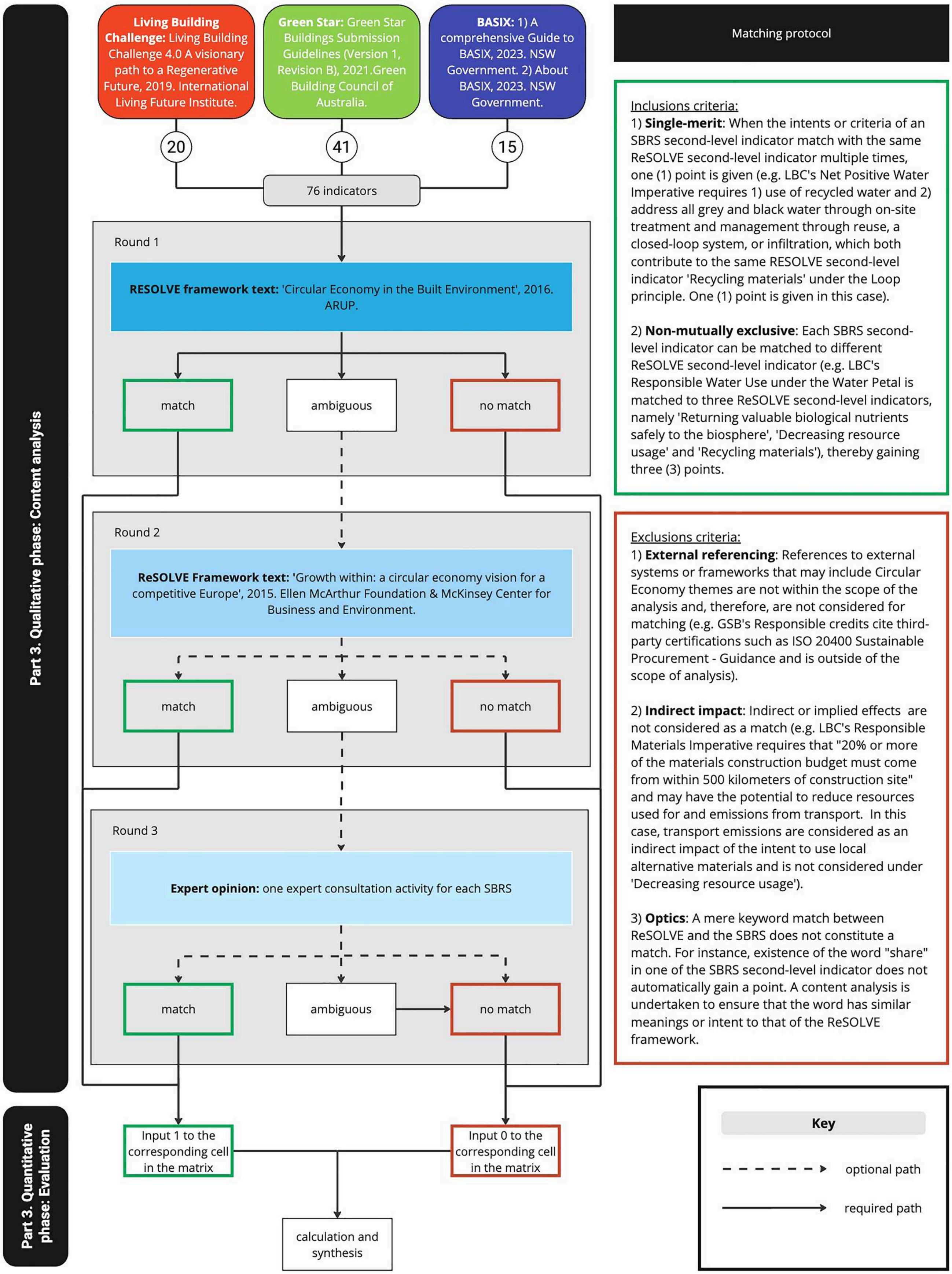

Figure 5. Matching protocol.

study, which identified that semantic analysis of the content – which considers values and conceptualization of sustainability embedded within the SBRS indicator – is recommended to effectively assess the potential of SBRS to contribute to sustainability outcomes (Goubran et al., 2023).

In addition, it is important to recognize that sustainability indicators can be synergistic in nature (Kroll et al., 2019; Xiao et al., 2023), therefore the protocol considers that the matching of second-level indicators of SBRS to those of ReSOLVE is not mutually exclusive. This means that a second-level indicator, for instance, an LBC imperative, that is deemed to address various ReSOLVE actions, can result in multiple matches. Lastly, numerical weights applied to SBRS sub-categories (as in the case of GSB only) are excluded from the evaluation to allow for uniform comparison across the selected SBRS.

Industry expert consultation

Industry expert consultation was employed to confirm any uncertainties or questions that have arisen during the qualitative content analysis stage and collect narrative data on the practical applications of each SBRS that are not covered by publicly available information (referred to as Round 3 in Figure 5). Industry experts were recruited using purposive sampling and identified through desktop research and the authors' professional networks. Purposive sampling of experts is employed to select information-rich cases to achieve depth of understanding of the phenomenon of interest (Creswell & Plano Clark, 2018; Palinkas et al., 2015). The primary criterion for expert selection is the possession of official first-hand experience either in developing and implementing an SBRS or in successfully acquiring an SBRS certification. A total of three separate consultation activities were conducted (one for each SBRS), two online and one in-person. Expert 2 and Expert 3 were both present in the consultation activity for GSB. Table 2 provides the profile of the industry experts who were consulted.

Results

ReSOLVE coverage in SBRS

Living building challenge

In comparing LBC against ReSOLVE, 14 out of 20 LBC imperatives could be matched with at least one ReSOLVE action (orange links) while six were deemed to be outside of the ReSOLVE scope (grey links) and clustered under 'Not covered'. The 14 imperatives that correspond with ReSOLVE come from the Place, Water, Energy, and Materials petals. The six imperatives that were not covered were from the Materials, Equity, Beauty, or Health + Happiness petals. These imperatives relate to social indicators such as indoor comfort of building occupants and inclusive local workforce and supply chain. Figure 6 shows the results of mapping LBC imperatives into RESOLVE.

From the 14 imperatives, a total of 43 matches with ReSOLVE actions were found. This figure – 43 matches from 14 imperatives – indicates that some imperatives contributed to multiple ReSOLVE actions and principles. For instance, the intent of Imperative 16: Net Positive Waste of the Materials petal was deemed to align with the Regenerate, Share, Loop, and Optimize principles, gaining four matches from this imperative. Figure 7 shows how the 14 imperatives from Figure 6 flow into the different ReSOLVE actions, summarized by principle.

In LBC, ReSOLVE principles were largely represented by imperatives under the Materials and Energy petals such as *Responsible Materials, Responsible Sourcing, Red List, Energy + Carbon Reductions,* and *Net Positive Energy*. As seen in Figure 7, the Materials petal (17) showed the largest coverage of CE principles in LBC, highlighting the importance of materials in CE transition.

At a principle level, LBC imperatives represented the Regenerate principle the most, accounting for 14 out of 43 matches. At an action level, LBC imperatives most frequently addressed the ReSOLVE action *Safeguarding, restoring, and increasing the resilience of ecosystems*

Table 2. Profile of industry experts consulted.

SBRS	Expert	Profession	Role/Involvement with SBRS	Industry Experience (years)	Location
LBC	1	Registered Architect (Practice Director)	Project Architect for the first LBC-certified building in Australia	30+	Sydney, Australia
GSB	2	Building professional	Green Building Council of Australia executive (Green Star Strategy and Development Manager)	20+	Sydney, Australia
GSB	3	Building professional	Green Building Council of Australia executive (Green Star Responsible Products Manager)	15+	Sydney, Australia
BASIX	4	Scientist	New South Wales (NSW) Department of Planning and Environment BASIX technical specialist	15+	Sydney, Australia

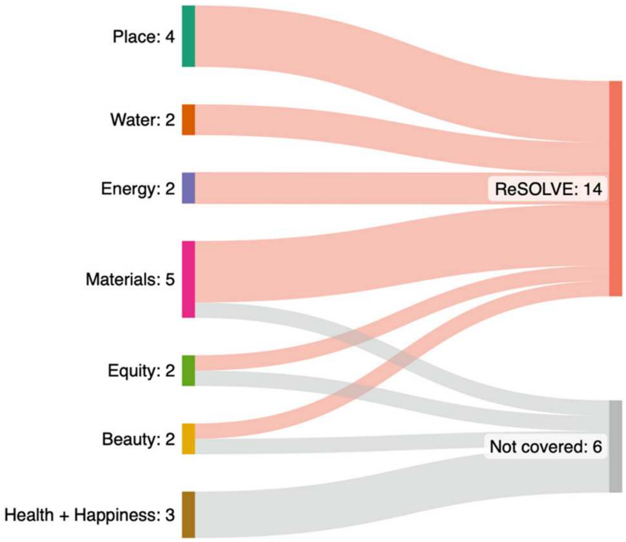

Figure 6. Mapping LBC imperatives into ReSOLVE.

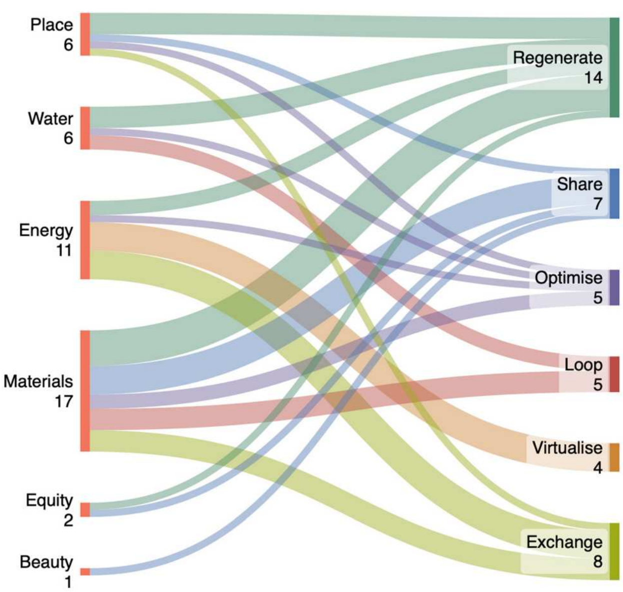

Figure 7. Flow of LBC imperatives into ReSOLVE principles.

(Re1), with a total of ten matches. The Exchange and Share principles were the second and third most salient ReSOLVE principles in LBC, with a total of eight and seven matches, respectively. LBC imperatives generated the least number of matches with the Virtualize principle, with only four out of 43 matches, while the Loop and Optimize principles have five matches each. Overall, LBC demonstrated alignment and potential application of the Regenerate, Share and Exchange principles of CE through its imperatives but was short in integrating the Virtualize, Loop, Optimize principles.

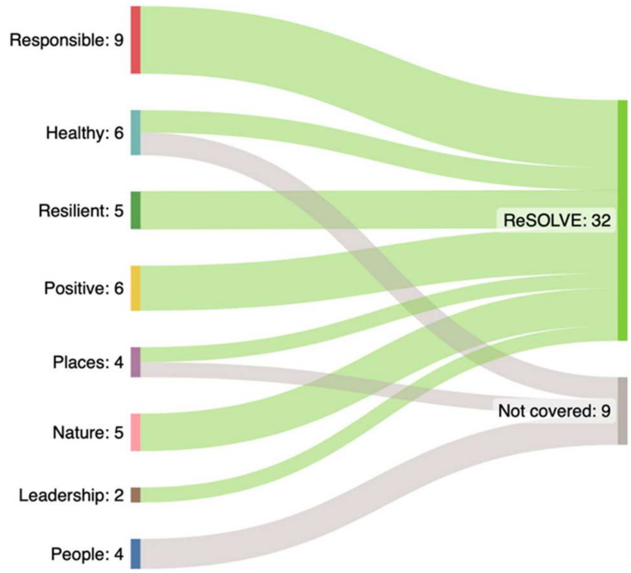

Figure 8. Mapping of GSB credits into ReSOLVE.

Green star buildings

For GSB, 32 out of 41 credits corresponded with at least one ReSOLVE action (green links), as shown in Figure 8. Nine GSB credits were not covered by ReSOLVE (grey links), which belong to the Health, Resilient, Places, or People categories. This result echoes the mapping for LBC, wherein indicators that could not be matched with ReSOLVE often can be categorized as social indicators, for instance, *Culture, Heritage and Identity*, and *Workforce Inclusion* credits.

Out of the 32 credits that were mapped into ReSOLVE, a total of 67 matches were found between GSB credits and ReSOLVE actions (see Figure 9), indicating that some credits addressed multiple ReSOLVE actions, similar to LBC. Credits from the Responsible category generated the highest number of matches (15) shadowed by the Positive category (10) – suggesting that these two categories present the greatest potential in embedding and promoting CE principles in GSB. The Responsible category, in particular, is anticipated to further integrate CE principles into GSB with the introduction of the Responsible Product Framework currently in development as of writing (GBCA, n.d.). It is noted that GSB has implemented a Circular Economy Challenge credit under the Leadership category, which covered each ReSOLVE action and added a total of 18 points. However, the credits under the Leadership category are still voluntary and can be entirely disregarded. It is worth highlighting that for GSB, Circular Economy actions in the planning and design stages of the development are still explicitly integrated into a 'challenge'. Expert consultation revealed that the industry does not yet consider the CE approach as the norm and the

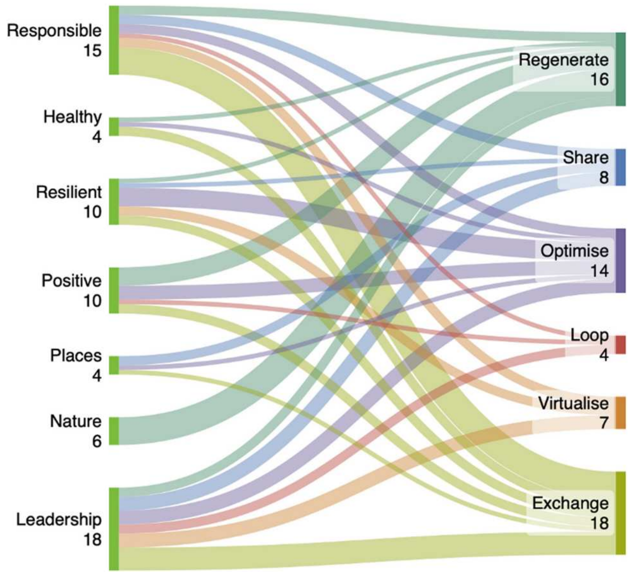

Figure 9. Flow of GSB credits into ReSOLVE principles.

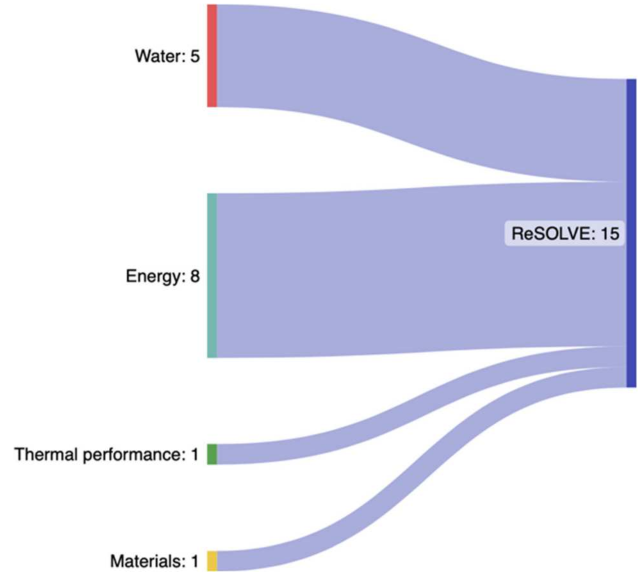

Figure 10. Mapping of BASIX elements into ReSOLVE.

Circular Economy Challenge credit is tackled currently only by a select number of market leaders.

At a principle level, GSB credits addressed the Exchange principle the most with 18 matches, followed closely by the Regenerate (16) and Optimize (14) principles. The Loop principle was the least represented with 4 matches, while the Virtualize and Share principle had 7 and 8 matches, respectively. At an action level, GSB credits showed the greatest overlap with *Safeguarding, restoring, and increasing the resilience of ecosystems (Re1)* followed by *Using alternative material input (E2)*. Based on the total number of matches, the results showed that the Exchange, Regenerate, and Optimize principles are the three most prominent CE principles found in GSB credits, while the other three principles (i.e. Share, Loop, and Virtualize) have limited presence amongst GSB credits.

BASIX

As shown in Figure 10, the 15 BASIX assessment elements under the four indices were matched with at least one ReSOLVE action, which denotes that ReSOLVE comprehensively covers the indicators currently included in BASIX. Unlike LBC and GSB, there were no indicators that were classified as 'not covered'.

The comparison of BASIX elements with ReSOLVE actions resulted in 37 matches, as evidenced in Figure 11. Matches were largely from the Energy (15 matches) and Water (14 matches) indices. Optimize was the most strongly represented principle in BASIX, totalling 14 matches. The second most salient ReSOLVE principle in BASIX was the Exchange principle with nine matches. At an action level, BASIX elements corresponded the most to the ReSOLVE action *Decreasing resource usage (O2)*, representing a substantial share (35%) of the total matches.

The other three principles (Loop, Regenerate, and Share) were poorly represented, with the Share principle having only one match. Nevertheless, these underrepresented principles were typically integrated into the Materials and Water indices, implying that these indices could be key to expanding the application of these principles in BASIX. Overall, BASIX largely reflects the Optimize and Exchange principles of CE given its focus on energy and water efficiency. However, CE principles like Regenerate, Share and Loop are still insufficient and may be further incorporated through the Materials index.

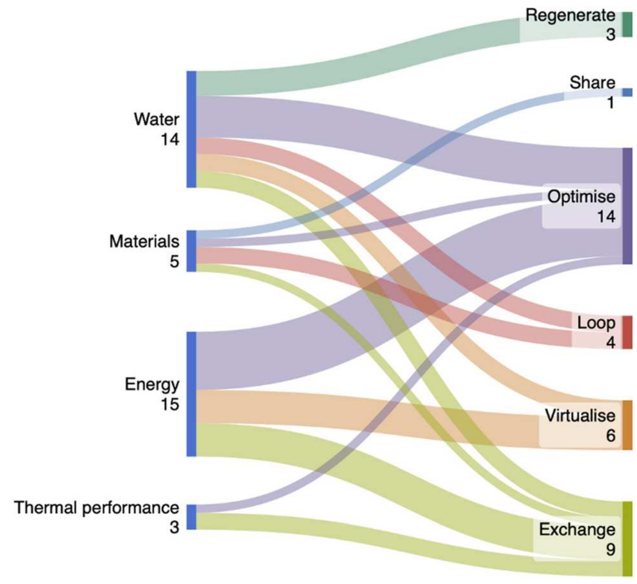

Figure 11. Flow of BASIX elements into ReSOLVE principles.

ReSOLVE coverage by the three SBRS

In response to RQ2, the results show that each of the three SBRS covered all the ReSOLVE principles, although represented at varying levels. LBC significantly contributed more to Regenerate than any other principle, while covering the other principles at similar levels. GSB provided a more balanced coverage, representing half of the principles at comparable levels and the other half at a lower level. BASIX highlighted the Optimize principle the most and covers the others at notably lower levels.

Aggregating the matches of each SBRS, Exchange was the most prominent principle amongst all SBRS (35 matches), with the Regenerate and Optimize principles coming a joint second (33 matches). Meanwhile, Loop, Virtualize and Share principles were represented the least by SBRS indicators, having 50% less matches compared to the more prominent principles. Figure 12 presents an aggregated result of the comparative analysis for all three SBRS.

At an action level, *Safeguarding, restoring, and increasing the resilience of ecosystems (Re1) and Decreasing resource usage (O2)* were the ReSOLVE actions with the highest number of matches (23) with SBRS second-level indicators (see Figure 13). Meanwhile, *Implementing Reverse Logistics (O3) and Replacing physical with virtual locations (V2)* were the ReSOLVE actions that have the weakest representation in the SBRS, each being referred to only once by an SBRS second-level indicator (i.e. GSB's Circular Economy Challenge credit).

Approaches to framing ReSOLVE principles across SBRS

The qualitative approach to the comparative analysis and expert consultation outcomes revealed the different

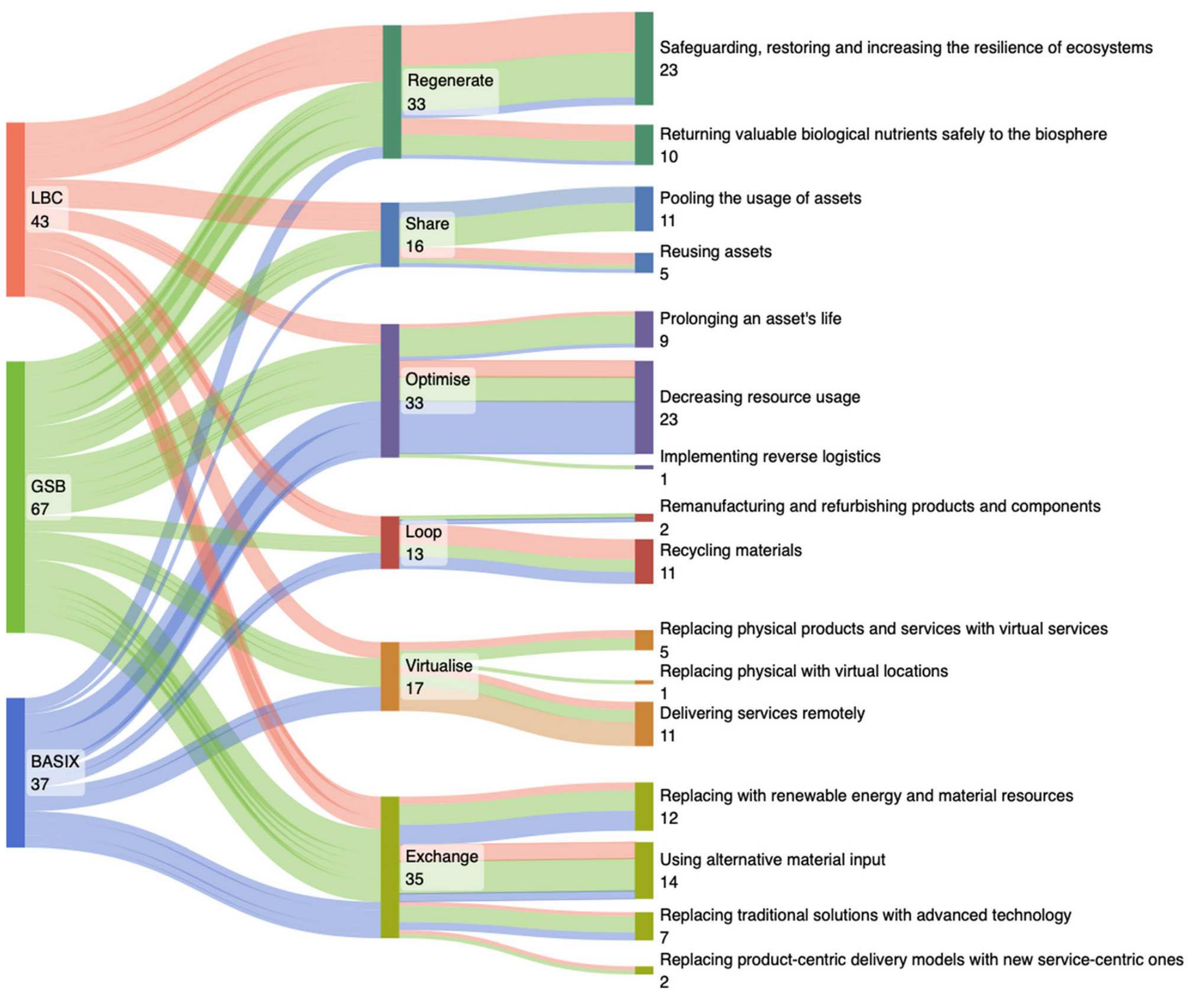

Figure 12. Sankey diagram showing connection flows of SBRS indicators to ReSOLVE principles and actions.

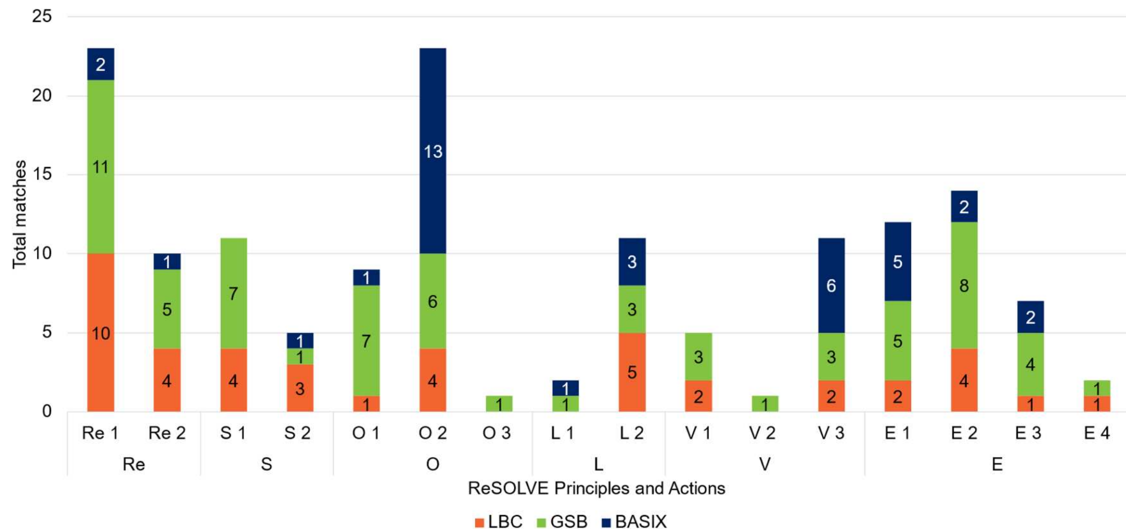

Figure 13. Aggregate matches between SBRS indicators and ReSOLVE actions.

approaches to CE adoption in each SBRS. The following subsections discuss the framing of each ReSOLVE principle across the three SBRS.

Regenerate

The Regenerate principle is one of the most salient CE principles in the SBRS studied. It was mostly addressed by indicators from LBC's Place, Water, and Materials petals, GSB's Positive and Nature categories, and BASIX's Water Index. However, the qualitative content analysis showed that this principle is represented differently and to varying degrees by each of the SBRS. For LBC, the language by which the Regenerate principle is expressed has a strong emphasis on positive ecological outcomes. The intents of LBC imperatives are described to be underpinned by proactively protecting and improving the ecological environment and not only by minimizing negative externalities to natural ecosystems. For example, the *Ecology of Place* imperative of the Place petal explicitly asks projects to 'protect wild and ecologically significant places and encourage ecological regeneration' (ILFI, 2019, p. 30). In line with its aspirational claims of moving beyond the paradigm of 'doing less harm', LBC imperatives are set out to facilitate nature-positive outcomes. GSB credits that reflect the Regenerate principle promote nature-positive outcomes, but also largely emphasize the reduction of negative environmental impacts by the building project. For example, the intended outcome of *Upfront Carbon Emissions* credit is that 'the building's upfront carbon emissions from materials and products have been reduced and offset' (Green Building Council of Australia, 2021, p. 137). The language of reduction and offset is also found in credits such as *Life Cycle Impacts*, *Responsible Construction*, and *Heat Resilience*. Compared to LBC and GSB, BASIX elements that represent the Regenerate principle are framed as a water efficiency measure rather than a nature-positive strategy.

Share

The Share principle is one of the least reflected CE principles in the SBRS studied. LBC leads in integrating the principle in its imperatives, mainly through its Materials petal. LBC covers the concept of sharing and reuse economy through its *Responsible Materials*, *Responsible Sourcing*, and *Net Positive Waste* imperatives, which encourage 'imaginative reuse of salvaged waste materials' (ILFI, 2019, p. 58). In addition, open-source information sharing is embedded in imperatives such as *Responsible Material*, *Red List*, and *Responsible Sourcing* imperatives, which call for a transparent materials economy, and *Education + Inspiration* imperative, which requires the provision of educational materials to the public. GSB applies the Share principle through credits under the Responsible, Resilient, Place, and Leadership categories. Information sharing is embedded in the *Industry Development* and *Market Transformation* credits, which both intend to facilitate knowledge-sharing, collaboration, and innovation. Co-ownership and co-location are also integrated into GSB through its *Enjoyable Places* and *Movement and Place* credits. The reuse and sharing economy are weak in the GSB credits and are only reflected under the voluntary Circular Economy Leadership credit. BASIX least integrates the Share principle amongst selected SBRS. The Materials Index of BASIX potentially applies this principle by encouraging building material retention and information sharing regarding the embodied carbon of building materials.

Optimize

In all SBRS, the Optimize principle generally has a strong presence across the board. This finding supports previous SBRS research, which found that SBRS credits largely contribute to energy efficiency (Optimize) and focus on the Design, Construction and Use stage of the building lifecycle (Braulio-Gonzalo et al., 2022; Olanrewaju et al., 2024). The Optimize principle has one of its actions, *Decreasing resource usage (O2)*, as one of the most addressed actions by SBRS indicators. This suggests that there is a strong push by all SBRS to reduce resource usage and demand for new materials. This Optimization action is widely reflected especially in BASIX, where its calculation and benchmarking method is underpinned by savings from energy and water consumption. However, it is equally important to note that the Optimize principle also has an action, *Implementing reverse logistics (O3),* which is one of the least referred to by SBRS indicators with only one match found across all three SBRS. This finding suggests that the Optimize principle embedded in SBRS gears more toward consumption reduction of users and producers and less toward implementing reverse logistics or returning assets to retailers or manufacturers. If this CE action is integrated further into SBRS, this presents the potential to eliminate externalities in the supply chain and enhance value capturing from existing building materials.

Loop

The Loop principle is the least represented principle amongst the selected SBRS. This result supports previous assessment of SBRS which found that embodied emissions are poorly addressed in SBRS (Olanrewaju et al., 2024). Loop is integrated in LBC's Water and Materials imperatives, GSB's Responsible, Positive and Leadership credits, and BASIX's Water and Materials index. Although the action *Recycling materials (L2)* is a common theme across SBRS, *Remanufacturing and refurbishing products and components (L1)* is one of the least addressed ReSOLVE actions by SBRS indicators. Loop actions are evident and straightforward in indicators addressing water use through recycled water initiatives. However, Loop actions related to building material use are less explicit. For instance, construction waste diversion from landfills is explicitly encouraged particularly in LBC and GSB, but promoting the use of remanufactured, repurposed, or recycled materials in the design and construction of buildings is not overtly incentivized. It is important to note, however, that the use of third-party certifications and guidelines such as LBC's Declare, or GSB's Responsible Product Framework, or Environmental Product Declarations (EPDs) to assess and promote responsible sourcing of building materials are already being incorporated in the SBRS. Furthermore, although Loop concepts such as Design for Disassembly or Deconstruction are present in LBC and GSB, they are rarely referred to or only treated as industry-leading initiatives. Loop concepts such as Buildings as Material Banks and Materials Passport (Luscuere, 2017) are yet to be fully embedded in the SBRS.

Virtualize

The Virtualize principle is one of the weakest ReSOLVE principles amongst SBRS indicators, with the action *Replacing physical with virtual locations (V2)* being addressed once. In the selected SBRS, the Virtualize principle is commonly integrated in indicators related to energy and water management such as in LBC's Energy petal, GSB's Responsible, Resilient and Leadership Categories and BASIX's Energy and Water indices. Across all SBRS, the Virtualize principle is represented using smart metres, sensors and other digital devices for energy and water consumption monitoring and management, which are meant to deliver services remotely mainly during the operational phase of the building. However, actions that may facilitate the adoption of the Virtualize principle during the design and construction phases of renovation such as utilizing Building Information Management (BIM) systems or Digital Twins are still lacking in the current SBRS indicators. This finding aligns with previous research that claims the digitalization level in renovation is still low (Pikas et al., 2021) and points to a compelling opportunity for SBRS to facilitate the adoption of Virtualize actions in building practices.

Exchange

The Exchange principle has the strongest representation amongst SBRS. Switching to renewable energy resources and using alternative low-carbon building materials are two key CE themes present across all SBRS, with *Replacing with renewable energy and material resources (E1) and Using alternative material input (E2)* being the third and fourth most common ReSOLVE actions in SBRS indicators. In LBC, propriety tools such as the *Red List* were developed to 'foster a transparent materials economy free of toxins and harmful chemicals' (ILFI, 2019, p. 53) and the *Declare* label to 'support sustainable extraction of materials and transparent labelling of products' (p. 54). In GSB, the Exchange principle is embedded through the promotion of renewable energy production and consumption, the use of advanced technology to support renewable energy transition, passive design, and third-party certifications and labelling for products. Like LBC, GSB has developed its framework, the *Responsible Product Framework*, to assess the responsible selection and sourcing of building materials. Lastly, BASIX integrates the Exchange principle by incentivizing the use of renewable energy, materials with lower embodied emissions, advanced monitoring and management systems for energy and water, and passive design as reflected in its Material, Energy, Water and Thermal performance indices.

Figure 14 enumerates the second-level indicators from each SBRS that address ReSOLVE principles.

Discussion

CE opportunities in SBRS development

The results showed that several principles of CE (Regenerate, Optimize, Exchange) are already strongly represented in existing SBRS, albeit at varying levels and

Figure 14. SBRS second-level indicators addressing ReSOLVE.

through different approaches. While SBRS have historically focused on improving energy efficiency (Chen et al., 2015; Wen et al., 2020), a gradual shift towards circularity through regenerative principles, resource efficiency, and renewable energy is evident in the current versions of the SBRS. This is a promising result in advancing CE through SBRS and provides an update on previous research indicating that current SBRS are not well prepared to adopt CE (Braulio-Gonzalo et al., 2022).

Conversely, while some CE principles are already present in the select SBRS, there is an opportunity to strengthen other CE principles that are lacking in SBRS such as Share, Loop, and Virtualize principles. This means integrating the sharing economy (Share), prioritizing value recapture in EoL stages of building materials (Loop) and leveraging digital technologies (Virtualize) in SBRS. The Share and Loop principles can be incorporated by adding and prioritizing targets for reused, refurbished, or remanufactured building materials usage over recycled materials in SBRS. Furthermore, the Virtualize principle can be embedded by adding indicators that promote circular digital technologies such as Building and Material passports and Digital Twins, which can also aid the renovation process and contribute to urban mining (Talla & McIlwaine, 2024).

By embedding these less represented CE principles, SBRS have the potential to accelerate the shift away from a material-intensive built environment through augmenting digitalization in the construction sector and reshaping the labour market (Borms et al., 2023) by prompting the development of labour-intensive markets based on repair, refurbishment, remanufacturing or deconstruction activities with potentially significant socio-economic benefits (Heisel et al., 2023). The potential of this may be higher in the case of market-leading SBRS such as Green Star, LEED and BREEAM and mandatory SBRS such as BASIX, which can have a significant influence on the local building supply chain. Furthermore, by strengthening the Loop principle, SBRS can be more suitable for building renovation projects, and the missing EoL stage credits and whole lifecycle approach in existing SBRS identified in previous research can be addressed (Braulio-Gonzalo et al., 2022; Olanrewaju et al., 2024).

Influence of SBRS on the residential sector

The outcomes of the expert consultations highlighted that the market influence and the level of sustainability standard of SBRS may differentiate their potential to promote CE adoption. On one hand, some SBRS can be pivotal in shifting design thinking amongst professionals but have a smaller market influence. On the other hand, other SBRS are considered as a 'box to tick' but have an apparent greater influence or educational potential. This finding suggests that existing SBRS may facilitate CE adoption in a fragmented approach, and they could have different roles in the CE transition depending on their market influence and level of sustainability standard among other factors. For instance, BASIX can be an instrumental educational tool as a mandatory SBRS, but its use of minimum targets suggests that its approach to CE transition remains incremental. Meanwhile, LBC is seen by its users as having a transformational effect amongst industry actors, driving new research and development (R&D) activities, and instigating steep learning curves among professionals. GSB can be both instrumental and educational for the broader industry as the leading voluntary SBRS in Australia. However, GSB and LBC certifications are currently limited to building projects with high potential market value due to the high cost and tedious process of certification, which substantiates previous findings on barriers to SBRS adoption (Darko & Chan, 2017). Despite leading the transition to CE, LBC and GSB may have l minimal influence in the residential sector due to their financial barriers, which could also be the case for other leading but high-cost SBRS in other geographies such as LEED and BREEAM.

For residential renovation, locally mandated SBRS, which automatically have a greater scope of influence and lower financial costs, may be more suitable for apartment renovation projects and have greater potential in promoting CE. This implies that for geographies without legislated SBRS, SBRS may not provide an accessible implementation pathway for circular renovation. However, a limitation of mandatory SBRS like BASIX is the incremental approach to sustainability and, thus, does not incentivize CE adoption more than minimum standards. To balance these opportunities and barriers and achieve optimal effect, CE adoption in apartment building renovation may benefit from future research exploring a more accessible and unified CE approach among SBRS, conceptually linking minimum standards with aspirational CE initiatives.

CE's conceptual clarity and social dimension

Furthermore, the research revealed two key weaknesses that need to be addressed for a successful CE transition. The first was the difficulty in interpreting ReSOLVE. Although developed as an operational tool for businesses and policymakers, the framework and the definition of its principles and actions are not clear-cut, which may prove to be a challenge in implementing it. The results of this research respond to this challenge by contextualizing

ReSOLVE in residential SBRS and providing concrete CE actions applicable to apartment building renovation, addressing some of the implementation gaps in CE. Specifically, the SBRS indicators outlined in Figure 14 and their criteria contribute to actionable CE knowledge and provide precedent for other international SBRS that are looking to further integrate CE, which can advance CE standardization in SBRS. The second weakness is the missing social dimension in ReSOLVE. The findings of the comparative analysis demonstrated that several socially oriented indicators of LBC and GSB were not mapped into ReSOLVE. These include Equity, Beauty, and Health + Happiness imperatives for LBC and Healthy, Places, and People credits for GSB (see Figures 6, 8, and 10). This finding corroborates the critique of the weak social dimension of CE (Murray et al., 2017). It also substantiates previous research recommendations for a more value-based and normative approach to CE (Mies & Gold, 2021) by strengthening its social aspect. The proposed integration of social impact assessment with ReSOLVE by Payne and Kowfie serves as a starting point to improve ReSOLVE's capacity as a practical and analytical tool and promote social value in CE adoption (Aubin Payne & Kwofie, 2024). The broader adoption of CE in apartment building renovation through SBRS can also support CE's social pillar, given the strong social agenda in the residential sector. Overall, the research contributes to the growing literature on CE and ReSOLVE framework and recommends the integration of social objectives in the CE transition as a research priority.

Limitations

There are several limitations to this research. First, the analysis focused on the content of published guidelines of SBRS. However, a review of the outcomes of SBRS-certified buildings which verifies the effectiveness of CE principles 'as built' would provide a critical addition to the content-focused analysis of this study. Understanding which CE-related SBRS indicators building projects have achieved or aim to achieve may provide a better representation of the state of play of CE transition, as driven by existing SBRS. Second, the analysis is limited to three SBRS, albeit two are internationally relevant. Future research may expand the scope to other global and local SBRS to provide a more comprehensive comparative study. Third, the qualitative approach to content analysis precludes the generalizability of the findings to other SBRS. However, given that two of the SBRS included in the study also apply to other building typologies, the findings particularly for LBC and GSB may be extended to typologies other than apartment buildings. Lastly, the expert consultation for this study involved a small sample size. Nevertheless, the experts consulted have first-hand experience with the development or application of the selected SBRS and thus reflect insider insights that provide value to the research and its aims. A larger sample for the expert consultation may provide broader insights in future research.

Conclusion

Renovation is paramount to reducing the significant environmental impact of buildings. This is particularly important in the residential sector, where urban housing demand continues to grow whilst the sustainability of existing housing stock declines. While the renovation agenda has initially focussed on energy efficiency, the importance of and interest in circular renovation has grown in recent years. Circular renovation allows for prolonging building lifecycle without resulting in significant emissions and waste. However, CE implementation pathways for building projects are still lacking, particularly for apartment building renovations. Meanwhile, SBRS have grown and evolved since their introduction to adapt to changing sustainability needs, both local and global. Leveraging the evolutionary capacity of SBRS, this research queries their potential as an implementation pathway for circular renovation Focusing on SBRS applicable to apartment buildings, the study analyzed and compared CE presence across threeSBRS (LBC, GSB, and BASIX) using the ReSOLVE framework for circularity in the built environment. The research revealed that (1) The three SBRS already integrate CE principles albeit to varying extents and with different approaches, with locally mandated SBRS potentially being more accessible for the residential sector. This suggests that SBRS are progressing towards CE and maysupport circular renovation in various ways; (2) The Exchange, Regenerate, and Optimize principles of ReSOLVE have a strong presence, while the Share, Loop, and Virtualize principles are underrepresented. These underrepresented principles require further integration in SBRS to increase suitability for renovation and facilitate a less material-intensive building sector; (3) There are social gaps in ReSOLVE, emphasizing the need for a stronger social agenda in the CE transition. Future research exploring a more accessible and unified CE approach that conceptually links minimum standards with aspirational CE initiatives can strengthen SBRS's role as an implementation pathway towards circular renovation.

Ultimately, the research findings contribute to both CE and SBRS knowledge, which can establish coherence between the two to advance circular renovation and reduce the environmental impact of buildings. The findings can inform SBRS practitioners and policy-makers in updating SBRS guidelines as well as CE proponents in understanding how SBRS can be leveraged to support the paradigm shift to CE. The research also contributes to sustainable apartment building renovation literature and brings attention to its relevance in building decarbonization.

Acknowledgements

The authors would like to thank Professor Hazel Easthope for her review of an early version of this paper and Dr Chirag Deb for his review of the final draft paper (pre-resubmission). The authors would like to acknowledge experts Joe Agius from COX Architecture (partner organization), Katherine Featherstone and Taryn Cornell from the Green Building Council of Australia, and Dr Anna Schlunke from the NSW Department of Planning and Environment for their participation in the industry expert consultation conducted as part of this research, and Ramin Jahromi from COX Architecture and Jeff Oatman from the Green Building Council of Australia for their support and assistance.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was conducted in the context of the research project Co-Design Guide for Transforming Ageing Apartment Buildings 2021–24 (LP200100053) and supported by the Australian Research Council, an Australian Government Research Training Program (RTP) Scholarship as well as the Australian Housing and Urban Research Institute (AHURI) Postgraduate Scholarship Top-up. Please refer to: https://www.sydney.edu.au/architecture/our-research/transforming-ageing-housing-through-co-and-re-design.html and https://www.renew.team/.

Ethical approval

The authors confirm that ethical approval was obtained from the University of Sydney Human Research Ethics Committee (Project identifier: 2022/HE000046).

Data availability statement

The authors confirm that the data supporting the findings of this study are available within its supplementary materials.

Author contributions

Alysson Nicole Lucas: Conceptualization, Methodology, Investigation, Formal Analysis, Data Curation, Writing – Original Draft, Visualization, Project Administration. **Sandra Karina Löschke**: Conceptualization, Methodology, Validation, Investigation, Writing – Review & Editing, Supervision, Funding Acquisition.

ORCID

Alysson Nicole Lucas http://orcid.org/0000-0003-4087-299X
Sandra Karina Löschke http://orcid.org/0000-0002-5215-9895

References

Ade, R., & Rehm, M. (2020). The unwritten history of green building rating tools: A personal view from some of the 'founding fathers'. *Building Research & Information*, *48*(1), 1–17. https://doi.org/10.1080/09613218.2019.1627179

Altmann, E. (2014). Apartments, co-ownership and sustainability: Implementation barriers for retrofitting the built environment. *Journal of Environmental Policy & Planning*, *16*(4), 437–457. https://doi.org/10.1080/1523908X.2013.858593

Antwi-Afari, P., Ng, S. T., & Hossain, M. U. (2021). A review of the circularity gap in the construction industry through scientometric analysis. *Journal of Cleaner Production*, *298*, 126870. https://doi.org/10.1016/j.jclepro.2021.126870

Aristi Capetillo, A., Bauer, F., & Chaminade, C. (2023). Emerging technologies supporting the transition to a circular economy in the plastic materials value chain. *Circular Economy and Sustainability*, *3*(2), 953–982. https://doi.org/10.1007/s43615-022-00209-2

ARUP. (2016). *Circular economy in the built environment*.

Ascione, F., De Masi, R. F., Mastellone, M., & Vanoli, G. P. (2022). Building rating systems: A novel review about capabilities, current limits and open issues. *Sustainable Cities and Society*, *76*, 103498. https://doi.org/10.1016/j.scs.2021.103498

Australian Bureau of Statistics. (2022). *2021 Census count includes Australians living on wheels and water, but most of us still firmly on land*. Census. https://www.abs.gov.au/media-centre/media-releases/2021-census-count-includes-australians-living-wheels-and-water-most-us-still-firmly-land#:~:text=The%202021%20Census%20separately%20identified,us%20now%20live%20in%20apartments

Australian Government Department of Climate Change, Energy, the Environment and Water. (2022). *Environment Ministers Meeting – 21 October 2022 Agreed Communiqué*.

Benachio, G. L. F., Freitas, M. D. C. D., & Tavares, S. F. (2020). Circular economy in the construction industry: A systematic literature review. *Journal of Cleaner Production*, *260*, 121046. https://doi.org/10.1016/j.jclepro.2020.121046

Borms, L., Van Opstal, W., Brusselaers, J., & Van Passel, S. (2023). The working future: An analysis of skills needed by circular startups. *Journal of Cleaner Production*, *409*, 137261. https://doi.org/10.1016/j.jclepro.2023.137261

Braulio-Gonzalo, M., Jorge-Ortiz, A., & Bovea, M. D. (2022). How are indicators in Green Building Rating Systems addressing sustainability dimensions and life cycle frameworks in residential buildings? *Environmental Impact*

Assessment Review, *95*, 106793. https://doi.org/10.1016/j.eiar.2022.106793

Cagno, E., Neri, A., Negri, M., Bassani, C. A., & Lampertico, T. (2021). The role of digital technologies in operationalizing the circular economy transition: A systematic literature review. *Applied Sciences*, *11*(8), 3328. https://doi.org/10.3390/app11083328

Chen, X., Yang, H., & Lu, L. (2015). A comprehensive review on passive design approaches in green building rating tools. *Renewable and Sustainable Energy Reviews*, *50*, 1425–1436. https://doi.org/10.1016/j.rser.2015.06.003

Çimen, Ö. (2021). Construction and built environment in circular economy: A comprehensive literature review. *Journal of Cleaner Production*, *305*, 127180. https://doi.org/10.1016/j.jclepro.2021.127180

ClimateWorks Centre. (2023). *Climate-ready homes: Building the case for a renovation wave in Australia*.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). SAGE.

Darko, A., & Chan, A. P. C. (2017). Review of barriers to green building adoption. *Sustainable Development*, *25*(3), 167–179. https://doi.org/10.1002/sd.1651

De Feijter, F. J. (2023). Trust in circular design: Active stakeholder participation in Chinese and Dutch housing retrofit projects. *Building Research & Information*, *51*(1), 105–118. https://doi.org/10.1080/09613218.2022.2121905

De Luca, G., Ballarini, I., Lorenzati, A., & Corrado, V. (2020). Renovation of a social house into a NZEB: Use of renewable energy sources and economic implications. *Renewable Energy*, *159*, 356–370. https://doi.org/10.1016/j.renene.2020.05.170

Densley Tingley, D. (2022). Embed circular economy thinking into building retrofit. *Communications Engineering*, *1*(1), 28. https://doi.org/10.1038/s44172-022-00027-2

Dewagoda, K. G., Ng, S. T., & Chen, J. (2022). Driving systematic circular economy implementation in the construction industry: A construction value chain perspective. *Journal of Cleaner Production*, *381*, 135197. https://doi.org/10.1016/j.jclepro.2022.135197

Ding, S., Tukker, A., & Ward, H. (2023). Opportunities and risks of internet of things (IoT) technologies for circular business models: A literature review. *Journal of Environmental Management*, *336*, 117662. https://doi.org/10.1016/j.jenvman.2023.117662

Doan, D. T., Ghaffarianhoseini, A., Naismith, N., Zhang, T., Ghaffarianhoseini, A., & Tookey, J. (2017). A critical comparison of green building rating systems. *Building and Environment*, *123*, 243–260. https://doi.org/10.1016/j.buildenv.2017.07.007

Doan, D. T., Wall, H., Ghaffarian Hoseini, A., Ghaffarianhoseini, A., & Naismith, N. (2021). Green building practice in the New Zealand construction industry: Drivers and limitations. *International Journal of Technology*, *12*(5), 946. https://doi.org/10.14716/ijtech.v12i5.5209

Easthope, H., Palmer, J., Sharam, A., Nethercote, M., Pignatta, G., & Crommelin, L. (2023). *Delivering sustainable apartment housing: New build and retrofit* (AHURI Final Report). https://doi.org/10.18408/ahuri7128201

EEA. (2022). *Building renovation: Where circular economy and climate meet*. Publications Office of the European Union.

Ellen MacArthur Foundation. (2013). *Towards the circular economy: Economic and business rationale for an accelerted transition*.

Ellen MacArthur Foundation. (2015a). *Growth within: A circular economy vision for a competitive Europe*. Ellen McArthur Foundation & McKinsey Center for Business and Environment.

Ellen MacArthur Foundation. (2015b). *Delivering the circular economy: A toolkit for policymakers* (No. v1.1).

Ellen MacArthur Foundation. (2019). *Completing the picture: How the circular economy tackles climate change*.

Ferrari, S., Zoghi, M., Blázquez, T., & Dall'O', G. (2022). New level(s) framework: Assessing the affinity between the main international Green Building Rating Systems and the European scheme. *Renewable and Sustainable Energy Reviews*, *155*, 111924. https://doi.org/10.1016/j.rser.2021.111924

Findik, D., Tirgil, A., & Özbuğday, F. C. (2023). Industry 4.0 as an enabler of circular economy practices: Evidence from European SMEs. *Journal of Cleaner Production*, *410*, 137281. https://doi.org/10.1016/j.jclepro.2023.137281

Forsberg, M., & De Souza, C. B. (2021). Implementing regenerative standards in politically green nordic social welfare states: Can Sweden adopt the living building challenge? *Sustainability*, *13*(2), 738. https://doi.org/10.3390/su13020738

GBCA. (n.d.). *The responsible products program*. https://new.gbca.org.au/green-star/the-responsible-products-program/

GhaffarianHoseini, A., Tien Doan, D., Naismith, N., Tookey, J., & GhaffarianHoseini, A. (2017). Amplifying the practicality of contemporary building information modelling (BIM) implementations for New Zealand green building certification (Green Star). *Engineering, Construction and Architectural Management*, *24*(4), 696–714. https://doi.org/10.1108/ECAM-02-2016-0043

Gonçalves, M. L. M. B. B., & Maximo, G. J. (2023). Circular economy in the food chain: Production, processing and waste management. *Circular Economy and Sustainability*, *3*(3), 1405–1423. https://doi.org/10.1007/s43615-022-00243-0

Goubran, S., Walker, T., Cucuzzella, C., & Schwartz, T. (2023). Green building standards and the United Nations' sustainable development goals. *Journal of Environmental Management*, *326*, 116552. https://doi.org/10.1016/j.jenvman.2022.116552

Greater London Authority. (2022). *London plan guidance: Circular economy statements*.

Green Building Council of Australia. (2021). *Green Star buildings submission guidelines version 1: Revision B*.

Green Building Council of Australia. (n.d.). *Green Star project directory*. Retrieved October 10, 2023, from https://www.gbca.org.au/project-directory.asp

Hamburg, A., Kuusk, K., Mikola, A., & Kalamees, T. (2020). Realisation of energy performance targets of an old apartment building renovated to nZEB. *Energy*, *194*, 116874. https://doi.org/10.1016/j.energy.2019.116874

Heisel, F., McGranahan, J., Lucas, A., Cohen, D., & Stone, G. (2023). Carbon, economics, and labor: A case study of deconstruction's relative costs and benefits compared to demolition. *Journal of Physics: Conference Series*, *2600*(19), 192003. https://doi.org/10.1088/1742-6596/2600/19/192003

Hoffman, D., Huang, L.-Y., van Rensburg, J., & Yorke-Hart, A. (2020). Trends in application of Green Star SA credits in South African green building. *Acta Structilia*, *27*, 1–29. https://doi.org/10.18820/24150487/as27i2.1

Horne, R., Dorignon, L., Lawson, J., Easthope, H., Dühr, S., Moore, T., Baker, E., Dalton, T., Pawson, H., Fairbrother, P., & Xiong, Z. (2023). *Informing a strategy for circular economy housing in Australia* (AHURI Final Report). https://doi.org/10.18408/ahuri5328001

ILFI. (2019). *Living building challenge 4.0: A visionary path to a regenerative future*.

Iyer-Raniga, U. (2019). Using the ReSOLVE framework for circularity in the building and construction industry in emerging markets. *IOP Conference Series: Earth and Environmental Science*, *294*(1), 012002. https://doi.org/10.1088/1755-1315/294/1/012002

Jiménez-Pulido, C., Jiménez-Rivero, A., & García-Navarro, J. (2022). Improved sustainability certification systems to respond to building renovation challenges based on a literature review. *Journal of Building Engineering*, *45*, 103575. https://doi.org/10.1016/j.jobe.2021.103575

Koc, K., Durdyev, S., Tleuken, A., Ekmekcioglu, O., Mbachu, J., & Karaca, F. (2023). Critical success factors for construction industry transition to circular economy: Developing countries' perspectives. *Engineering, Construction and Architectural Management*, 1–20. https://doi.org/10.1108/ECAM-02-2023-0129

Kroll, C., Warchold, A., & Pradhan, P. (2019). Sustainable Development Goals (SDGs): Are we successful in turning trade-offs into synergies? *Palgrave Communications*, *5*(1), 140. https://doi.org/10.1057/s41599-019-0335-5

Lazar, N., & Chithra, K. (2021). Comprehensive bibliometric mapping of publication trends in the development of building sustainability assessment systems. *Environment, Development and Sustainability*, *23*(4), 4899–4923. https://doi.org/10.1007/s10668-020-00796-w

Living Building Projects in Australia. (n.d.). *Living Future Inst. Aust*. Retrieved January 11, 2023, from https://living-future.org.au/aus-projects/

Lopes de Sousa Jabbour, A. B., Jabbour, C. J. C., Godinho Filho, M., & Roubaud, D. (2018). Industry 4.0 and the circular economy: A proposed research agenda and original roadmap for sustainable operations. *Annals of Operations Research*, *270*(1-2), 273–286. https://doi.org/10.1007/s10479-018-2772-8

Lopes de Sousa Jabbour, A. B., Rojas Luiz, J. V., Rojas Luiz, O., Jabbour, C. J. C., Ndubisi, N. O., Caldeira de Oliveira, J. H., & Junior, F. H. (2019). Circular economy business models and operations management. *Journal of Cleaner Production*, *235*, 1525–1539. https://doi.org/10.1016/j.jclepro.2019.06.349

Löschke, S. K., & Easthope, H. (2017). *Postproduced: How adaptive redesign and participatory approaches can transform ageing housing, in: From conflict to inclusion in housing: Interaction of communities, residents and activists*. UCL Press.

Luscuere, L. M. (2017). Materials passports: Optimising value recovery from materials. *Proceedings of the Institution of Civil Engineers - Waste and Resource Management*, *170*, 25–28. https://doi.org/10.1680/jwarm.16.00016

Marchesi, M., & Tweed, C. (2021). Social innovation for a circular economy in social housing. *Sustainable Cities and Society*, *71*, 102925. https://doi.org/10.1016/j.scs.2021.102925

Marchesi, M., Tweed, C., & Gerber, D. (2020). Applying circular economy principles to urban housing. *IOP Conference Series: Earth and Environmental Science*, *588*(5), 052065. https://doi.org/10.1088/1755-1315/588/5/052065

Marcon, M., Provensi, T., Sehnem, S., Campos, L. M. S., & Queiroz, A. A. F. S. L. (2023). The internalisation of the circular economy and ESG in Brazilian B corps from the perspective of the stakeholder theory. *Sustainable Development*, *31*(5), 3513–3527. https://doi.org/10.1002/sd.2601

Marinova, S., Deetman, S., Van Der Voet, E., & Daioglou, V. (2020). Global construction materials database and stock analysis of residential buildings between 1970-2050. *Journal of Cleaner Production*, *247*, 119146. https://doi.org/10.1016/j.jclepro.2019.119146

Martek, I., Hosseini, M. R., Shrestha, A., Edwards, D. J., Seaton, S., & Costin, G. (2019). End-user engagement: The missing link of sustainability transition for Australian residential buildings. *Journal of Cleaner Production*, *224*, 697–708. https://doi.org/10.1016/j.jclepro.2019.03.277

Mattinzioli, T., Sol-Sánchez, M., Moreno, B., Alegre, J., & Martínez, G. (2021). Sustainable building rating systems: A critical review for achieving a common consensus. *Critical Reviews in Environmental Science and Technology*, *51*(5), 512–534. https://doi.org/10.1080/10643389.2020.1732781

Mattoni, B., Guattari, C., Evangelisti, L., Bisegna, F., Gori, P., & Asdrubali, F. (2018). Critical review and methodological approach to evaluate the differences among international green building rating tools. *Renewable and Sustainable Energy Reviews*, *82*, 950–960. https://doi.org/10.1016/j.rser.2017.09.105

Metabolic. (2022). *Modelling the renovation of buildings in Europe from a circular economy and climate perspective*.

Mhatre, P., Panchal, R., Singh, A., & Bibyan, S. (2021). A systematic literature review on the circular economy initiatives in the European Union. *Sustainable Production and Consumption*, *26*, 187–202. https://doi.org/10.1016/j.spc.2020.09.008

Mies, A., & Gold, S. (2021). Mapping the social dimension of the circular economy. *Journal of Cleaner Production*, *321*, 128960. https://doi.org/10.1016/j.jclepro.2021.128960

Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: An interdisciplinary exploration of the concept and application in a global context. *Journal of Business Ethics*, *140*(3), 369–380. https://doi.org/10.1007/s10551-015-2693-2

NSW Department of Planning and Environment. (2023). *A comprehensive guide to BASIX: The building sustainability index*.

NSW Government. (n.d.). *About BASIX*. https://pp.planningportal.nsw.gov.au/basix-certificate/about-basix

Nußholz, J., Çetin, S., Eberhardt, L., De Wolf, C., & Bocken, N. (2023). From circular strategies to actions: 65 European circular building cases and their decarbonisation potential. *Resources, Conservation & Recycling Advances*, *17*, 200130. https://doi.org/10.1016/j.rcradv.2023.200130

Olanrewaju, O. I., Enegbuma, W. I., & Donn, M. (2024). Operational, embodied and whole life cycle assessment credits in green building certification systems: Desktop analysis and natural language processing approach. *Building and Environment*, *258*, 111569. https://doi.org/10.1016/j.buildenv.2024.111569

Ossio, F., Salinas, C., & Hernández, H. (2023). Circular economy in the built environment: A systematic literature review and definition of the circular construction concept. *Journal of Cleaner Production*, *414*, 137738. https://doi.org/10.1016/j.jclepro.2023.137738

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research*, *42*(5), 533–544. https://doi.org/10.1007/s10488-013-0528-y

Payne, A., & Kwofie, E. M. (2024). Unleashing circular economy potential in agriculture: Integrating social impact assessment with the framework as a tool for sustainable development. *Sustainable Development*, *2952*, 1–16. https://doi.org/10.1002/sd.2952

Pikas, E., Seppänen, O., Koskela, L., & Peltokorpi, A. (2021). *Challenges in industrialized renovation of apartment buildings* [Paper presentation]. 29th Annual Conference of the International Group for Lean Construction (IGLC), Lima, Peru (pp. 985–994). https://doi.org/10.24928/2021/0155

Prendeville, S., Cherim, E., & Bocken, N. (2018). Circular cities: Mapping six cities in transition. *Environmental Innovation and Societal Transitions*, *26*, 171–194. https://doi.org/10.1016/j.eist.2017.03.002

Rahla, K., Mateus, R., & Bragança, L. (2021). Implementing circular economy strategies in buildings—From theory to practice. *Applied System Innovation*, *4*(2), 26. https://doi.org/10.3390/asi4020026

Rosewall, T., & Shoory, M. (2017). *Houses and apartments in Australia*. Reserve Bank Aust. Bull.

Rusch, M., Schöggl, J., & Baumgartner, R. J. (2023). Application of digital technologies for sustainable product management in a circular economy: A review. *Business Strategy and the Environment*, *32*(3), 1159–1174. https://doi.org/10.1002/bse.3099

Sáez-de-Guinoa, A., Zambrana-Vasquez, D., Fernández, V., & Bartolomé, C. (2022). Circular economy in the European construction sector: A review of strategies for implementation in building renovation. *Energies*, *15*(13), 4747. https://doi.org/10.3390/en15134747

Sánchez Cordero, A., Gómez Melgar, S., & Andújar Márquez, J. M. (2019). Green building rating systems and the new framework level(s): A critical review of sustainability certification within Europe. *Energies*, *13*(1), 66. https://doi.org/10.3390/en13010066

Sehnem, S., Godoi, L., Simioni, F., Martins, C., Soares, S. V., de Andrade Guerra, J. B. S. O., & Provensi, T. (2023). Management food waste in municipality schools: An analysis from a circular economy perspective. *Logistics*, *7*(2), 20. https://doi.org/10.3390/logistics7020020

Shan, M., & Hwang, B. (2018). Green building rating systems: Global reviews of practices and research efforts. *Sustainable Cities and Society*, *39*, 172–180. https://doi.org/10.1016/j.scs.2018.02.034

Shooshtarian, S., Hosseini, M. R., Kocaturk, T., Arnel, T., & Garofano, N. (2023). Circular economy in the Australian AEC industry: Investigation of barriers and enablers. *Building Research & Information*, *51*(1), 56–68. https://doi.org/10.1080/09613218.2022.2099788

Smol, M., Mejia, A., & Howarth, M. (2023). Business opportunities in the water and wastewater sector through the ReSOLVE framework. In M. Smol, M. N. V. Prasad, & A. Stefanakis (Eds.), *Advances in science, technology and innovation* (pp. 225–233). Springer Nature.

Superti, V., Houmani, C., & Binder, C. R. (2021). A systemic framework to categorize circular economy interventions: An application to the construction and demolition sector. *Resources, Conservation and Recycling*, *173*, 105711. https://doi.org/10.1016/j.resconrec.2021.105711

Talla, A., & McIlwaine, S. (2024). Industry 4.0 and the circular economy: Using design-stage digital technology to reduce construction waste. *Smart and Sustainable Built Environment*, *13*, 179–198. https://doi.org/10.1108/SASBE-03-2022-0050

Tedesco, M., Simioni, F. J., Sehnem, S., Soares, J. F., & Coelho Junior, L. M. (2022). Assessment of the circular economy in the Brazilian planted tree sector using the ReSOLVE framework. *Sustainable Production and Consumption*, *31*, 397–406. https://doi.org/10.1016/j.spc.2022.03.005

Torgautov, B., Zhanabayev, A., Tleuken, A., Turkyilmaz, A., Mustafa, M., & Karaca, F. (2021). Circular economy: Challenges and opportunities in the construction sector of Kazakhstan. *Buildings*, *11*(11), 501. https://doi.org/10.3390/buildings11110501

Tutore, I., Parmentola, A., di Fiore, M. C., & Calza, F. (2024). A conceptual model of artificial intelligence effects on circular economy actions. *Corporate Social Responsibility and Environmental Management*, *31*(3), 2852–2864. https://doi.org/10.1002/csr.2827

UNEP. (2022). *2022 global status report for buildings and construction: Towards a zero-emission, efficient and resilient buildings and construction sector*. Nairobi.

Van Bueren, B. J. A., Iyer-Raniga, U., Leenders, M. A. A. M., & Argus, K. (2021). Comprehensiveness of circular economy assessments of regions: A systematic review at the macro-level. *Environmental Research Letters*, *16*(10), 103001. https://doi.org/10.1088/1748-9326/ac209c

Varma, C. R. S., & Palaniappan, S. (2019). Comparision of green building rating schemes used in North America, Europe and Asia. *Habitat International*, *89*, 101989. https://doi.org/10.1016/j.habitatint.2019.05.008

Vitale, P., Alfano, V., Pastore, T., Menna, C., Maffettone, P., & Asprone, D. (2021). Toward a holistic rating system: An attempt to expand the boundaries of building sustainability using SDGs. *Frontiers in Built Environment*, *7*, 679014. https://doi.org/10.3389/fbuil.2021.679014

Wang, C., Che, Y., Xia, M., Lin, C., Chen, Y., Li, X., Chen, H., Luo, J., & Fan, G. (2024). The evolution and future directions of green buildings research: A scientometric analysis. *Buildings*, *14*(2), 345. https://doi.org/10.3390/buildings14020345

Wen, B., Musa, S. N., Onn, C. C., Ramesh, S., Liang, L., Wang, W., & Ma, K. (2020). The role and contribution of green buildings on sustainable development goals. *Building and Environment*, *185*, 107091. https://doi.org/10.1016/j.buildenv.2020.107091

Wu, Z., He, Q., Chen, Q., Xue, H., & Li, S. (2021). A topical network based analysis and visualization of global research trends on green building from 1990 to 2020. *Journal of Cleaner Production*, *320*, 128818. https://doi.org/10.1016/j.jclepro.2021.128818

Wuni, I. Y. (2023). Drivers of circular economy adoption in the construction industry: A systematic review and conceptual model. *Building Research & Information*, *51*(7), 816–833. https://doi.org/10.1080/09613218.2023.2211689

Xiao, H., Liu, Y., & Ren, J. (2023). Synergies and trade-offs across sustainable development goals: A novel method incorporating indirect interactions analysis. *Sustainable Development*, *31*(2), 1135–1148. https://doi.org/10.1002/sd.2446

Yu, Y., Junjan, V., Yazan, D. M., & Iacob, M.-E. (2022). A systematic literature review on circular economy implementation in the construction industry: A policy-making perspective. *Resources, Conservation and Recycling*, *183*, 106359. https://doi.org/10.1016/j.resconrec.2022.106359

Zhao, X., Zuo, J., Wu, G., & Huang, C. (2019). A bibliometric review of green building research 2000–2016. *Architectural Science Review*, *62*(1), 74–88. https://doi.org/10.1080/00038628.2018.1485548

Appendix B Published Manuscript

Carbon, economics, and labor: a case study of deconstruction's relative costs and benefits compared to demolition

F Heisel[1,*], J McGranahan[1], A Lucas[2], D Cohen[3], G Stone[4]
[1] Circular Construction Lab, Cornell University, Ithaca, NY 14853, USA
[2] University of Sydney, School of Architecture, Design and Planning, 148 City Rd, Darlington NSW 2008, Australia
[3] Finger Lakes ReUse, 214 Elmira Rd, Ithaca, NY 14850, USA
[4] Trade Design Build, 1672 Slaterville Rd, Ithaca, NY 14850, USA

Corresponding author felix.heisel@cornell.edu

Abstract. The authors formed a collaborative working group with the "specific aim to investigate the circular potentials of the local built environment by researching and proposing methods for material reuse and recycling, reversible construction, reactivating embodied values, creating green jobs, and reinventing the underlying business models of construction." Seeking to demonstrate deconstruction as an alternative to demolition, the group found a collection of 11 residential structures from the year 1910 that were planned for demolition. The group was able to convince the developer to deconstruct – instead of demolish – one of the structures. Over the course of five days in January 2022, a crew of up to eight workers methodically carved the 420 square meter, 13-bedroom structure into sections from top to bottom. Data was collected during this process on material quantities successfully salvaged from the structure in relation to its total mass, the associated carbon savings the salvage of these materials indicate, their resale value, and labor time and costs required to both remove and process these materials for resale. The results of the study show an increase in carbon savings and sequestration through deconstruction and reuse when compared to demolition, but increased labor and economic costs. However, the resale of materials significantly discounts a significant portion of the cost of the deconstruction, and as capacity and knowledge is built in the local reuse ecosystem the authors believe deconstruction can reach parity with demolition in the future.

1. Introduction

Deconstruction is defined as the use of manual and mechanical methods to disassemble a building into its component parts for reuse [1]. It has been established that deconstruction represents a more sustainable alternative to demolition. This is demonstrated through a reduction in waste materials sent to landfills and the associated carbon and methane emissions reduction compared to demolition, a minimization of harmful fugitive dust in the process itself as well as reduced emissions from the production of new materials through building material reuse [2] [3] [4]. However, carbon savings are dependent on the types and amounts of salvaged materials which are contingent on the material palette of the local building stock.

The business and economic argument in favor of deconstruction is another aspect studies have focused on, evaluating differences in costs between deconstruction and demolition. Dantata et al. shows an increase in economic costs in deconstruction when compared to demolition in the state of Massachusetts [5], while Guy et al. show the price of a deconstruction can match or be slightly cheaper than a demolition in the state of Florida, with the initial greater cost being recouped through the sale of reuse materials and lower fees for waste hauling and dumping [6]. Understanding that a circular economy is one that is increasingly local and decentralized [7], it is important to understand that the economic and environmental impact of a deconstruction varies greatly based on locality.

To investigate the potential of deconstruction in the context of the Finger Lakes region of New York, the authors formed a collaborative working group lead by the Circular Construction Lab at Cornell University with the "specific aim to investigate the circular potentials of the local built environment by researching and proposing methods for material reuse and recycling, reversible construction, reactivating embodied values, creating green jobs, and reinventing the underlying business models of construction" [8]. Seeking to demonstrate deconstruction as an alternative to demolition in the City of Ithaca, NY, the group identified 11 residential structures from the year 1910 that were planned for demolition. The group was able to convince the developer to deconstruct - instead of demolish - one of the structures providing for the case study comparison discussed in this paper.

2. Methodology

2.1. Deconstruction

Prior to the deconstruction effort, a series of onsite surveys were conducted to assess the material content of the building, 206 College Avenue. Two survey methods were tested, one which generated a model from tape-measured distances and onsite sketches, and a second which generated a surface model and material estimates utilizing LiDAR enabled mobile devices [9]. From these surveys, a detailed model was created in Rhinoceros 3D. The digital model allowed the authors to assess material quantities present within the building prior to deconstruction. The model would also help track which materials were salvaged and processed for resale, and which were unable to be salvaged. The building measured 420 square meters, split among three apartments on three floors, with 13 bedrooms in total.

An initial salvage effort was conducted by Finger Lakes Reuse and Historic Ithaca/Significant Elements volunteers, taking easily removable high value elements and transporting them offsite to be denailed and/or processed. Following this, an ambitious timeline was set for the project. The developer required that the deconstruction take no more time than would be necessary to demolish the adjacent buildings, which gave the deconstruction team a timeline of 5 working days to complete the project.

The work was broken into two groups: The removal of interior plaster, window trim, glazing and other architectural features was carried out by the apprenticeship program of Laborers' Local 785, beginning with the top floor (finished attic) of the three-story building and working downwards. Following close behind was a team of carpenters from Trade Design Build under the guidance of the Building Deconstruction Institute making precise cuts into the structure, segmenting the building into panels which could be strapped to a telehandler, tilted and then lifted from the building as components. The order of operations was to remove the dormers first, then gables, roof segments and the attic interior walls before lifting out floor panels. The crew then removed the top portion of the stair as an architectural element before moving down a floor. On the second floor, exterior walls were removed first, then interior walls, the floor and the stairs. This process was repeated for the ground floor. The basement, which was cast-in-place concrete, was not within the scope of the deconstruction and removed by a demolition crew later. All panels and materials were transported by flatbed truck to a warehouse of Finger Lakes ReUse, where they were stacked, before being processed (cleaned, denailed, sorted, stacked, inventoried) and finally offered for sale at the local ReUse Centers.

2.2. Analysis Scope and Scale

Following Stewart Brand's shearing layer allocation [10], the scope of the soft-stripping and deconstruction included the structure, skin, services and spaceplan elements, but excluded the foundation of the building. 206 College Avenue was constructed as a platform-framed timber structure with wooden cladding, cellulose insulation with plaster and lath interior walls and oak hardwood flooring. Given the age of the building, the structural timber elements are of high-quality Eastern Hemlock and nominal 2x10 and 2x6 inch joist, as well as 2x4 inch studs.

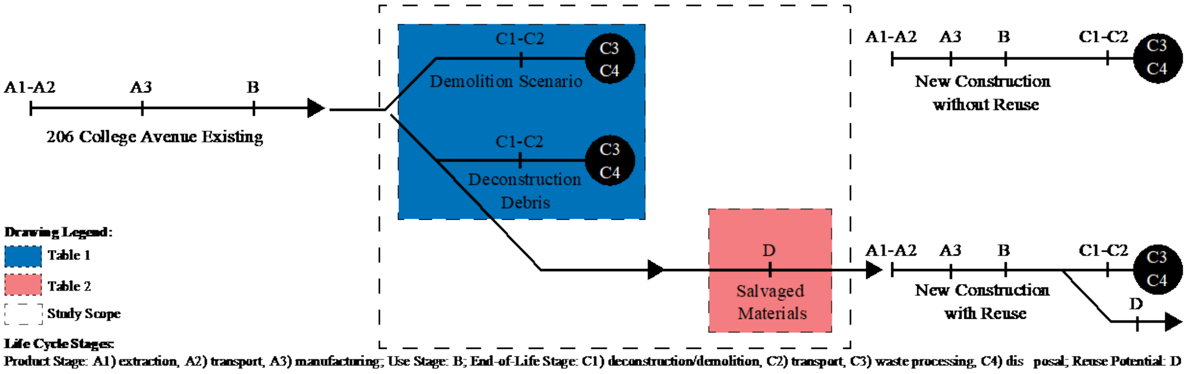

Figure 1. Methodology and phases for carbon calculations

2.2.1. Carbon Calculations. 'Figure 1' outlines the scope of the study with respect to LCA phases A-D and references the relevant tables in the results section. 'Table 1' models the Phase C emissions and carbon capture of a theoretical demolition of the building and the actual deconstruction project. 'Table 2' outlines Phase D carbon savings potentials through continued use of embodied carbon and the prevention of new emissions from production through reuse. Carbon emissions from landfill processes are sourced from the United States Environmental Protection Agency's (EPA) Waste Reduction Model (WARM) [11]. The outputs for this tool are dependent on the local landfill's waste management practices. Mixed C&D waste from the deconstruction project was hauled to Chemung County Landfill, approximately 66 km from the site. This particular landfill does not recapture methane emissions resulting from the decomposition of biotic C&D materials. Carbon savings from the reuse of materials are calculated from Environmental Product Declarations (EPD) sourced from the web platform Embodied Carbon in Construction Calculator (EC3) [12]. When possible, industry EPDs were referenced over specific products. When EC3 lacked verified EPDs for certain materials, alternative sources were consulted [13].

2.2.2. Labor Calculations. Labor hours are noted for the process of deconstruction and recorded. While the entire deconstruction was conducted by paid professionals, much of the soft-stripping and denailing efforts were conducted by volunteer labor. For the purposes of this study, this volunteer labor is counted as labor hours. An estimate of their cost as if this was paid labor is calculated and included in the project costs.

2.2.3. Cost Calculations. Costs of the deconstruction project are calculated from collected accounting information and invoices from stakeholders and partners. For demolition costs, the authors referenced the demolition contractor's initial quote, which was $24,000 USD including labor, equipment, foundation removal, waste hauling and tipping fees. The majority of the material salvaged from the deconstruction has not yet been put up for sale. As a result, estimates are made based on prices Finger Lakes Reuse has charged in the past for similar materials.

3. Results

'Tables 1-4' below summarize the findings of the comparison between demolition and deconstruction.

Table 1. Demolition (dark gray) vs reuse (light gray) carbon emissions scenarios for 206 College Ave

Description	Mass Landfilled (Metric Tons)	Carbon Emissions (LCA Phase C1-C4) (Metric Tons CO2E)	Carbon Storage (LCA Phase C1-C4) (Metric Tons CO2E)	Mass Landfilled (Metric Tons)	Mass Reused (Metric Tons)	Carbon Emissions (LCA Phase C1-C4) (Metric Tons CO2E)	Carbon Storage (LCA Phase C1-C4) (Metric Tons CO2E)
Demo/Decon Emissions	N/A	1.280	N/A	N/A	N/A	0.640	N/A
Asphalt Shingles	2.087	0.046	0.000	2.087	0.000	0.046	0.000
Concrete	42.221	0.931	0.000	41.016	1.205	0.904	0.000

Dimensional Lumber	33.439	6.266	-39.072	7.979	25.461	1.495	-9.323
Plaster	31.174	0.687	0.000	31.174	0.000	0.687	0.000
Hardwood Flooring and Trim	8.947	1.677	-10.455	0.107	8.840	0.020	-0.125
Total	**117.869**	**10.887**	**-49.527**	**82.363**	**35.506**	3.793	**-9.448**

Table 2. Estimated carbon savings through reuse

Material	Mass Reused (Metric Tons)	Reuse Carbon Savings (Phase D) (Metric Tons CO2E)	Reuse Sequestered Carbon (Phase D) (Metric Tons CO2E)	Reference
Concrete	1.205	-2.045	0.000	[12]
Dimensional Lumber	25.461	-3.493	-46.715	[12]
Hardwood Flooring and Trim	8.840	-2.705	-14.056	[13]
Glazing	0.275	-0.369	0.000	[12]
Total	**35.506**	**-8.243**	**-60.771**	

Table 3. Labor contributed on- and offsite

Location	Group	Hours Worked	Workers	Hours Per Individual
Onsite Deconstruction	Finger Lakes Reuse	23	11	2.09
	Local Laborers 785	300.5	7.5	40.07
	Trade Design Build	124	3	41.33
Offsite	Finger Lakes Reuse	96	11	8.73
Demolition Estimate	Demo Contractor	48	2	24.00

Table 4. Revenue and expenses for 206 College Ave (all monetary values in USD)

	Category	Total	Per m2
Anticipated Material Sales Revenue	Appliance/Electronic	$ 651.00	NA
	Door	$ 865.00	NA
	Finishes	$ 5,087.50	$ 12.11
	Flooring	$ 8,700.00	$ 20.71
	Furniture	$ 1,175.00	NA
	Mechanical/Equipment	$ 4,427.50	NA
	Miscellaneous	$ 780.00	NA
	Structural Timber	$ 3,236.80	$ 7.71
	Windows	$ 1,250.00	NA
Anticipated Material Sales Total Revenue		**$ 26,172.80**	**$ 62.32**
Expenses	Labor Salaries & Wages	$ (31,777.00)	$ (75.66)
	Denailing Salaries and Wages (Est.)	$ (3,360.00)	$ (8.00)
	Consulting Services	$ (8,496.89)	$ (20.23)
	Contract Services	$ (1,778.11)	$ (4.23)
	Facilities and Equipment	$ (1,203.40)	$ (2.87)
	Demo and Hauling Fees	$ (9,750.00)	$ (23.21)
	Tools & Supplies	$ (1,884.08)	$ (4.48)
Total Expenses		**$ (58,249.48)**	$ (138.69)
Net		**$ (32,076.68)**	$ (76.37)
Demolition Cost		**$ (24,000.00)**	$ (57.14)
Anticipated Cost Difference Between Deconstruction and Demolition		**$ 8,076.68**	$ 19.23

4. Discussion

‘Figure 2’ below summarizes the main takeaways of ‘Tables 1-4’. The following sections draw conclusions across the discussed aspects relevant to the themes of carbon, economics and labor:

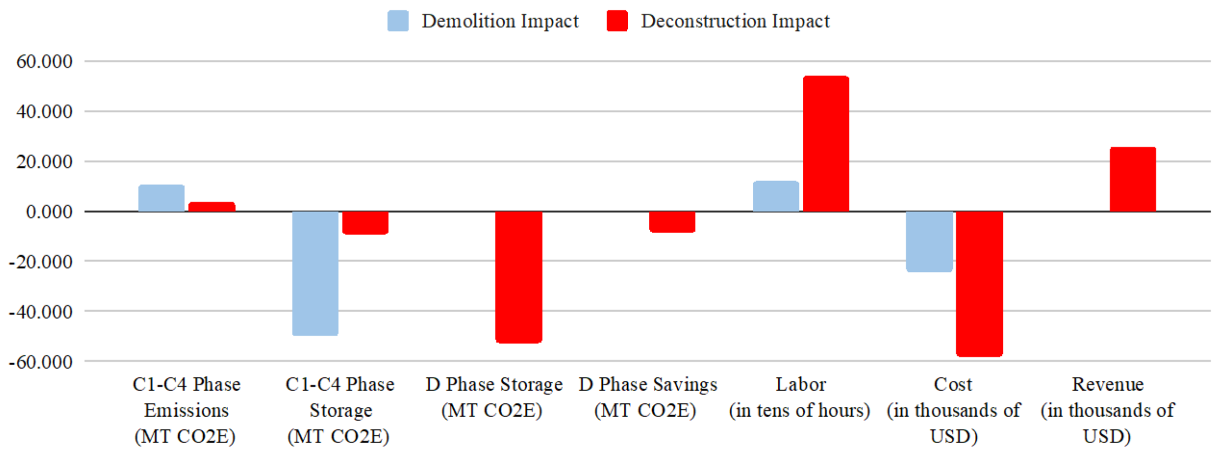

Figure 2. Comparing the Impact of Demolition vs Deconstruction

4.1 Discussion of Carbon Emissions and Storage

The results show that deconstruction causes significantly less direct process emissions in building removal, transport and landfill operation when compared to demolition. Although ‘Table 1’ shows that carbon storage is greater in demolition within the scope of the calculation, the authors argue that carbon storage should not be considered a carbon savings when biotic materials are landfilled. This is because the carbon was sequestered over 100 years ago and has already been removed from the atmosphere and that, unless burned and released into the atmosphere, the carbon will remain stored. The landfilling of the material does not store any additional material. On the contrary, as part of the timber decomposes and releases methane emissions in the process, the storage capacity is actually reduced. Furthermore, New York State has a state-wide goal to prioritize alternative end-of-use pathways over landfilling [14]. This will entail a less profitable business environment for landfill operators, leading to higher hauling fees to offset a lack of volume. As a result, the construction industry is further incentivized to consider alternatives for end-of-use material management. As noted in the introduction, the outcomes of a deconstruction are contingent on the local building stock and the building in question. If the case study building had been made from steel instead of timber, higher carbon savings through reuse could be expected, though given the weight and scale of steel also greater costs might need to be anticipated.

4.2 Discussion of Labor and Cost Results

Results show an anticipated increase in labor hours worked in deconstruction over demolition. While this increases deconstruction costs, it also shows that there is the potential for green workforce development around deconstruction with significant social and societal benefits. When considering cost and material revenues together, the net difference between deconstruction and demolition is rather small (about 8,000 USD), especially when taking into consideration the fact that this project was the first deconstruction attempt for the majority of partnered organizations. Consequently, the decision was made to bring in a deconstruction consultant to advise the process and train new workers. The authors view this as a startup cost for a contractor’s first several jobs. Therefore, once sufficient local knowledge is built up one could anticipate a savings of $8,500 USD. As local capacity is being built up, less external knowledge will be required and an economy of scale can further reduce costs, especially in the realms of equipment and tool rental, and time required for deconstruction projects.

4.3 General Conclusions

Deconstruction requires a re-evaluation of the business of building removal. Demolition is purely a service, with the demo-contractor billing the client for their services; deconstruction, however, is more a systems question involving for example the procurement and sale of material to offset higher labor costs. Clients currently are often billed for expenses comparable to the cost of a demolition but are wary of paying the full cost of a deconstruction. This creates a problem for the material reseller, who instead of billing a service - then needs to recover up-front costs through material resale (with all its uncertainty), while material storage and handling add further costs. One solution to this question can be the pre-sale of material using detailed materials passports as a catalogue. Buyers can purchase material in advance of the deconstruction. In addition to limiting storage costs and helping to close the time and material gap between demand and supply, this information would help guide the deconstruction process, as pre-sold materials would be high priority for salvage.

On a macroeconomic scale, given the existing workforce and market gaps this case study has identified, fiscal policies can be utilized by governments to ease the business of deconstruction and facilitate the growth of secondary materials market (e.g. reuse or recycled materials). For instance, tax incentives or subsidies can be used to address upfront costs faced by material resellers or to reduce labor costs of deconstruction to be competitive against demolition. On a microeconomic scale, a market shift favoring deconstruction will increase demand for workers and firms offering deconstruction expertise – signaling a market opportunity for industry players and workforce to pivot their strategic focus. While deconstruction requires a different skillsets and business models, deconstruction becoming a norm need not necessarily lead to significant loss of jobs in resource-intensive industries such as the construction industry, rather pushes the adaptive capacity of firms and workers and gradually facilitate the restructuring of the current economic system. Future studies may focus on determining effective economic policies by local or state governments and trialing deconstruction business model innovations.

References

[1] Guy B, Falk RH 2007 Unbuilding: Salvaging the Architectural Treasures of Unwanted (Newtown, CT: Taunton Press) p 256
[2] US EPA 2008 Lifecycle Construction Resource Guide
[3] Nunes A, Palmeri J, Love S 2019 Deconstruction vs. Demolition: An evaluation of carbon and energy impacts from deconstructed homes in the City of Portland, State of Oregon DEQ
[4] Sparandara L, Werner M, Kaminsky A, Finch L, Douglas K 2019 *Accelerating the Circular Economy through Commercial Deconstruction and Reuse,* Ellen MacArthur Foundation
[5] Dantata N, Touran A, Wang J 2005 *Resourc., Conserv. and Recycl.* 2005 **44(1)** 1–15
[6] Guy B, McLendon S 2000 *Building Deconstruction: Reuse and Recycling of Building Materials,* Center for Construction and Environment, University of Florida
[7] Heisel F, Hebel DE, Webster K 2022 Building Better - Less - Different: Circular Construction and Circular Economy (Basel: Birkhäuser)
[8] Circular Construction Lab: Catherine Commons Deconstruction Project [Internet] [cited 2023 Apr 26] Available from: https://labs.aap.cornell.edu/ccl/decon
[9] Heisel F, McGranahan J, Boghossian A 2022 *IOP Conf Ser: Earth Environ Sci* **1078(1)** 012012
[10] Brand S 1995 How Buildings Learn: What Happens After They're Built (New York: Penguin Books) p 256
[11] US EPA 2016 *Basic Information about the Waste Reduction Model (WARM)*
[12] EC3 [Internet] [cited 2023 May 3] Available from: https://buildingtransparency.org/ec3
[13] Jones C, Hammond J 2019 ICE (Inventory of Carbon and Energy)
[14] NYS DEC 2023 New York State Solid Waste Management Plan: Building the Circular Economy through Sustainable Materials Management

7 References

ACT Government, 2023. Building Canberra's Circular Economy: ACT Circular Economy Strategy and Action Plan 2023-2030. Canberra.
Ade, R., Rehm, M., 2020. The unwritten history of green building rating tools: A personal view from some of the 'founding fathers.' Build. Res. Inf. 48, 1–17. https://doi.org/10.1080/09613218.2019.1627179
Akinade, O., Oyedele, L., Oyedele, A., Davila Delgado, J.M., Bilal, M., Akanbi, L., Ajayi, A., Owolabi, H., 2020. Design for deconstruction using a circular economy approach: barriers and strategies for improvement. Prod. Plan. Control 31, 829–840. https://doi.org/10.1080/09537287.2019.1695006
Alnajem, M., Mostafa, M.M., ElMelegy, A.R., 2021. Mapping the first decade of circular economy research: a bibliometric network analysis. J. Ind. Prod. Eng. 38, 29–50. https://doi.org/10.1080/21681015.2020.1838632
Altmann, E., 2014. Apartments, Co-ownership and Sustainability: Implementation Barriers for Retrofitting the Built Environment. J. Environ. Policy Plan. 16, 437–457. https://doi.org/10.1080/1523908X.2013.858593
Antwi-Afari, P., Ng, S.T., Hossain, Md.U., 2021. A review of the circularity gap in the construction industry through scientometric analysis. J. Clean. Prod. 298, 126870. https://doi.org/10.1016/j.jclepro.2021.126870
Architects Accreditation Council of Australia, 2023. Number of Architects in Australia 01122022. URL https://aaca.org.au/number-of-architects-in-australia-01122022/
Architects Accreditation Council of Australia, 2018. The Profession of Architecture in Australia. Architects Accreditation Council of Australia.
Aristi Capetillo, A., Bauer, F., Chaminade, C., 2023. Emerging Technologies Supporting the Transition to a Circular Economy in the Plastic Materials Value Chain. Circ. Econ. Sustain. 3, 953–982. https://doi.org/10.1007/s43615-022-00209-2
ARUP, 2016. Circular Economy in the Built Environment. ARUP, London.
Ascione, F., De Masi, R.F., Mastellone, M., Vanoli, G.P., 2022. Building rating systems: A novel review about capabilities, current limits and open issues. Sustain. Cities Soc. 76. https://doi.org/10.1016/j.scs.2021.103498
Australia ICOMOS Incorporated, 2013. Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance.
Australian Building Codes Board, 2022. Understanding the NCC Building classifications. Australian Building Codes Board.
Australian Bureau of Statistics, 2022a. 2021 Census All persons QuickStats. URL https://www.abs.gov.au/census/find-census-data/quickstats/2021/AUS
Australian Bureau of Statistics, 2022b. 2021 Census count includes Australians living on wheels and water, but most of us still firmly on land. Census. URL https://www.abs.gov.au/media-centre/media-releases/2021-census-count-includes-australians-living-wheels-and-water-most-us-still-firmly-land#:~:text=The%202021%20Census%20separately%20identified,us%20now%20live%20in%20apartments.
Australian Bureau of Statistics, 2021. Dwelling structure (STRD). URL https://www.abs.gov.au/census/guide-census-data/census-dictionary/2021/variables-topic/housing/dwelling-structure-strd
Australian Bureau of Statistics, 2020. Telling storeys - apartment building heights. URL https://www.abs.gov.au/articles/telling-storeys-apartment-building-heights

Australian Government Department of Climate Change, Energy, the Environment and Water, 2022. Environment Ministers Meeting – 21 October 2022 Agreed Communiqué.
Australian Institute of Architects, 2023. National Novation Survey. Australian Institute of Architects, Melbourne, Victoria.
Australian Institute of Architects, 2021. 2021 NSW Architecture Awards Winners. URL https://www.architecture.com.au/awards/2021-awards/2021-nsw-architecture-awards-winners-2
Australian Institute of Architects, 2019. The Benefits and Challenges of Novation for Architects - Victoria. Australian Institute of Architects, Melbourne, Victoria.
Australia's Circular Economy Framework, 2024. . Department of Climate Change, Energy, the Environment and Water, Canberra, ACT, Australia.
Baum, F., 2006. Participatory action research. J. Epidemiol. Community Health 60, 854–857. https://doi.org/10.1136/jech.2004.028662
Benachio, G.L.F., Freitas, M.D.C.D., Tavares, S.F., 2020. Circular economy in the construction industry: A systematic literature review. J. Clean. Prod. 260, 121046. https://doi.org/10.1016/j.jclepro.2020.121046
Benyus, J.M., 2009. Biomimicry: innovation inspired by nature, Nachdr. ed. Perennial, New York, NY.
Bleischwitz, R., Yang, M., Huang, B., Xu, X., Zhou, J., McDowall, W., Andrews-Speed, P., Liu, Z., Yong, G., 2022. The circular economy in China: Achievements, challenges and potential implications for decarbonisation. Resour. Conserv. Recycl. 183, 106350. https://doi.org/10.1016/j.resconrec.2022.106350
Blomsma, F., Brennan, G., 2017a. The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity. J. Ind. Ecol. 21, 603–614. https://doi.org/10.1111/jiec.12603
Blomsma, F., Brennan, G., 2017b. The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity: The Emergence of Circular Economy. J. Ind. Ecol. 21, 603–614. https://doi.org/10.1111/jiec.12603
Bocken, N.M.P., De Pauw, I., Bakker, C., Van Der Grinten, B., 2016. Product design and business model strategies for a circular economy. J. Ind. Prod. Eng. 33, 308–320. https://doi.org/10.1080/21681015.2016.1172124
Borms, L., Van Opstal, W., Brusselaers, J., Van Passel, S., 2023. The working future: An analysis of skills needed by circular startups. J. Clean. Prod. 409, 137261. https://doi.org/10.1016/j.jclepro.2023.137261
Boulding, K., 1966. The Economics of the Coming Spaceship Earth, in: Environmental Quality in a Growing Economy. Resources for the Future/Johns Hopkins University Press, Baltimore, pp. 3–14.
Boulding, K.E., 1972. The Future of Personal Responsibility. Am. Behav. Sci. 15, 329–359. https://doi.org/10.1177/000276427201500303
Bourdieu, P., 1977. Outline of a Theory of Practice, 1st ed. Cambridge University Press. https://doi.org/10.1017/CBO9780511812507
Boyd, P., Schweber, L., 2018. Unintended consequences: institutional artefacts, closure mechanisms and the performance gap. Build. Res. Inf. 46, 10–22. https://doi.org/10.1080/09613218.2017.1331096
Brand, S., 2007. Shearing Layers, in: How Buildings Age: What Happens after They Are Built. Penguin Books, Harmondsworth, pp. 12–23.
Braulio-Gonzalo, M., Jorge-Ortiz, A., Bovea, M.D., 2022. How are indicators in Green Building Rating Systems addressing sustainability dimensions and life cycle frameworks in residential buildings? Environ. Impact Assess. Rev. 95, 106793. https://doi.org/10.1016/j.eiar.2022.106793

Buckley, C., 2012. Never Demolish: Bois-le-Prêtre Regrows in Paris. Log 43–50.
Butler-Bowdon, C., Pickett, C., Dupain, M., Sierins, E., 2007. Homes in the sky: apartment living in Australia, Miegunyah volumes, second numbered series. Miegunyah Press ; Published in association with Historic Houses Trust, Carlton, Vic. : Sydney.
Cagno, E., Neri, A., Negri, M., Bassani, C.A., Lampertico, T., 2021. The role of digital technologies in operationalizing the circular economy transition: A systematic literature review. Appl. Sci. Switz. 11. https://doi.org/10.3390/app11083328
Cairns, S., Jacobs, J.M., 2014. Buildings must die: a perverse view of architecture. The MIT Press, Cambridge, Massachusetts.
Casson, C., Welch, D., 2021. Histories and Futures of Circular Economy, in: Bali Swain, R., Sweet, S. (Eds.), Sustainable Consumption and Production, Volume II. Springer International Publishing, Cham, pp. 35–54. https://doi.org/10.1007/978-3-030-55285-5_3
Çetin, S., Gruis, V., Straub, A., 2022. Digitalization for a circular economy in the building industry: Multiple-case study of Dutch social housing organizations. Resour. Conserv. Recycl. Adv. 15, 200110. https://doi.org/10.1016/j.rcradv.2022.200110
Çetin, S., Gruis, V., Straub, A., 2021. Towards Circular Social Housing: An Exploration of Practices, Barriers, and Enablers. Sustainability 13, 2100. https://doi.org/10.3390/su13042100
Chen, X., Yang, H., Lu, L., 2015. A comprehensive review on passive design approaches in green building rating tools. Renew. Sustain. Energy Rev. 50, 1425–1436. https://doi.org/10.1016/j.rser.2015.06.003
Çimen, Ö., 2021. Construction and built environment in circular economy: A comprehensive literature review. J. Clean. Prod. 305, 127180. https://doi.org/10.1016/j.jclepro.2021.127180
Circular Construction Lab, 2022a. Catherine Commons Deconstruction Project. URL https://labs.aap.cornell.edu/ccl/decon
Circular Construction Lab, 2022b. Circulating Matters. URL https://labs.aap.cornell.edu/ccl/circulatingmatters
City of Ithaca, n.d. East Hill Historic District Significance Statement. New York.
City of Ithaca, n.d. Planned Unit Development. URL https://www.cityofithaca.org/513/Planned-Unit-Development-PUD
ClimateWorks Centre, 2023. Climate-ready homes: Building the case for a renovation wave in Australia. ClimateWorks Centre, Australia.
Collins, R., Laws, C., Wadhwani, T., 2023. Circularity in Australian Business. Australian Circular Economy Hub Planet Ark Environmental Foundation.
Corvellec, H., Böhm, S., Stowell, A., Valenzuela, F., 2020. Introduction to the special issue on the contested realities of the circular economy. Cult. Organ. 26, 97–102. https://doi.org/10.1080/14759551.2020.1717733
Corvellec, H., Stowell, A.F., Johansson, N., 2022. Critiques of the circular economy. J. Ind. Ecol. 26, 421–432. https://doi.org/10.1111/jiec.13187
Costanza, R., Alperovitz, G., Daly, H., Farley, J., Franco, C., Jackson, T., Kubiszewski, I., Schor, J., Victor, P., 2013. Building a sustainable and desirable economy-in-society-in-nature. Australian National University E Press, Canberra, ACT, Australia.
Creswell, J.W., 2013. Qualitative inquiry and research design: choosing among five approaches, third edition. ed. SAGE, Los Angeles, Calif. London New Dehli Singapore Washington DC.
Creswell, J.W., Plano Clark, V.L., 2018. Designing and conducting mixed methods research, Third Edition. ed. SAGE, Los Angeles.

Creswell, J.W., Poth, C.N., 2018. Qualitative Inquiry & Research Design, Fourth edition. ed. SAGE, Los Angeles.
Crommelin, L., Thompson, S., Easthope, H., Loosemore, M., Yang, H., Buckle, C., Randolph, B., 2021. Cracks in the Compact City: Tackling defects in multi-unit strata housing. City Futures Research Centre, Sydney.
Cronen, V.E., 2001. Practical theory, practical art, and the pragmatic-systemic account of inquiry. Commun. Theory 11, 14–35. https://doi.org/10.1111/j.1468-2885.2001.tb00231.x
Crutzen, P.J., 2006. The "Anthropocene," in: Ehlers, E., Krafft, T. (Eds.), Earth System Science in the Anthropocene. Springer-Verlag, Berlin/Heidelberg, pp. 13–18. https://doi.org/10.1007/3-540-26590-2_3
Cruz Rios, F., Grau, D., Bilec, M., 2021. Barriers and Enablers to Circular Building Design in the US: An Empirical Study. J. Constr. Eng. Manag. 147, 04021117. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002109
CSIRO, 2024. Australian material flow analysis to progress to a circular economy.
Dalton, T., Dorignon, L., Boehme, T., Kempton, L., Iyer-Raniga, U., Oswald, D., Amirghasemi, M., Moore, T., 2023. Building materials in a circular economy. AHURI Final Rep. https://doi.org/10.18408/ahuri5328401
Darko, A., Chan, A.P.C., 2017. Review of Barriers to Green Building Adoption. Sustain. Dev. 25, 167–179. https://doi.org/10.1002/sd.1651
DCCEEW, 2025. National waste and resource recovery report 2024. The Department of Climate Change, Energy, the Environment and Water.
DCCEEW, 2024. Australia's Circular Economy Framework. Department of Climate Change, Energy, the Environment and Water, Canberra.
DCCEEW, 2022. Nature Positive Plan: better for the environment, better for business. Australian Government Department of Climate Change, Energy, the Environment and Water.
De Feijter, F.J., 2023. Trust in circular design: active stakeholder participation in Chinese and Dutch housing retrofit projects. Build. Res. Inf. 51, 105–118. https://doi.org/10.1080/09613218.2022.2121905
De Silva, S., Samarakoon, S.M.S.M.K., Haq, M.A.A., 2023. Use of circular economy practices during the renovation of old buildings in developing countries. Sustain. Futur. 6, 100135. https://doi.org/10.1016/j.sftr.2023.100135
Dean, J., 2022. Unbuild Better: a Collegetown case study in deconstruction. Cornell Chron.
Denman, M., Ullah, F., Qayyum, S., Olatunji, O., 2024. Post-Construction Defects in Multi-Unit Australian Dwellings: An Analysis of the Defect Type, Causes, Risks, and Impacts. Buildings 14, 231. https://doi.org/10.3390/buildings14010231
Densley Tingley, D., 2022. Embed circular economy thinking into building retrofit. Commun. Eng. 1, 28. https://doi.org/10.1038/s44172-022-00027-2
Densley Tingley, D., Cooper, S., Cullen, J., 2017. Understanding and overcoming the barriers to structural steel reuse, a UK perspective. J. Clean. Prod. 148, 642–652. https://doi.org/10.1016/j.jclepro.2017.02.006
Department of Communities and Justice, n.d. Rent Report. URL https://public.tableau.com/app/profile/dcj.statistics/viz/Rentandsales_16849924917120/Rent?publish=yes
Dewagoda, K.G., Ng, S.T., Chen, J., 2022. Driving systematic circular economy implementation in the construction industry: A construction value chain perspective. J. Clean. Prod. 381. https://doi.org/10.1016/j.jclepro.2022.135197

Ding, S., Tukker, A., Ward, H., 2023. Opportunities and risks of internet of things (IoT) technologies for circular business models: A literature review. J. Environ. Manage. 336, 117662. https://doi.org/10.1016/j.jenvman.2023.117662
Doan, D.T., Ghaffarianhoseini, Ali, Naismith, N., Zhang, T., Ghaffarianhoseini, Amirhosein, Tookey, J., 2017. A critical comparison of green building rating systems. Build. Environ. 123, 243–260. https://doi.org/10.1016/j.buildenv.2017.07.007
Doan, D.T., Wall, H., Ghaffarian Hoseini, A., Ghaffarianhoseini, A., Naismith, N., 2021. Green Building Practice in the New Zealand Construction Industry: Drivers and Limitations. Int. J. Technol. 12, 946. https://doi.org/10.14716/ijtech.v12i5.5209
D'Oca, S., Ferrante, A., Ferrer, C., Pernetti, R., Gralka, A., Sebastian, R., Op 'T Veld, P., 2018. Technical, Financial, and Social Barriers and Challenges in Deep Building Renovation: Integration of Lessons Learned from the H2020 Cluster Projects. Buildings 8, 174. https://doi.org/10.3390/buildings8120174
Dokter, G., Thuvander, L., Rahe, U., 2021. How circular is current design practice? Investigating perspectives across industrial design and architecture in the transition towards a circular economy. Sustain. Prod. Consum. 26, 692–708. https://doi.org/10.1016/j.spc.2020.12.032
Dyer, M., Wu, S., Weng, M.-H., 2021. Convergence of Public Participation, Participatory Design and NLP to Co-Develop Circular Economy. Circ. Econ. Sustain. 1, 917–934. https://doi.org/10.1007/s43615-021-00079-0
Easthope, H., Palmer, J., Sharam, A., Nethercote, M., Pignatta, G., Crommelin, L., 2023a. Delivering sustainable apartment housing: New build and retrofit. AHURI Final Rep. https://doi.org/10.18408/ahuri7128201
Easthope, H., Thompson, S., Sisson, A., 2023b. Australasian Strata Insights 2020. City Futures Research Centre, Sydney.
Eberhardt, L.C.M., Birkved, M., Birgisdottir, H., 2022. Building design and construction strategies for a circular economy. Archit. Eng. Des. Manag. 18, 93–113. https://doi.org/10.1080/17452007.2020.1781588
EEA, 2022. Building renovation: where circular economy and climate meet. Publications Office of the European Union, Luxembourg.
Ellen MacArthur Foundation, 2015. Growth within: a circular economy vision for a competitive Europe. Ellen McArthur Foundation & McKinsey Center for Business and Environment.
Ellen MacArthur Foundation, 2013. Towards the Circular Economy: Economic and Business Rationale for an Accelerted Transition.
European Commission, 2020. A new Circular Economy Action Plan For a cleaner and more competitive Europe (OMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS). European Commission, Brussels.
European Union, 2024. Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings (recast) [WWW Document]. Eur. Union. URL https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202401275
Eurostat, 2021. House or flat: where do you live? Eurostat. URL https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210521-1
Fairbrother, P., Banks, M., 2024. A Just Transition for Labour: The Challenges of Moves to a Circular Economy. Relat. Ind. Ind. Relat. 78. https://doi.org/10.7202/1109482ar
Ferrari, S., Zoghi, M., Blázquez, T., Dall'O', G., 2022. New Level(s) framework: Assessing the affinity between the main international Green Building Rating Systems and the european scheme. Renew. Sustain. Energy Rev. 155, 111924. https://doi.org/10.1016/j.rser.2021.111924

Findik, D., Tirgil, A., Özbuğday, F.C., 2023. Industry 4.0 as an enabler of circular economy practices: Evidence from European SMEs. J. Clean. Prod. 410. https://doi.org/10.1016/j.jclepro.2023.137281
Flats, 2008. . EMelbourne City Pasusit Present.
Flyvbjerg, B., 2006. Five Misunderstandings About Case-Study Research. Qual. Inq. 12, 219–245. https://doi.org/10.1177/1077800405284363
Forsberg, M., De Souza, C.B., 2021. Implementing Regenerative Standards in Politically Green Nordic Social Welfare States: Can Sweden Adopt the Living Building Challenge? Sustainability 13, 738. https://doi.org/10.3390/su13020738
Fotopoulou, A., Semprini, G., Cattani, E., Schihin, Y., Weyer, J., Gulli, R., Ferrante, A., 2018. Deep renovation in existing residential buildings through façade additions: A case study in a typical residential building of the 70s. Energy Build. 166, 258–270. https://doi.org/10.1016/j.enbuild.2018.01.056
Fraser, M., Conde, Á., Haigh, L., 2024. The Circularity Gap Report 2024. Circle Economy Foundation.
Gasparri, E., Arasteh, S., Kuru, A., Stracchi, P., Brambilla, A., 2023. Circular economy in construction: A systematic review of knowledge gaps towards a novel research framework. Front. Built Environ. 9, 1239757. https://doi.org/10.3389/fbuil.2023.1239757
GBCA, n.d. The Responsible Products program. URL https://new.gbca.org.au/green-star/the-responsible-products-program/
Geels, F.W., 2019. Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. Curr. Opin. Environ. Sustain. 39, 187–201. https://doi.org/10.1016/j.cosust.2019.06.009
Geels, F.W., 2018. Socio-Technical Transitions to Sustainability, in: Oxford Research Encyclopedia of Environmental Science. Oxford University Press. https://doi.org/10.1093/acrefore/9780199389414.013.587
Geels, F.W., 2011. The multi-level perspective on sustainability transitions: Responses to seven criticisms. Environ. Innov. Soc. Transit. 1, 24–40. https://doi.org/10.1016/j.eist.2011.02.002
Geels, F.W., 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Res. Policy 39, 495–510. https://doi.org/10.1016/j.respol.2010.01.022
Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Policy 36, 399–417. https://doi.org/10.1016/j.respol.2007.01.003
Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy – A new sustainability paradigm? J. Clean. Prod. 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048
Genovese, A., Pansera, M., 2021. The Circular Economy at a Crossroads: Technocratic Eco-Modernism or Convivial Technology for Social Revolution? Capital. Nat. Social. 32, 95–113. https://doi.org/10.1080/10455752.2020.1763414
GhaffarianHoseini, Ali, Tien Doan, D., Naismith, N., Tookey, J., GhaffarianHoseini, Amirhosein, 2017. Amplifying the practicality of contemporary building information modelling (BIM) implementations for New Zealand green building certification (Green Star). Eng. Constr. Archit. Manag. 24, 696–714. https://doi.org/10.1108/ECAM-02-2016-0043
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007
Giddens, A., 1984. The Constitution of Society. Outline of the Theory of Structuration. University of California Press, Berkeley.

Gillott, C., Mihkelson, W., Lanau, M., Cheshire, D., Densley Tingley, D., 2023. Developing Regenerate: A circular economy engagement tool for the assessment of new and existing buildings. J. Ind. Ecol. 27, 423–435. https://doi.org/10.1111/jiec.13377
Giorgi, S., Lavagna, M., Campioli, A., 2020. Circular Economy and Regeneration of Building Stock: Policy Improvements, Stakeholder Networking and Life Cycle Tools, in: Della Torre, S., Cattaneo, S., Lenzi, C., Zanelli, A. (Eds.), Regeneration of the Built Environment from a Circular Economy Perspective, Research for Development. Springer International Publishing, Cham, pp. 291–301. https://doi.org/10.1007/978-3-030-33256-3_27
GML Heritage, 2024. Woollahra Interwar Buildings Thematic History. Woollahra Municipal Council.
Gonçalves, M.L.M.B.B., Maximo, G.J., 2023. Circular Economy in the Food Chain: Production, Processing and Waste Management. Circ. Econ. Sustain. 3, 1405–1423. https://doi.org/10.1007/s43615-022-00243-0
Goubran, S., Walker, T., Cucuzzella, C., Schwartz, T., 2023. Green building standards and the United Nations' Sustainable Development Goals. J. Environ. Manage. 326, 116552. https://doi.org/10.1016/j.jenvman.2022.116552
Graedel, T., Allenby, B.R., 2003. Industrial ecology, 2. ed. ed, Prentice-Hall international series in industrial and systems engineering. Prentice Hall, Upper Saddle River, NJ.
Greater London Authority, 2022. London Plan Guidance: Circular Economy Statements.
Green Building Council of Australia, 2021. Green Star Buildings Submission Guidelines Version 1: Revision B.
Green Building Council of Australia, n.d. Green Star Project Directory. URL https://www.gbca.org.au/project-directory.asp (accessed 10.31.23).
Gromark, S., Paadam, K., 2017. Social Housing Renewal Challenged: La tour Bois-le-Prêtre, Paris 2012, in: Ways of Residing in Transformation: Interdisciplinary Perspectives. Routledge, London, pp. 173–197.
Guerra, B.C., Shahi, S., Mollaei, A., Skaf, N., Weber, O., Leite, F., Haas, C., 2021. Circular economy applications in the construction industry: A global scan of trends and opportunities. J. Clean. Prod. 324, 129125. https://doi.org/10.1016/j.jclepro.2021.129125
Heatmaps, n.d. HeatMaps.
Heisel, F., McGranahan, J., Boghossian, A., 2022. ScanR: A composite building scanning and survey method for the evaluation of materials and reuse potentials prior to demolition and deconstruction. IOP Conf. Ser. Earth Environ. Sci. 1078, 012012. https://doi.org/10.1088/1755-1315/1078/1/012012
Heisel, F., McGranahan, J., Lucas, A., Cohen, D., Stone, G., 2023. Carbon, economics, and labor: a case study of deconstruction's relative costs and benefits compared to demolition. J. Phys. Conf. Ser. 2600, 192003. https://doi.org/10.1088/1742-6596/2600/19/192003
Historic Ithaca, n.d. About Us. URL https://www.historicithaca.org/about-us
Hjaltadóttir, R.E., Hild, P., 2021. Circular Economy in the building industry European policy and local practices. Eur. Plan. Stud. 29, 2226–2251. https://doi.org/10.1080/09654313.2021.1904838
Hobson, K., Lynch, N., 2016. Diversifying and de-growing the circular economy: Radical social transformation in a resource-scarce world. Futures 82, 15–25. https://doi.org/10.1016/j.futures.2016.05.012
Hoffman, D., Huang, L.-Y., van Rensburg, J., Yorke-Hart, A., 2020. Trends in application of Green Star SA credits in South African green building. Acta Structilia 27. https://doi.org/10.18820/24150487/as27i2.1

Holmes, H., Wieser, H., Kasmire, J., 2021. Critical Approaches to Circular Economy Research: Time, Space and Evolution, in: Bali Swain, R., Sweet, S. (Eds.), Sustainable Consumption and Production, Volume II. Springer International Publishing, Cham, pp. 55–74. https://doi.org/10.1007/978-3-030-55285-5_4

Horne, R., Dorignon, L., Lawson, J., Easthope, H., Dühr, S., Moore, T., Baker, E., Dalton, T., Pawson, H., Fairbrother, P., Xiong, Z., 2023. Informing a strategy for circular economy housing in Australia. AHURI Final Rep. https://doi.org/10.18408/ahuri5328001

Hosseini, M.R., Memari, S., Martek, I., Kocaturk, T., Bararzadeh, M., Arashpour, M., 2024. Dismantling linear lock-ins in the Australian AEC industry: A pathway to a circular economy. Sustain. Dev. https://doi.org/10.1002/sd.3082

ILFI, 2019. Living Building Challenge 4.0: A Visionary Path to a Regenerative Future. International Living Future Institute.

IPCC, 2023. IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland. Intergovernmental Panel on Climate Change (IPCC). https://doi.org/10.59327/IPCC/AR6-9789291691647

Ithaca ReUse, n.d. Ithaca. URL https://ithacareuse.org/about

Iyer-Raniga, U., 2019. Using the ReSOLVE framework for circularity in the building and construction industry in emerging markets. IOP Conf. Ser. Earth Environ. Sci. 294, 012002. https://doi.org/10.1088/1755-1315/294/1/012002

James, P., 2022. Re-embedding the circular economy in Circles of Social Life: beyond the self-repairing (and still-rapacious) economy. Local Environ. 27, 1208–1224. https://doi.org/10.1080/13549839.2022.2040469

Jiménez-Pulido, C., Jiménez-Rivero, A., García-Navarro, J., 2022. Improved sustainability certification systems to respond to building renovation challenges based on a literature review. J. Build. Eng. 45, 103575. https://doi.org/10.1016/j.jobe.2021.103575

Kanters, J., 2020. Circular Building Design: An Analysis of Barriers and Drivers for a Circular Building Sector. Buildings 10, 77. https://doi.org/10.3390/buildings10040077

Kaushik, V., Walsh, C.A., 2019. Pragmatism as a Research Paradigm and Its Implications for Social Work Research. Soc. Sci. 8, 255. https://doi.org/10.3390/socsci8090255

Keena, N., Friedman, A., 2024. Sustainable Housing in a Circular Economy, 1st ed. Routledge, London. https://doi.org/10.4324/9781003333975

Keller, M., Noorkõiv, M., Vihalemm, T., 2022a. Systems and practices: Reviewing intervention points for transformative socio-technical change. Energy Res. Soc. Sci. 88, 102608. https://doi.org/10.1016/j.erss.2022.102608

Keller, M., Sahakian, M., Hirt, L.F., 2022b. Connecting the multi-level-perspective and social practice approach for sustainable transitions. Environ. Innov. Soc. Transit. 44, 14–28. https://doi.org/10.1016/j.eist.2022.05.004

Kelly, L.M., Cordeiro, M., 2020. Three principles of pragmatism for research on organizational processes. Methodol. Innov. 13, 2059799120937242. https://doi.org/10.1177/2059799120937242

Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resour. Conserv. Recycl. 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Kirchherr, J., Urbinati, A., Hartley, K., 2023a. Circular economy: A new research field? J. Ind. Ecol. 27, 1239–1251. https://doi.org/10.1111/jiec.13426

Kirchherr, J., Yang, N.-H.N., Schulze-Spüntrup, F., Heerink, M.J., Hartley, K., 2023b. Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions.

Resour. Conserv. Recycl. 194, 107001. https://doi.org/10.1016/j.resconrec.2023.107001
Koc, K., Durdyev, S., Tleuken, A., Ekmekcioglu, O., Mbachu, J., Karaca, F., 2023. Critical success factors for construction industry transition to circular economy: developing countries' perspectives. Eng. Constr. Archit. Manag. https://doi.org/10.1108/ECAM-02-2023-0129
Köhler, J., Turnheim, B., Hodson, M., 2020. Low carbon transitions pathways in mobility: Applying the MLP in a combined case study and simulation bridging analysis of passenger transport in the Netherlands. Technol. Forecast. Soc. Change 151, 119314. https://doi.org/10.1016/j.techfore.2018.06.003
Korhonen, J., Nuur, C., Feldmann, A., Birkie, S.E., 2018. Circular economy as an essentially contested concept. J. Clean. Prod. 175, 544–552. https://doi.org/10.1016/j.jclepro.2017.12.111
Kozminska, U., 2019. Circular design: reused materials and the future reuse of building elements in architecture. Process, challenges and case studies. IOP Conf. Ser. Earth Environ. Sci. 225, 012033. https://doi.org/10.1088/1755-1315/225/1/012033
Kroll, C., Warchold, A., Pradhan, P., 2019. Sustainable Development Goals (SDGs): Are we successful in turning trade-offs into synergies? Palgrave Commun. 5, 140. https://doi.org/10.1057/s41599-019-0335-5
Kuittinen, M., 2023. Building within planetary boundaries: moving construction to stewardship. Build. Cities 4, 565–574. https://doi.org/10.5334/bc.351
Lami, I.M., Abastante, F., Gaballo, M., 2021. Supporting the Transition from Linear to Circular Economy Through the Sustainability Protocols, in: Gervasi, O., Murgante, B., Misra, S., Garau, C., Blečić, I., Taniar, D., Apduhan, B.O., Rocha, A.M.A.C., Tarantino, E., Torre, C.M. (Eds.), Computational Science and Its Applications – ICCSA 2021, Lecture Notes in Computer Science. Springer International Publishing, Cham, pp. 626–641. https://doi.org/10.1007/978-3-030-87007-2_45
Lane, R., Allen, M.K., 2024. What Gets Measured Gets Managed: Targets, Reporting and the Benefits of Community Reuse Organisations in the Circular Economy, in: Waste Research from the Social Sciences and Humanities Perspectives: Reopening the Bin. Cambridge Scholars Publishing, pp. 10–29.
Lasker, P., Goloubeva, J., 2018. Australia needs to start recycling and reusing its own waste, says industry struggling under China's ban. ABC News.
Lazar, N., Chithra, K., 2021. Comprehensive bibliometric mapping of publication trends in the development of Building Sustainability Assessment Systems. Environ. Dev. Sustain. 23, 4899–4923. https://doi.org/10.1007/s10668-020-00796-w
Le Corbusier, Cohen, J.-L., Goodman, J., 2007. Toward an architecture, Texts & documents. Getty Research Institute, Los Angeles, Calif.
Leising, E., Quist, J., Bocken, N., 2018. Circular Economy in the building sector: Three cases and a collaboration tool. J. Clean. Prod. 176, 976–989. https://doi.org/10.1016/j.jclepro.2017.12.010
Liu, K., 2024. Circular economy and the separated yet inseparable social dimension: Views from European circular city experts. Sustain. Prod. Consum. 51, 474–483. https://doi.org/10.1016/j.spc.2024.09.016
Living Building Projects in Australia, n.d. . Living Future Inst. Aust. URL https://living-future.org.au/aus-projects/ (accessed 11.1.23).
Llorente-González, L.J., Vence, X., 2020. How labour-intensive is the circular economy? A policy-orientated structural analysis of the repair, reuse and recycling activities in the European Union. Resour. Conserv. Recycl. 162, 105033. https://doi.org/10.1016/j.resconrec.2020.105033

Lopes de Sousa Jabbour, A.B., Rojas Luiz, J.V., Rojas Luiz, O., Jabbour, C.J.C., Ndubisi, N.O., Caldeira de Oliveira, J.H., Junior, F.H., 2019. Circular economy business models and operations management. J. Clean. Prod. 235, 1525–1539. https://doi.org/10.1016/j.jclepro.2019.06.349

Lopes de Sousa Jabbour, A.B., Jabbour, C.J.C., Godinho Filho, M., Roubaud, D., 2018. Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Ann. Oper. Res. 270, 273–286. https://doi.org/10.1007/s10479-018-2772-8

Löschke, S.K., Easthope, H., 2017. Postproduced: How Adaptive Redesign and Participatory Approaches Can Transform Ageing Housing, in: From Conflict to Inclusion in Housing: Interaction of Communities, Residents and Activists. UCL Press.

Luscuere, L.M., 2017. Materials Passports: Optimising value recovery from materials. Proc. Inst. Civ. Eng. - Waste Resour. Manag. 170, 25–28. https://doi.org/10.1680/jwarm.16.00016

Lyle, J.T., 1994. Regenerative design for sustainable development, Wiley series in sustainable design. Wiley, New York, NY.

Marchesi, M., Tweed, C., 2021. Social innovation for a circular economy in social housing. Sustain. Cities Soc. 71, 102925. https://doi.org/10.1016/j.scs.2021.102925

Marchesi, M., Tweed, C., Gerber, D., 2020. Applying Circular Economy Principles to Urban Housing. IOP Conf. Ser. Earth Environ. Sci. 588, 052065. https://doi.org/10.1088/1755-1315/588/5/052065

Marcon, M., Provensi, T., Sehnem, S., Campos, L.M.S., Queiroz, A.A.F.S.L., 2023. The internalisation of the circular economy and ESG in Brazilian B Corps from the perspective of the Stakeholder Theory. Sustain. Dev. 31, 3513–3527. https://doi.org/10.1002/sd.2601

Marinova, S., Deetman, S., Van Der Voet, E., Daioglou, V., 2020. Global construction materials database and stock analysis of residential buildings between 1970-2050. J. Clean. Prod. 247, 119146. https://doi.org/10.1016/j.jclepro.2019.119146

Markard, J., Geels, F.W., Raven, R., 2020. Challenges in the acceleration of sustainability transitions 7 p. https://doi.org/10.3929/ETHZ-B-000439169

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

Martin-Goñi, P., Avellaneda, J., González, J.M., 2024. Energetic and Functional Rehabilitation of Residential Buildings in Europe: Analysis and Cataloguing of the Strategies Used. Buildings 14, 525. https://doi.org/10.3390/buildings14020525

Mattinzioli, T., Sol-Sánchez, M., Moreno, B., Alegre, J., Martínez, G., 2021. Sustainable building rating systems: A critical review for achieving a common consensus. Crit. Rev. Environ. Sci. Technol. 51, 512–534. https://doi.org/10.1080/10643389.2020.1732781

Mattoni, B., Guattari, C., Evangelisti, L., Bisegna, F., Gori, P., Asdrubali, F., 2018. Critical review and methodological approach to evaluate the differences among international green building rating tools. Renew. Sustain. Energy Rev. 82, 950–960. https://doi.org/10.1016/j.rser.2017.09.105

Mazur, C., Contestabile, M., Offer, G.J., Brandon, N.P., 2015. Assessing and comparing German and UK transition policies for electric mobility. Environ. Innov. Soc. Transit. 14, 84–100. https://doi.org/10.1016/j.eist.2014.04.005

McDonough, W., Braungart, M., 2002. Cradle to cradle: remaking the way we make things. North Point Press, New York.

McGregor, S.L.T., 2018. Understanding and Evaluating Research: A Critical Guide. SAGE Publications, Inc, 2455 Teller Road, Thousand Oaks California 91320. https://doi.org/10.4135/9781071802656
Mead, M., n.d. Garron Tower from the boardwalk of the Murray Rose pool.
Meadows, D.H., Club of Rome, Potomac Associates (Eds.), 1972. The limits to growth: a report for the club of rome's project on the predicament of mankind, 2. ed. ed, A potomac associates book. Universe books, New York.
Mêda, P., Hjelseth, E., Calvetti, D., Sousa, H., 2024. Exploring the significance and priority of digital product passports implementation in building renovation projects targeting circular economy. Smart Sustain. Built Environ. https://doi.org/10.1108/SASBE-05-2024-0193
Menegaki, M., Damigos, D., 2018. A review on current situation and challenges of construction and demolition waste management. Curr. Opin. Green Sustain. Chem. 13, 8–15. https://doi.org/10.1016/j.cogsc.2018.02.010
Mhatre, P., Gedam, V., Unnikrishnan, S., Verma, S., 2021a. Circular economy in built environment – Literature review and theory development. J. Build. Eng. 35, 101995. https://doi.org/10.1016/j.jobe.2020.101995
Mhatre, P., Panchal, R., Singh, A., Bibyan, S., 2021b. A systematic literature review on the circular economy initiatives in the European Union. Sustain. Prod. Consum. 26, 187–202. https://doi.org/10.1016/j.spc.2020.09.008
Miatto, A., Emami, N., Goodwin, K., West, J., Taskhiri, M.S., Wiedmann, T., Schandl, H., 2024. Australia's circular economy metrics and indicators. J. Ind. Ecol. jiec.13458. https://doi.org/10.1111/jiec.13458
Mies, A., Gold, S., 2021. Mapping the social dimension of the circular economy. J. Clean. Prod. 321, 128960. https://doi.org/10.1016/j.jclepro.2021.128960
Millais, M., 2015. A CRITICAL APPRAISAL OF THE DESIGN, CONSTRUCTION AND INFLUENCE OF THE UNITÉ D'HABITATION, MARSEILLES, FRANCE. J. Archit. Urban. 39, 103–115. https://doi.org/10.3846/20297955.2015.1062636
Mishra, A., Dutta, P., Jayasankar, S., Jain, P., Mathiyazhagan, K., 2023. A review of reverse logistics and closed-loop supply chains in the perspective of circular economy. Benchmarking Int. J. 30, 975–1020. https://doi.org/10.1108/BIJ-11-2021-0669
Moore, T., Doyon, A., 2023. A Transition to Sustainable Housing: Progress and Prospects for a Low Carbon Housing Future. Springer Nature, Singapore.
Moosavi, S., Hurlimann, A., Nielsen, J., Bush, J., Warren-Myers, G., March, A., 2023. Transforming the agency and influence of landscape architects in climate change actions: An empirical analysis of barriers and facilitators. Landsc. Urban Plan. 234, 104735. https://doi.org/10.1016/j.landurbplan.2023.104735
Moreau, V., Sahakian, M., Van Griethuysen, P., Vuille, F., 2017. Coming Full Circle: Why Social and Institutional Dimensions Matter for the Circular Economy. J. Ind. Ecol. 21, 497–506. https://doi.org/10.1111/jiec.12598
Morgan, D.L., 2014. Pragmatism as a Paradigm for Social Research. Qual. Inq. 20, 1045–1053. https://doi.org/10.1177/1077800413513733
Morseletto, P., 2020a. Restorative and regenerative: Exploring the concepts in the circular economy. J. Ind. Ecol. 24, 763–773. https://doi.org/10.1111/jiec.12987
Morseletto, P., 2020b. Targets for a circular economy. Resour. Conserv. Recycl. 153, 104553. https://doi.org/10.1016/j.resconrec.2019.104553
Mosman MunicipalCouncil, 2012. Site Waste Minimisation and Management Plan. Sydney.
Munaro, M.R., Tavares, S.F., Bragança, L., 2020. Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built

environment. J. Clean. Prod. 260, 121134. https://doi.org/10.1016/j.jclepro.2020.121134
Murray, A., Skene, K., Haynes, K., 2017. The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. J. Bus. Ethics 140, 369–380. https://doi.org/10.1007/s10551-015-2693-2
Mylan, J., Holmes, H., Paddock, J., 2016. Re-Introducing Consumption to the 'Circular Economy': A Sociotechnical Analysis of Domestic Food Provisioning. Sustainability 8, 794. https://doi.org/10.3390/su8080794
Neubauer, B.E., Witkop, C.T., Varpio, L., 2019. How phenomenology can help us learn from the experiences of others. Perspect. Med. Educ. 8, 90–97. https://doi.org/10.1007/S40037-019-0509-2
Nicholson, V., Miatto, A., 2024. Architects as catalysts of reuse in construction. Nat. Cities 1, 179–181. https://doi.org/10.1038/s44284-024-00042-8
Nigumann, E., Kalamees, T., Kuusk, K., Pihelo, P., 2024. Circular Renovation of an Apartment Building with Prefabricated Additional Insulation Elements to Nearly Zero Energy Building. J. Sustain. Archit. Civ. Eng. 34, 22–34. https://doi.org/10.5755/j01.sace.34.1.35674
NSW Architects Registration Board, 2024. Continuing professional development (CPD). CPD Requir. NSW Archit. URL https://www.architects.nsw.gov.au/download/FACTSHEET%20-%20CONTINUING%20PROFESSIONAL%20DEVELOPMENT.pdf
NSW Circular, 2020. NSW Circular Strategic Plan 2020-2023 (Strategic Plan). NSW Circular, NSW, Australia.
NSW Department of Planning and Environment, 2023. A comprehensive guide to BASIX: The Building Sustainability Index.
NSW Environment Protection Authority, 2019. NSW Circular Economy Policy Statement Too Good To Waste (No. EPA 2019P1379). NSW Environment Protection Authority, Sydney.
NSW Government, 2023. New planning rules to fast track low and mid rise housing. Planning. URL https://www.planning.nsw.gov.au/news/new-planning-rules-fast-track-low-and-mid-rise-housing
NSW Government, 2015. Apartment design guide: tools for improving the design of residential apartment development. NSW Department of Planning and Environment, Sydney, NSW.
NSW Government, n.d. About BASIX. URL https://pp.planningportal.nsw.gov.au/basix-certificate/about-basix
Nunez Madrigal, A., Iyer-Raniga, U., Yang, R.J., 2023. Exploring PV Waste Management Solutions Using Circular Strategies. J. Sustain. Res. 5. https://doi.org/10.20900/jsr20230008
Nußholz, J., Çetin, S., Eberhardt, L., De Wolf, C., Bocken, N., 2023. From circular strategies to actions: 65 European circular building cases and their decarbonisation potential. Resour. Conserv. Recycl. Adv. 17, 200130. https://doi.org/10.1016/j.rcradv.2023.200130
Office of Energy and Climate Change,, NSW Treasury, 2023. Circular design guidelines for the built environment: Whole-of-life principles for transitioning buildings, precincts and infrastructure to a circular economy.
Olanrewaju, O.I., Enegbuma, W.I., Donn, M., 2024. Operational, embodied and whole life cycle assessment credits in green building certification systems: Desktop analysis and natural language processing approach. Build. Environ. 258, 111569. https://doi.org/10.1016/j.buildenv.2024.111569

Onwuegbuzie, A.J., Leech, N.L., 2005. On Becoming a Pragmatic Researcher: The Importance of Combining Quantitative and Qualitative Research Methodologies. Int. J. Soc. Res. Methodol. 8, 375–387. https://doi.org/10.1080/13645570500402447
Orlikowski, W.J., 2007. Sociomaterial Practices: Exploring Technology at Work. Organ. Stud. 28, 1435–1448. https://doi.org/10.1177/0170840607081138
Orlikowski, W.J., Scott, S.V., 2008. 10 Sociomateriality: Challenging the Separation of Technology, Work and Organization. Acad. Manag. Ann. 2, 433–474. https://doi.org/10.5465/19416520802211644
Oyinlola, M., Kolade, O., Schröder, P., Odumuyiwa, V., Rawn, B., Wakunuma, K., Sharifi, S., Lendelvo, S., Akanmu, I., Mtonga, R., Tijani, B., Whitehead, T., Brighty, G., Abolfathi, S., 2023. A Socio-Technical Perspective on Transitioning to a Circular Plastic Economy in Africa. SSRN Electron. J. https://doi.org/10.2139/ssrn.4332904
Pál, V., 2022. Social and Cultural Aspects of the Circular Economy: Toward Solidarity and Inclusivity, 1st ed. Routledge, London. https://doi.org/10.4324/9781003255246
Palinkas, L.A., Horwitz, S.M., Green, C.A., Wisdom, J.P., Duan, N., Hoagwood, K., 2015. Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. Adm. Policy Ment. Health Ment. Health Serv. Res. 42, 533–544. https://doi.org/10.1007/s10488-013-0528-y
Parry-Husbands, H., Zwart, J., Rice-Jenkins, B., Gilling, R., Garofano, N., 2021. Circularity in Australian Businesses 2021. Planet Ark Environmental Foundation.
Payne, A., Kwofie, E.M., 2024. Unleashing circular economy potential in agriculture: Integrating social impact assessment with the framework as a tool for sustainable development. Sustain. Dev. sd.2952. https://doi.org/10.1002/sd.2952
Pikas, E., Seppänen, O., Koskela, L., Peltokorpi, A., 2021. Challenges in Industrialized Renovation of Apartment Buildings. Presented at the 29th Annual Conference of the International Group for Lean Construction (IGLC), Lima, Peru, pp. 985–994. https://doi.org/10.24928/2021/0155
Pomponi, F., Moncaster, A., 2017. Circular economy for the built environment: A research framework. J. Clean. Prod. 143, 710–718. https://doi.org/10.1016/j.jclepro.2016.12.055
Potting, J., Hekkert, M., Worrell, E., Hanemaaijer, A., 2017. Circular Economy: Measuring innovation in the product chain. PBL Netherlands Environmental Assessment Agency, Netherlands.
Prendeville, S., Cherim, E., Bocken, N., 2018. Circular Cities: Mapping Six Cities in Transition. Environ. Innov. Soc. Transit. 26, 171–194. https://doi.org/10.1016/j.eist.2017.03.002
Purvis, B., Celebi, D., Pansera, M., 2023. A framework for a responsible circular economy. J. Clean. Prod. 400, 136679. https://doi.org/10.1016/j.jclepro.2023.136679
Rahla, K., Mateus, R., Bragança, L., 2021. Implementing Circular Economy Strategies in Buildings—From Theory to Practice. Appl. Syst. Innov. 4, 26. https://doi.org/10.3390/asi4020026
Randolph, B., 2006. Delivering the Compact City in Australia: Current Trends and Future Implications. Urban Policy Res. 24, 473–490. https://doi.org/10.1080/08111140601035259
Randolph, B., 2002. 'Third city suburbs': Options for housing policy in ageing middle ring suburbs. Aust. Plan. 39, 173–178. https://doi.org/10.1080/07293682.2002.9982316
Randwick City Council, 2023. Randwick Architecture and Urban Design Awards 2023 winners announced. URL https://www.randwick.nsw.gov.au/about-us/news/news-items/2023/march/randwick-architecture-and-urban-design-awards-2023-winners-announced
Randwick City Council, 2012. Medium Density Residential. Sydney.
Randwick City Council, 2006. Rejuvenation of Apartment Buildings Urban Design.

Randwick City Council, n.d. Randwick Local Environmental Plan.
Randwick City Council, n.d. Local Environmental Plan (LEP). URL http://randwick.nsw.gov.au/planning-and-building/planning-strategies-and-control/local-environmental-plan-lep
Raven, R. (Rob), 2005. Strategic niche management for biomass:a comparative study on the experimental introduction of bioenergy technologies in the Netherlands and Denmark. https://doi.org/10.6100/IR590593
Raworth, K., 2017. A Doughnut for the Anthropocene: humanity's compass in the 21st century. Lancet Planet. Health 1, e48–e49. https://doi.org/10.1016/S2542-5196(17)30028-1
Reckwitz, A., 2002. Toward a Theory of Social Practices: A Development in Culturalist Theorizing. Eur. J. Soc. Theory 5, 243–263. https://doi.org/10.1177/13684310222225432
Rip, A., Kemp, R., 1998. Technological Change, in: Rayner, S., Malone, E.L. (Eds.), Human Choice and Climate Change: Vol. II, Resources and Technology. Battelle Press, Columbus, OH, pp. 327–354.
Rosewall, T., Shoory, M., 2017. Houses and Apartments in Australia. Reserve Bank Aust. Bull.
Rusch, M., Schöggl, J., Baumgartner, R.J., 2023. Application of digital technologies for sustainable product management in a circular economy: A review. Bus. Strategy Environ. 32, 1159–1174. https://doi.org/10.1002/bse.3099
Sáez-de-Guinoa, A., Zambrana-Vasquez, D., Fernández, V., Bartolomé, C., 2022. Circular Economy in the European Construction Sector: A Review of Strategies for Implementation in Building Renovation. Energies 15, 4747. https://doi.org/10.3390/en15134747
Saldaña, J., 2013. The coding manual for qualitative researchers, 2nd ed. ed. SAGE, Los Angeles.
Sánchez Cordero, A., Gómez Melgar, S., Andújar Márquez, J.M., 2019. Green Building Rating Systems and the New Framework Level(s): A Critical Review of Sustainability Certification within Europe. Energies 13, 66. https://doi.org/10.3390/en13010066
Schandl, H., Boxall, N.J., MacMillan, C., Porter, N., Terhorst, A., Kong, T., Walton, A., Skidmore, M., Muhlhausler, B., Hodgkinson, J., Ambrose, M., 2025. Mission-Oriented Research and Theory of Change: Driving Australia's Transition to a Circular Economy. Circ. Econ. Sustain. 5, 837–850. https://doi.org/10.1007/s43615-024-00460-9
Schandl, H., King, S., Kaksonen, A., Tapsuwan, S., Baynes, T., 2020. National circular economy roadmap for plastics, tyres, glass and paper. CSIRO, Australia.
Schatzki, T.R., 2001. The Site of the Social: A Philosophical Account of the Constitution of Social Life and Change. Penn State University Press. https://doi.org/10.5325/j.ctv1rnpjpt
Schnapp, S., Sitjà, R., Laustsen, J., 2013. What is Deep Renovation Definition? (Technical Report). Global Buildings Performance Network.
Schöggl, J.-P., Stumpf, L., Baumgartner, R.J., 2020. The narrative of sustainability and circular economy - A longitudinal review of two decades of research. Resour. Conserv. Recycl. 163, 105073. https://doi.org/10.1016/j.resconrec.2020.105073
Schulz, C., Hjaltadóttir, R.E., Hild, P., 2019. Practising circles: Studying institutional change and circular economy practices. J. Clean. Prod. 237, 117749. https://doi.org/10.1016/j.jclepro.2019.117749
Sehnem, S., Godoi, L., Simioni, F., Martins, C., Soares, S.V., de Andrade Guerra, J.B.S.O., Provensi, T., 2023. Management Food Waste in Municipality Schools: An Analysis from a Circular Economy Perspective. Logistics 7. https://doi.org/10.3390/logistics7020020
Semprini, G., Gulli, R., Ferrante, A., 2017. Deep regeneration vs shallow renovation to achieve nearly Zero Energy in existing buildings. Energy Build. 156, 327–342. https://doi.org/10.1016/j.enbuild.2017.09.044

Seo, S.N., 2017. Beyond the Paris Agreement: Climate change policy negotiations and future directions. Reg. Sci. Policy Pract. 9, 121–141. https://doi.org/10.1111/rsp3.12090
Seyfang, G., Hielscher, S., Hargreaves, T., Martiskainen, M., Smith, A., 2014. A grassroots sustainable energy niche? Reflections on community energy in the UK. Environ. Innov. Soc. Transit. 13, 21–44. https://doi.org/10.1016/j.eist.2014.04.004
Shan, M., Hwang, B., 2018. Green building rating systems: Global reviews of practices and research efforts. Sustain. Cities Soc. 39, 172–180. https://doi.org/10.1016/j.scs.2018.02.034
Shooshtarian, S., Hosseini, M.R., Kocaturk, T., Arnel, T., T. Garofano, N., 2023. Circular economy in the Australian AEC industry: investigation of barriers and enablers. Build. Res. Inf. 51, 56–68. https://doi.org/10.1080/09613218.2022.2099788
Shooshtarian, S., Maqsood, T., Caldera, S., Ryley, T., 2022. Transformation towards a circular economy in the Australian construction and demolition waste management system. Sustain. Prod. Consum. 30, 89–106. https://doi.org/10.1016/j.spc.2021.11.032
Shove, E., Pantzar, M., Watson, M., 2012. The Dynamics of Social Practice: Everyday Life and How it Changes. SAGE Publications Ltd, 1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom. https://doi.org/10.4135/9781446250655
Shove, E., Walker, G., 2010. Governing transitions in the sustainability of everyday life. Res. Policy 39, 471–476. https://doi.org/10.1016/j.respol.2010.01.019
Smith, A., Fressoli, M., 2024. Niche-regime interactions: post-automation in the Fourth Industrial Revolution. https://doi.org/10.33774/coe-2024-2xq0l
Smith, A., Fressoli, M., Thomas, H., 2014. Grassroots innovation movements: challenges and contributions. J. Clean. Prod. 63, 114–124. https://doi.org/10.1016/j.jclepro.2012.12.025
Smith, A., Hargreaves, T., Hielscher, S., Martiskainen, M., Seyfang, G., 2016. Making the most of community energies: Three perspectives on grassroots innovation. Environ. Plan. Econ. Space 48, 407–432. https://doi.org/10.1177/0308518X15597908
Smith, A., Raven, R., 2012. What is protective space? Reconsidering niches in transitions to sustainability. Res. Policy 41, 1025–1036. https://doi.org/10.1016/j.respol.2011.12.012
Smol, M., Mejia, A., Howarth, M., 2023. Business Opportunities in the Water and Wastewater Sector Through the ReSOLVE Framework, in: Smol, M., Prasad, M.N.V., Stefanakis, A.I. (Eds.), Water in Circular Economy, Advances in Science, Technology & Innovation. Springer International Publishing, Cham, pp. 225–233. https://doi.org/10.1007/978-3-031-18165-8_17
Stahel, W.R., 2020. History of the Circular Economy. The Historic Development of Circularity and the Circular Economy, in: Eisenriegler, S. (Ed.), The Circular Economy in the European Union. Springer International Publishing, Cham, pp. 7–19. https://doi.org/10.1007/978-3-030-50239-3_2
Stahel, W.R., 2010. The Performance Economy. Palgrave Macmillan UK, London. https://doi.org/10.1057/9780230274907
Stahel, W.R., 1982. The Product-Life Factor An Inquiry into the Nature of Sustainable Societies. The Role of the Private Sector. Houston Area Research Centre, Houston, 72–105. https://p2infohouse.org/ref/33/32217.pdf
Starks, H., Brown Trinidad, S., 2007. Choose Your Method: A Comparison of Phenomenology, Discourse Analysis, and Grounded Theory. Qual. Health Res. 17, 1372–1380. https://doi.org/10.1177/1049732307307031
Stoiljković, B., Petković, N., Krstić, H., Petrović, V., 2023. Application of Circular Economy Principles to Architectural Design: A Case Study of Serbia. Buildings 13, 1990. https://doi.org/10.3390/buildings13081990

Sumter, D., De Koning, J., Bakker, C., Balkenende, R., 2020. Circular Economy Competencies for Design. Sustainability 12, 1561. https://doi.org/10.3390/su12041561

Superti, V., Houmani, C., Binder, C.R., 2021. A systemic framework to categorize Circular Economy interventions: An application to the construction and demolition sector. Resour. Conserv. Recycl. 173, 105711. https://doi.org/10.1016/j.resconrec.2021.105711

Talla, A., McIlwaine, S., 2024. Industry 4.0 and the circular economy: using design-stage digital technology to reduce construction waste. Smart Sustain. Built Environ. 13, 179–198. https://doi.org/10.1108/SASBE-03-2022-0050

Tedesco, M., Simioni, F.J., Sehnem, S., Soares, J.F., Coelho Junior, L.M., 2022. Assessment of the circular economy in the Brazilian planted tree sector using the ReSOLVE framework. Sustain. Prod. Consum. 31, 397–406. https://doi.org/10.1016/j.spc.2022.03.005

Terzioğlu, N., 2021. Repair motivation and barriers model: Investigating user perspectives related to product repair towards a circular economy. J. Clean. Prod. 289, 125644. https://doi.org/10.1016/j.jclepro.2020.125644

The Crowd Network, n.d. About Us. URL https://www.cr0wd.org/about-us

The Wellbeing of Architects, 2022. The Wellbeing of Architects 2021 Practitioner Survey, Primary Report.

Thomsen, A., Van Der Flier, K., 2011. Understanding obsolescence: a conceptual model for buildings. Build. Res. Inf. 39, 352–362. https://doi.org/10.1080/09613218.2011.576328

Tigani, D., Van Kan, D., Tennakoon, G., Geng, L., Chan, M., 2024. Measuring Embodied Carbon of Buildings: A Review of Methodologies and Benchmarking Towards Net Zero. IOP Conf. Ser. Earth Environ. Sci. 1363, 012030. https://doi.org/10.1088/1755-1315/1363/1/012030

Torgautov, B., Zhanabayev, A., Tleuken, A., Turkyilmaz, A., Mustafa, M., Karaca, F., 2021. Circular economy: Challenges and opportunities in the construction sector of Kazakhstan. Buildings 11. https://doi.org/10.3390/buildings11110501

Townsend, C., Pert, A., 2020. "The worst disaster" ever to blight Melbourne's residential landscape. Six-pack flats, rhetoric, and the stigmatisation of an important urban housing typology in post-war Melbourne, Australia. Presented at the The Terms of Habitation: Re-theorizing the Architecture of Housing Conference.

Trubina, N., Pešta, J., Lupíšek, A., 2024. Developing of Comprehensive Circular Rating System for Office Buildings: A Review of Existing Tools and Case Study, in: Bragança, L., Cvetkovska, M., Askar, R., Ungureanu, V. (Eds.), Creating a Roadmap Towards Circularity in the Built Environment, Springer Tracts in Civil Engineering. Springer Nature Switzerland, Cham, pp. 359–370. https://doi.org/10.1007/978-3-031-45980-1_29

Tsui, T., Furlan, C., Wandl, A., Van Timmeren, A., 2024. Spatial Parameters for Circular Construction Hubs: Location Criteria for a Circular Built Environment. Circ. Econ. Sustain. 4, 317–338. https://doi.org/10.1007/s43615-023-00285-y

Tutore, I., Parmentola, A., di Fiore, M.C., Calza, F., 2024. A conceptual model of artificial intelligence effects on circular economy actions. Corp. Soc. Responsib. Environ. Manag. https://doi.org/10.1002/csr.2827

TWLA Architects, 2020. Collegetown Innovation District Planned Unit Development Application. Ithaca, New York.

UNEP (Ed.), 2024. Bend the trend: pathways to a liveable planet as resource use spikes, Global resources outlook. International Resource Panel, Nairobi, Kenya.

UNEP, 2022. 2022 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. United Nations Environment Programme, Nairobi.

United Nations, 2018. 2018 Revision of World Urbanization Prospects. Dep. Econ. Soc. Aff. URL https://www.un.org/en/desa/2018-revision-world-urbanization-prospects#:~:text=Today%2C%2055%25%20of%20the%20world's,increase%20to%2068%25%20by%202050.
United Nations, 2015. Paris Agreement.
Van Bueren, B.J.A., Iyer-Raniga, U., Leenders, M.A.A.M., Argus, K., 2021. Comprehensiveness of circular economy assessments of regions: A systematic review at the macro-level. Environ. Res. Lett. 16. https://doi.org/10.1088/1748-9326/ac209c
Van Den Berg, M., Schraven, D., De Wolf, C., Voordijk, H., 2024. Materializing responsible futures: An interpretative phenomenological analysis of circular design experiences in construction. Sustain. Prod. Consum. 51, 92–104. https://doi.org/10.1016/j.spc.2024.09.005
Van Manen, M., 2014. Phenomenology of practice: meaning-giving methods in phenomenological research and writing, Developing qualitative inquiry. Left Coast Press, Walnut Creek, California.
Van Uden, M., Wamelink, H., Van Bueren, E., Heurkens, E., 2025. Aligning practices towards a circular economy in the architecture, engineering, and construction sector: seven transitions in different stages of reconfiguration. Constr. Manag. Econ. 43, 153–174. https://doi.org/10.1080/01446193.2024.2401829
Van Uden, M.F.M., Wamelink, J.W.F., Van Bueren, E.M., Heurkens, E.W.T.M., 2024. Crossovers between Sustainability Transitions Research and Social Practice Theory: A Systematic Literature Review. Clean. Prod. Lett. 7, 100083. https://doi.org/10.1016/j.clpl.2024.100083
Varma, C.R.S., Palaniappan, S., 2019. Comparision of green building rating schemes used in North America, Europe and Asia. Habitat Int. 89, 101989. https://doi.org/10.1016/j.habitatint.2019.05.008
Victoria State Government, 2022. Building future homes: adaptation guide. Victoria State Government, Melbourne, Victoria.
Vitale, P., Alfano, V., Pastore, T., Menna, C., Maffettone, P., Asprone, D., 2021. Toward a Holistic Rating System: An Attempt to Expand the Boundaries of Building Sustainability Using SDGs. Front. Built Environ. 7, 679014. https://doi.org/10.3389/fbuil.2021.679014
Walker, P., Townsend, C., 2020. Australia's Home: An Alternative Narrative. Robin Boyd's Writing on Flats and Medium Density Housing, in: Proceedings of the Society of Architectural Historians Australia and New Zealand (SAHANZ). Presented at the What If? What Next? Speculations on History's Futures.
Wang, C., Che, Y., Xia, M., Lin, C., Chen, Y., Li, X., Chen, H., Luo, J., Fan, G., 2024. The Evolution and Future Directions of Green Buildings Research: A Scientometric Analysis. Buildings 14. https://doi.org/10.3390/buildings14020345
Wang, D., Groat, L.N., 2013. Architectural research methods, Second Edition. ed. Wiley, Hoboken.
Wang, K., Costanza-van den Belt, M., Heath, G., Walzberg, J., Curtis, T., Barrie, J., Schöder, P., Lazer, L., Altamirano, J.C., 2022. Circular economy as a climate strategy: current knowledge and calls-to-action, Working Paper. World Resources Institute.
Warren-Myers, G., Moosavi, S., Hurlimann, A., Raisbeck, P., Bush, J., March, A., Browne, G., 2024. Barriers to and facilitators of climate change action in architecture practice. J. Clean. Prod. 469, 143149. https://doi.org/10.1016/j.jclepro.2024.143149
Wastling, T., Charnley, F., Moreno, M., 2018. Design for Circular Behaviour: Considering Users in a Circular Economy. Sustainability 10, 1743. https://doi.org/10.3390/su10061743
Watson, M., 2012. How theories of practice can inform transition to a decarbonised transport system. J. Transp. Geogr. 24, 488–496. https://doi.org/10.1016/j.jtrangeo.2012.04.002

Wen, B., Musa, S.N., Onn, C.C., Ramesh, S., Liang, L., Wang, W., Ma, K., 2020. The role and contribution of green buildings on sustainable development goals. Build. Environ. 185, 107091. https://doi.org/10.1016/j.buildenv.2020.107091

White, R.E., Cooper, K., 2022. Case Study Research, in: Qualitative Research in the Post-Modern Era. Springer International Publishing, Cham, pp. 233–285. https://doi.org/10.1007/978-3-030-85124-8_7

Willana Associates, 2014. Statement of Environmental Effects. Willana Associates.

Wu, Z., He, Q., Chen, Q., Xue, H., Li, S., 2021. A topical network based analysis and visualization of global research trends on green building from 1990 to 2020. J. Clean. Prod. 320. https://doi.org/10.1016/j.jclepro.2021.128818

Xiao, H., Liu, Y., Ren, J., 2023. Synergies and trade-offs across sustainable development goals: A novel method incorporating indirect interactions analysis. Sustain. Dev. 31, 1135–1148. https://doi.org/10.1002/sd.2446

Yang, H., Oldfield, P., Easthope, H., 2022. Influences on Apartment Design: A History of the Spatial Layout of Apartment Buildings in Sydney and Implications for the Future. Buildings 12, 628. https://doi.org/10.3390/buildings12050628

Yin, R.K., 2018. Case study research and applications: design and methods, Sixth edition. ed. SAGE, Los Angeles.

Yin, R.K., 2014. Case study research: design and methods, Fifth edition. ed. SAGE, Los Angeles.

Yvonne Feilzer, M., 2010. Doing Mixed Methods Research Pragmatically: Implications for the Rediscovery of Pragmatism as a Research Paradigm. J. Mix. Methods Res. 4, 6–16. https://doi.org/10.1177/1558689809349691

Zaman, A., Caceres Ruiz, A.M., Shooshtarian, S., Ryley, T., Caldera, S., Maqsood, T., 2023. Development of the Circular Economy Design Guidelines for the Australian Built Environment Sector. Sustain. Switz. 15. https://doi.org/10.3390/su15032500

Zanardo, M., Sisson, A., Logan, C., McLaughlan, R., 2024. Wilful ignorance at Waterloo: public housing quality and political stigma in Sydney's largest estate renewal. Plan. Perspect. 39, 1207–1239. https://doi.org/10.1080/02665433.2024.2337268

Zavos, S., Lehtokunnas, T., Pyyhtinen, O., 2024. The (missing) social aspect of the circular economy: a review of social scientific articles. Sustain. Earth Rev. 7, 11. https://doi.org/10.1186/s42055-024-00083-w

Zeccola, C., n.d. High Rise Pre-cast Towers.

Zhao, X., Zuo, J., Wu, G., Huang, C., 2019. A bibliometric review of green building research 2000–2016. Archit. Sci. Rev. 62, 74–88. https://doi.org/10.1080/00038628.2018.1485548