NUS National University of Singapore | Sustainable and Green Finance Institute

Integrated Impact Valuation Framework for Green Buildings

SGFIN Whitepaper Series #4

Jefferson | Weina Zhang | Aaron Mueller | Chunyu Yang

About SGFIN

The Sustainable and Green Finance Institute (SGFIN) is a research institute established by National University of Singapore (NUS). SGFIN aims to develop deep research capabilities in sustainable and green finance with a focal point on Asia, and to provide thought leadership and shape sustainability outcomes in policymaking across the financial sector and the economy at large. Supported by exceptional domain experts across NUS, SGFIN equips businesses with critical cross-disciplinary knowledge, training, and toolkits to integrate sustainability dynamics into their business strategies and investment decisions to better quantify the environmental and social impacts of their business developments, operations, products, and services. In essence, SGFIN seeks to help companies embed sustainability as a key pillar in their business decisions.

Recommended citation

Jefferson, Weina Zhang, Aaron Mueller, and Chunyu Yang. (2024). *Integrated Impact Valuation Framework for Green Buildings*, SGFIN Whitepaper #4.

Keywords: *Green buildings; Impact valuation; Building certification standards; Impact measurement frameworks; Economic, Environmental, Social, and Governance (EESG) impacts; Integrated Return on Investment (IROI) method.*

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Whitepaper cover image acknowledgement

The cover page features the photo of SDE4 building in NUS, taken by Jefferson.

Foreword

It is my pleasure to present this whitepaper on the *Integrated Impact Valuation Framework for Green Buildings*; SGFIN's important contribution to sustainable development and the built environment sector. This work represents a crucial step forward in bridging the gap between financial returns and the broader social, environmental, and governance (ESG) impacts generated by green buildings. At a time when the urgency to address climate change and create sustainable urban solutions is greater than ever, this framework offers a useful tool to measure and integrate the often-overlooked externalities of buildings, providing a more comprehensive assessment of their value.

There is an increasing demand from investors, policymakers, and developers for methods that go beyond the traditional economic metrics. The framework is developed to incorporate ESG factors into the valuation process. Through the Integrated Return on Investment methodology, it offers a new perspective on the holistic return generated by green buildings, capturing the full spectrum of impacts and providing the basis for more informed decision-making.

The development of this framework is the culmination of two years' research efforts led by Associate Professor Weina Zhang and her team in collaboration with experts from diverse fields—finance, sustainability, and architecture. This framework is adaptable across various building types and scales, making it relevant not only for individual projects but also for building portfolios and urban development. The harmonization of existing certification standards and impact measurement frameworks into a unified model is particularly noteworthy, as it provides a valuable tool to navigate the complex landscape of green building investments.

I am confident that this whitepaper will have a profound impact on how we approach green building development, inspiring greater alignment between financial success and sustainability goals. The potential applications of the framework extend beyond the valuation to influence policy, inform capital budgeting, and support the adoption of green financing mechanisms. I hope this latest effort from SGFIN will be an impetus for an exciting journey toward a more sustainable and resilient built environment.

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September 2024

Executive Summary

This whitepaper introduces SGFIN's integrated impact valuation framework for green buildings, a comprehensive approach built on the harmonized impact indicators of 13 existing building certification standards and impact measurement frameworks. Developed to meet the growing need for a holistic evaluation of green buildings in the era of sustainable development, our proposed framework integrates Economic, Environmental, Social, and Governance (EESG) impacts into a unified monetary assessment model. As such, it aims to provide a better understanding of the impact values created by green buildings, which on top of the traditional economic metrics include environmental, social, and governance considerations.

Green buildings have emerged as a crucial component in global efforts to combat climate change, promote sustainability, and improve the quality of life for urban populations. However, the existing standards and frameworks often differ in specific measurements and indicators to capture the impacts generated by green buildings. Our proposed framework attempted to address this gap through three ways. First, using the Theory of Change and Logic Model, we mapped the causality between green buildings and their long-term impact. Second, we reviewed 1,141 impact indicators of ten selected certification standards and three impact measurement frameworks to arrive at a harmonized list of 82 impact indicators in our framework. Lastly, we leveraged the Integrated Return on Investment (IROI) methodology to monetize the impact metrics of green buildings. We based this approach on the Social Return on Investment (SROI) method and expanded it to cover environmental and governance impact aspects, thus offering an integrated perspective on the return on investment for green building projects.

The IROI methodology to monetize the impact indicators involves identifying relevant stakeholders of a green building, selecting the contextual impact indicators, and multiplying with financial proxies. We end up with a list of 171 monetarized impact metrics, the cash flows of which can be further adjusted for different financial considerations to simulate financial fluctuations. This process results in a final IROI value for a green building that represents the integrated return on investment. By translating the intangible and non-monetary values into financial terms, our proposed framework facilitates the comparison across different building projects and development scales.

A key strength of our harmonized framework is its adaptability to different building contexts and development scales. Whether applied to an individual building project, a portfolio of buildings, or urban development, our framework offers valuable insights for sustainable planning and financing. For building developers, owners, and investors, the framework highlights different impact value drivers which can be prioritized to maximize the integrated benefits, be it design features, or technology used. For policymakers, the framework offers a tool to assess the effectiveness of regulations, incentives, and schemes related to green buildings, ensuring efficient resource allocation to promote sustainable building practices.

About the Authors

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Acknowledgments

We would like to express our gratitude to NUS's University Campus Infrastructure for their support in the development of this framework.

We also appreciate the insights and collaboration from Associate Professor Nirmal Tuldas Kishnani, Alakesh Dutta, and their team at College of Design and Engineering (CDE) of NUS for the past years of testing and refining our framework.

Special thanks to Giovanni Cossu and Benjamin Towell, for lending their expertise and advice in the preliminary stages of this project, and our Research Analyst Johannine Salvilla Enerio, for her support in the ongoing translation of the framework into a web calculator for stakeholders to use.

We would also like to thank the members of panel discussion for their lively contribution in the launching event of this Whitepaper: Associate Professor Nirmal Tuldas Kishnani from NUS CDE, Benjamin Towell, and our moderator Associate Professor Cristian Badarinza from NUS Business School.

Moreover, we are grateful for the assistance from our Research Analysts, Phang Kuang Wei and Fanny Or, and the student research assistants Alvern Mak, Zhang Xinyuan, Wu Yaoyao, Roy Ang, Luluk Kurrata Aini, and Maura Finessa Winayo.

Last but not least, we would like to thank the SGFIN management team, Professor Sumit Agarwal, Associate Professor Johan Sulaeman, and Rachel Phuak, for their support as we worked on the project and completed this Whitepaper.

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1 Introduction

Our world is at a critical juncture as we grapple with the intertwined issues of accelerated population growth, exploitation of natural resources, climate change, and social inequality. Achieving sustainable development, where present needs are met without compromising the ability of future generations to meet theirs (WCED, 1987), requires a holistic approach which transforms every aspect of human activity.

In this context, the built environment sector encompassing buildings and infrastructures emerged with great potential to address the complex issues above. There have been increasing demands for the industry to develop new green buildings and convert the existing ones into green buildings, minimising their negative impacts and creating positive impacts for people and the planet in their design, construction, and operation (BCA, n.d.). From the technical point of view, green buildings should be certified by at least a national or internationally recognized standard, 20% more energy efficient compared to their non-green counterparts, and track and report their environmental impacts (e.g., water use, energy use, and carbon emissions) as quantitative indicators (Likhachova et al., 2019). Accounting for 6% of the global Gross Domestic Product and employing more than 100 million people globally (Renz & Solas, 2016), the sector is well-positioned to contribute to achieving the Sustainable Development Goals (SDGs) and to drive positive impacts (Czerwinska, 2022).

In light of population growth and urbanization trends, the global demand for buildings was projected to grow exponentially in the next few decades. The world population reached eight billion people in 2023, up from seven billion in 2011 and doubled the 1974 number (World Bank, 2023). Of this population, 85% had already been affected by climate change (Callaghan et al., 2021). Anticipating the accelerated population growth to 10 billion by 2050, Archer and Langbroek (2023) forecasted that the global number of buildings needs to double its current tally to meet this future need. This prediction exceeded the previous estimate of global total gross floor area (GFA) doubling by 2060, or roughly 230 billion square metres (GABC et al., 2017). With the global urban population likely to reach 68% in 2050 (UN, 2018), a unique opportunity is presented to build cities and communities that enable a more sustainable way of living and a better quality of life (Czerwinska, 2022). Embracing sustainable practices in building design, construction, and operation would ensure that this population growth would not come at the cost of environmental degradation and social inequity.

This future construction boom may exacerbate the pressure the built environment sector has already been exerting on nature. Meanwhile, it provides an opportunity for buildings to be environmental stewards. In cities worldwide, constructing and maintaining buildings accounted for 40% of materials consumed, 33% of energy used, and 50% of waste generated (Castellano et al., 2016). Building construction and operation alone contributed 37% of the global energy-related greenhouse gas (GHG) emissions in 2021, higher than any other sector (UNEP, 2022). In addition to depleting natural resources and driving climate change, developing and operating buildings could pollute habitats and threaten biodiversity (WGBC, 2016). Nevertheless, the increasingly prevalent sustainable building practices might minimize the negative impacts and benefit the environment (US EPA, 2023). For example, low-energy lightbulbs and a rooftop design that maximizes insolation for solar panels could work hand in hand to reduce a building's energy use and reliance on fossil fuels for electricity (IEA & ASEAN, 2022). Balancing between buildings' positive and negative environmental impacts would be crucial in conserving natural resources and mitigating climate change.

In contrast to the more visible environmental impacts, the social impacts of buildings often remain hidden within their structure. As highlighted in the World Green Building Council (WGBC) social impact framework paper, buildings can profoundly affect their stakeholders, from the occupants' health and well-being to accessibility considerations to the livelihood of those working in the building supply chain (Kawamura & Brady, 2023). Buildings with good access to natural light and ventilation can enhance the occupants' productivity and health, but buildings with poor indoor environmental quality may harm the users' well-being (Mewomo et al., 2021). Buildings also play an integral role in shaping communities. Inclusive design and integrated master planning would foster social cohesion and ensure accessibility for all users regardless of their abilities and conditions. Conversely, poorly designed buildings and urban environments where the needs of certain user groups (e.g., elderlies, people with disabilities, mothers) were not catered for may create a sense of exclusion and worsen social inequities (Go Construct, 2017). As such, the social impacts of buildings must be considered carefully to ensure that they contribute positively to their users and surrounding communities.

Underlying buildings' social and environmental impacts are their economic and governance considerations. From the economical point of view, a building can produce benefits in the form of revenue but also incur costs, ranging from construction to operation and retrofit. Coupled with these economic considerations, how buildings are planned and governed by developers and regulatory bodies can positively or negatively affect the other stakeholders in a significant way. Developers can champion sustainability throughout their buildings' lifecycle, such as by prioritizing energy efficiency features, using responsibly sourced materials, and getting their buildings certified by international green building standards. However, some developers may prioritize short-term profit over long-term sustainability, leading to environmentally harmful practices and buildings that exacerbate social inequities. For example, many buildings in Lebanon were on the verge of collapse due to negligence of safety on the developers' end despite the obvious threats of earthquakes (Amnesty International, 2024). This example highlighted the need for robust regulations and policies to incentivize sustainable building design and practices. Close collaboration between building developers, market players in the value chain (WBCSD, n.d.), and authorities is essential in driving the transition towards a sustainable built environment sector.

One of the major hindrances in advancing sustainable development in the sector is the lack of a systematic framework to measure and value the externalities generated by the buildings. Externalities occur when an economic activity results in unintentional side impacts which either benefit or harm the third parties who are not directly involved in the activity (Helbling, 2010). In the case of buildings, the economic activities include their design, construction, maintenance, operation, renovation, and demolition. As evidenced above, these building activities may positively or negatively affect their stakeholders and other external parties. The lack of a comprehensive valuation method and standardized metrics makes it difficult to value holistically the externalities in the decision-making process for buildings. Consequently, the true costs of unsustainable buildings – and, inversely, the true benefits of green buildings – may be underestimated or even not valued, hindering the efforts to promote the adoption of sustainable building practices and design.

Monetizing the integrated impacts of buildings, especially green buildings, may become the key to unlocking their full potentials. By translating the impact metrics of a building into financial terms, its stakeholders can better understand and compare the costs and benefits of different sustainable practices and designs when planning and evaluating their building. This integrated valuation approach can also facilitate more informed decision-making by developers, investors, and policymakers, thus incentivizing investments in green buildings to offer long-term, sustainable returns. Finally, an integrated impact valuation framework can drive policy changes at various governance levels to prioritize sustainability in buildings, thus empowering the sector to maximize its contribution in the pursuit of a sustainable future.

The following chapters delved into these topics. Chapter 2 reviewed ten building certification standards and three impact measurement frameworks, mapping and classifying their indicators across Environmental, Social, and Governance (ESG) aspects to identify the gaps in their impact coverage. Chapter 3 established the impact causality for green buildings, using the Theory of Change and Logic Model to map the relationship between building interventions and their outcomes and long-term impacts. Building on this causality, we proposed a harmonized framework which integrates the impact coverage of the existing standards and frameworks to offer a comprehensive impact valuation method for green buildings. Chapter 4 explained the valuation methodology of our framework, detailing how to monetize the impact metrics using financial proxies and compute the Integrated Return on Investment (IROI) value. Chapter 5 explored how green building stakeholders could leverage our proposed framework across different development scales and contexts, including guiding decision-making, optimizing building design and plan, and assessing the effectiveness of green building regulations and incentives. Chapter 6 concluded the whitepaper by summarizing the key features of our framework and describing its implications on sustainability integration and scaling effects through systems thinking.

2 Review of Existing Building Standards and Frameworks

In this chapter, we examined ten existing building certification standards across the world according to the Environmental, Social, and Governance (ESG) aspects to grasp their respective coverage. We also explored three frameworks from the financial sector which aimed to measure impacts generated by buildings. Subsequently, we proposed a new framework which harmonized the existing standards and frameworks to capture the integrated impacts of a (green) building. In addition to the buildings' economic aspect, our harmonized framework encompasses the environmental, social, and governance aspects (EESG).

2.1 Existing Building Certification Standards

The history of building certification standards can be traced to the launch of BREEAM (Building Research Establishment Environmental Assessment Method) standard in 1990 (Townsend, 2016). Many standards have since been released globally to measure and assess building performance in various aspects, especially environmental and social. According to WGBC (2020), there are more than 70 green building councils all around the world governing their respective country's standard. All these standards have a common goal of conserving natural resources and enhancing the health and well-being of building users (Simon & Jackson, 2020), essentially making buildings "green".

Building developers and government authorities are not the only stakeholders interested in gauging and comprehending the environmental and social impacts of buildings. In 2006, the United Nations released the Principles for Responsible Investment (PRI), prompting investors and asset managers to factor ESG considerations into their investment assets and portfolios, including green buildings. Many impact measurement frameworks for real estate have since been released, notably including the Real Estate Assessment in 2009 by the Global Real Estate Sustainability Benchmark (GRESB, 2019), which evaluates the ESG performance of a building or real estate company and benchmarks it against its peers.

Based on the literature review and consultation with our collaborators, we selected ten existing building certification standards for review and comparison. This selection aimed to gain insights into the indicators and coverage of the local building standards (i.e., Singapore's Green Mark), building standards in other Asian countries (i.e., Hong Kong's BEAM Plus, Japan's CASBEE, and United Arab Emirates' Estidama Pearl Rating System), and globally recognized standards outside Asia (i.e., the UK's BREEAM, Germany's DGNB, and the USA's EDGE, Living Building Challenge / LBC, LEED, and WELL). As such, this coverage offered a broad overview from the local, Asian, and international angles on what should constitute a green building. **Table 1** summarized the profile of the selected ten building certification standards, and each was briefly described in Appendix A.

***Table 1**. Profile of the Selected Building Certification Standards*

	GM	BEAM Plus	CASBEE	Estidama	BREEAM	DGNB	EDGE	LBC	LEED	WELL
Governing body	Building and Construction Authority	Hong Kong Green Building Council	Japan Sustainable Building Consortium	Abu Dhabi Urban Planning Council	Building Research Establishment	German Sustainable Building Council	International Finance Corporation	International Living Future Institute	U.S. Green Building Council	International WELL Building Institute
Country of origin	Singapore	Hong Kong	Japan	UAE	UK	Germany	–	USA	USA	USA
Year established	2005	2010	2002	2010	1990	2007	2015	2006	1998	2014
Latest version and year	GM: 2021 (2nd ed.), 2023	New Buildings v2.0, 2023	CASBEE 2021	v1.0, 2010	Version 6.1, 2023	2023	Version 3.0.a, 2021	4.1, 2024	v4.1, 2023	v2, Q1-Q2 2024
Grading system	Certified, Gold, GoldPLUS, Platinum	Bronze, Silver, Gold, Platinum	C, B-, B+, A, S	1–5 Pearls	Pass, Good, Very Good, Excellent, Outstanding	Bronze, Silver, Gold, Platinum	Certified, Advanced, Zero Carbon	Core, Petal, Living	Certified, Silver, Gold, Platinum	Bronze, Silver, Gold, Platinum
Building project types covered	New and existing, Residential and non-residential, and other specific uses	New Buildings, Existing Buildings, Interiors, Neighbourhoods, Schools, Data Centres	New Construction, Existing Buildings, Renovation	All building typologies, their sites and associated facilities	New construction, Refurbishment and fit-out, In-use, Communities	New Construction, Buildings In Use, Renovation, Districts	Buildings in concept or design stage, New construction, Existing buildings, Renovations	New building, Building renovation, Interior, Landscape or infrastructure	Building Design + Construction, Interior Design +Construction, Operations + Maintenance, Residential, Cities and Communities, Recertification	Owner-occupied, WELL Core
Adoption worldwide	16 countries in Asia and Africa	Hong Kong, Macau, Mainland China	Japan, limited in other Asian countries	Abu Dhabi, UAE	>75 nations, including UK	29 countries, primarily in Europe	103 nations, mainly in emerging economies	North & South America, Europe, Asia, Middle East, and Oceania	North & South America, Europe, Asia, Middle East, Africa, and Oceania	North & South America, Europe, Asia, Middle East, Africa, and Oceania

2.2 Existing Impact Measurement Frameworks of Buildings

In addition to GRESB's Real Estate Assessment, our literature review uncovered two additional impact measurement frameworks of buildings published in recent years. First, the *Handbook on Harmonised Framework for Impact Reporting* by International Capital Market Association (ICMA, 2024) provided a comprehensive guideline for issuers of green, social, and sustainability bonds to report the bonds' environmental and social impacts. It outlined the impact reporting guidance and metrics for ten sectors, including green buildings. The second framework was introduced in the *Social Impact across the Built Environment* position paper by WGBC, assessed social impacts of buildings across their lifecycle (Kawamura & Brady, 2023). WGBC divided the social impact assessment into four scopes: i) entity and internal practices, ii) building users and sites, iii) community and surroundings, and iv) supply and value chains. **Table 2** summarized the profile of these frameworks, and each was described in Appendix A.

Table 2. *Profile of the Selected Impact Measurement Frameworks*

	Real Estate Assessment	***Handbook on Harmonised Framework for Impact Reporting***	***Social Impact across the Built Environment***
Institution	GRESB	ICMA	WGBC
Nature	ESG performance evaluation framework	Impact reporting framework of projects funded by green, social, and sustainability bonds	Position paper on social impact measurement framework of a building
Year established	2009	2019	2023
Latest version	2024	2024	2023
Building project types covered	All building types	New and retrofitted buildings	All building types
Adoption worldwide	2,084 firms in 75 countries (2023)	Recommended for global adoption	Called for worldwide adoption

2.3 Impact Coverage of Existing Standards and Frameworks

Having selected the building certification standards and impact measurement frameworks for review, we compiled the impact indicators from the guideline documents of each standard and framework. Where available, we reviewed the international version of the guidelines to understand how the standards and frameworks adapted their criteria in the global context. To avoid double counting the indicators, we limited our review to only indicators from guidelines for new and existing buildings. Since not all standards and frameworks have guidelines for specific building uses, focusing on indicators in the general guidelines allowed for more analogous comparison. In addition, we also collapsed overlapping indicators in the guidelines for new and existing buildings within a standard or framework into singular and unique indicators. For example, the Green Mark standard has an "Architectural Interior" indicator in the Maintainability section for existing, non-residential, and residential buildings. Following the rule of thumb, we listed the three "Architectural Interior" indicators as one singular indicator.

Altogether, we collected and reviewed 1,141 impact indicators from the 13 selected building certification standards and impact measurement frameworks. **Figure 1** visualized the breakdown for each standard and framework. The full list of the reviewed guideline documents is provided in Appendix B.

***Figure 1**. Tally of Reviewed Indicators in Selected Standards and Frameworks*

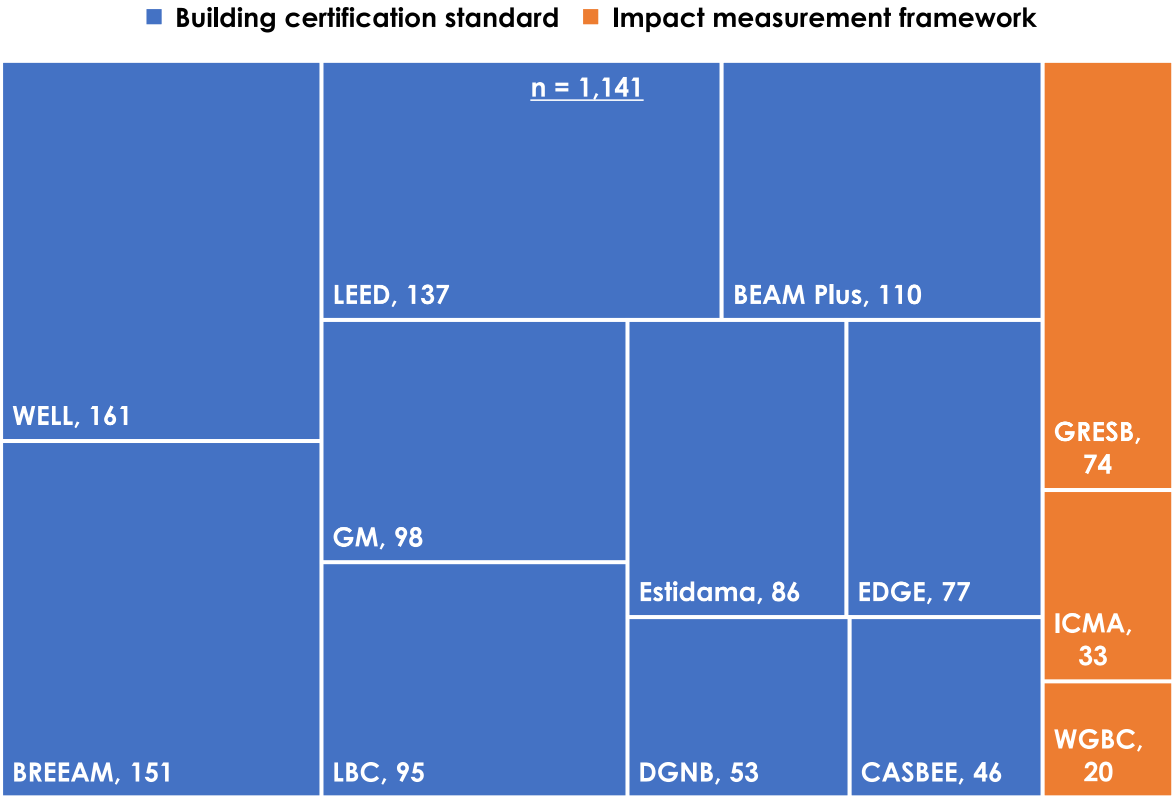


Table 3 presented the mapped impact coverage of the selected standards and frameworks according for each of the ESG impact aspects. We framed the impact indicators of buildings within the PRI's ESG focus (UNEP FI & UNGC, n.d.) to create a bridge between the built environment and financial sectors. We added "pillars" to further categorize the impact metrics. The table also tallied, for the purpose of comparison, the number of "value drivers" covered by each standard and framework and the number of standards and frameworks covering a value driver. Values shown as orange in the rightmost column and the bottom row of the table indicated that they are lower than their respective average value.

Based on the findings in **Table 3**, we discuss the major observations and evident gaps of the ESG impact coverage in the existing standards and frameworks.

***Table 3**. Impact Coverage Comparison of Reviewed Standards and Frameworks*

Aspect		**ENVIRONMENTAL**														**Number of value drivers covered (mean = 9.2)**
Pillar		**Ecological factors**				**Carbon and energy**			**Water and wastewater**				**Material and waste**			
Value Driver (total = 14)		Biodiversity	Site and surrounding environment	Outdoor env. quality	Climate change	Energy efficiency	Renewable energy	GHG emissions	Responsible water sourcing	Water quality	Water efficiency	Wastewater management	Life cycle assessment	Responsible material use	Waste management	
Building certification standards	**GM**	•	•	•		•	•	•			•			•	•	9
	BEAM Plus	•	•	•	•	•	•	•	•	•	•	•	•	•	•	14
	CASBEE		•	•	•	•	•	•	•		•		•	•		10
	Estidama		•	•		•	•	•	•		•		•	•	•	10
	BREEAM	•	•	•	•	•	•	•		•	•	•	•	•	•	13
	DGNB	•	•	•	•			•			•	•	•	•	•	10
	EDGE					•	•	•	•		•	•		•		7
	LBC	•	•			•	•	•	•		•	•	•	•	•	11
	LEED		•	•		•	•	•			•		•	•	•	9
	WELL		•	•				•	•	•				•	•	7
Impact measurement frameworks	**GRESB**		•			•	•	•			•		•	•	•	8
	ICMA	•	•			•	•	•	•		•			•	•	9
	WGBC				•									•		2
Number of standards/ frameworks covering the value driver (mean = 8.5)		6	11	8	5	10	10	12	7	3	11	5	8	13	10	

Aspect		**SOCIAL**								**Number of value drivers covered (mean = 4.5)**
Pillar		**Direct user experience**						**Indirect externalities**		
Value Driver (total = 8)		Accessibility, inclusivity, and privacy	Indoor env. quality	Health and well-being	Safety and security	Food production	Aesthetics	Community development	Business and employment	
Building certification standards	**GM**	•	•	•	•			•	•	6
	BEAM Plus	•	•	•				•		4
	CASBEE	•	•							2
	Estidama	•	•	•	•		•	•		6
	BREEAM	•	•	•	•		•	•		6
	DGNB	•	•	•	•				•	5
	EDGE		•	•						2
	LBC	•	•	•		•	•	•	•	7

Aspect		SOCIAL								Number of value drivers covered (mean = 4.5)
Pillar		Direct user experience						Indirect externalities		
Value Driver (total = 8)		Accessibility, inclusivity, and privacy	Indoor env. quality	Health and well-being	Safety and security	Food production	Aesthetics	Community development	Business and employment	
Impact measurement frameworks	LEED	•	•	•			•	•		5
	WELL	•	•	•	•	•	•	•	•	8
	GRESB							•		1
	ICMA		•							1
	WGBC	•	•	•	•			•		5
Number of standards/ frameworks covering the value driver (mean = 7.3)		10	12	10	6	2	5	9	4	

Aspect		GOVERNANCE								Number of value drivers covered (mean = 4.6)
Pillar		Building and environs		Planning, construction, and management			Transportation and other infrastructure			
Value Driver (total = 8)		Architecture and design	Technology and innovation	Planning	Construction	Management	Public transit	Amenities	Supporting infrastructure	
Building certification standards	GM	•	•	•		•				4
	BEAM Plus	•	•	•	•	•		•	•	7
	CASBEE	•						•		2
	Estidama	•	•	•	•	•	•		•	7
	BREEAM	•	•	•	•	•	•	•	•	8
	DGNB	•	•	•	•	•	•	•	•	8
	EDGE	•				•				2
	LBC								•	1
	LEED	•	•	•	•	•	•		•	7
	WELL	•	•			•	•		•	5
Impact measurement frameworks	GRESB	•		•	•	•				4
	ICMA	•					•		•	3
	WGBC				•	•				2
Number of standards/ frameworks covering the value driver (mean = 7.5)		11	7	7	7	10	6	4	8	

First, the Environmental aspect (E) was covered more extensively than the other two ESG aspects. This prominence was evident across all standards and frameworks. Not only were there more standards and frameworks covering the specific Environmental value driver (mean of 8.5 versus Social's 7.3 and Governance's 7.5) but existing standards and frameworks also covered more Environmental value drivers (mean of 9.2 out of 14 value drivers, roughly 66%) than Social and Governance value drivers (mean of 4.5 and 4.6 out of 8, less than 58%). This significance may be due to the relative easiness of measuring Environmental impacts and performance compared to Social and Governance aspects, which are less visible and concrete. For example, measuring a building's operational carbon emission is more straightforward than evaluating its accessibility for visitors or assessing the impacts of having a Sustainability Champion in its development.

Second, the table showed that none of the existing standard or framework covered all ESG aspects. Certain standards did encompass all value drivers of one ESG aspect – i.e., BEAM Plus for the Environmental aspect, WELL for Social, and BREEAM and DGNB for Governance – but none provided a holistic coverage of all ESG aspects. This gap in impact scope can be attributed to several reasons. Some standards and frameworks were created to address specific ESG aspects. For example, WELL (2024b) and LBC's (2024) focused on the Social aspect of occupant health and well-being, thus their Environmental and Governance impact coverage would not be as strong as the other standards and frameworks. Other standards and frameworks might have specific contexts and target audiences, such as the EDGE framework (2021) that was designed to assess buildings in emerging markets (Likhachova et al., 2019). This purpose dictated EDGE's streamlined approach and emphasised on Environmental impact pillars such as energy, water, and materials efficiency. Furthermore, to remain accessible and feasible for adoption, a building certification standard or impact measurement framework may have to limit its scope and depth in certain ESG aspects. This trade-off between comprehensiveness and practicality may explain why BREEAM and WELL did not comprehensively cover all ESG value drivers even though they each had more than 150 impact indicators, as shown in **Figure 1**.

The gap in **Table 3**'s impact coverage map might paint a seemingly bleak portrait of diverse ESG impact measurement and evaluation in the built environment sector. However, it also offered an opportunity to harmonize the existing standards and frameworks to support the efforts for a sustainable built environment. This harmonization was what we aimed to achieve while developing the impact map in **Table 3**. As a result, we can now see clearly the gaps in the current landscape and proposed a more complete list of impact metrics based on the existing standards and frameworks.

2.4 Integrating the Impacts of Green Buildings

Building on this harmonization, we were one step away from arriving at an integrated impact valuation framework to assess green buildings from the point of view of ESG aspects. One problem remained: all the building certification standards and impact measurement frameworks have their unique grading system with different scale and units. So, how do we synchronize the different scoring systems to evaluate the harmonized impact value drivers from 13 different standards and frameworks?

The inkling to the solution came in the form of our recognition that the economic considerations of a building are intertwined with those of governance considerations in Chapter 1. Therefore, we looked beyond the existing building grading systems and explored methods from the fields of finance and economy that can evaluate the harmonized impact value drivers of a green building on a common ground. This also necessitated the expansion of our integrated impact valuation framework to include the Economic aspects, creating a more complete picture of Economic, Environmental, Social, and Governance (EESG) aspects.

***Figure 2**. Integrated Impacts of a Green Building*

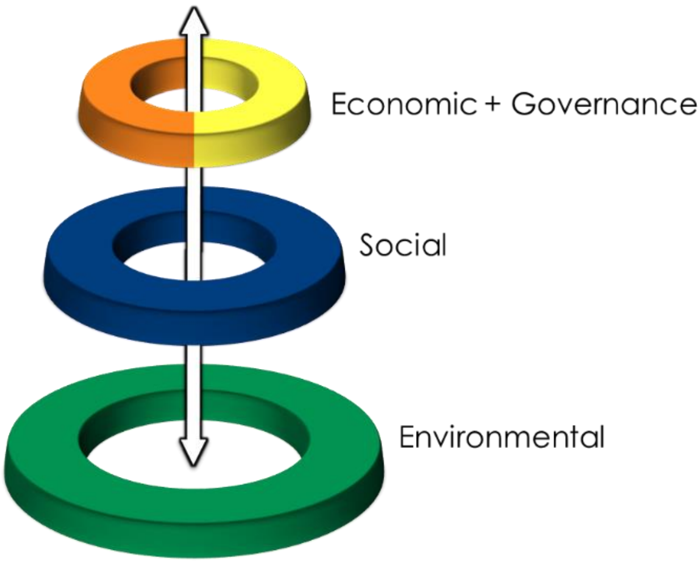


Figure 2 illustrates the EESG aspects of our proposed integrated impact valuation framework for green buildings as the layers of a wedding cake. This analogy, originally proposed by Johan Rockström and Pavan Sukhdev of the Stockholm Resilience Centre (2016), showed the interconnectivity between the Sustainable Development Goals in food production sector. By depicting the SDGs as layers of a wedding cake, Rockström and Sukhdev argued that economic and social activities should be viewed as integral parts of the natural environment. We depicted our framework in **Figure 2** in similar vein of Rockström and Sukhdev's illustration to underscore our proposed new framework's aim of measuring and valuing the integrated EESG aspects of a green building.

After reviewing the existing impact investment literature, we discovered a methodology which can monetize the metrics of each impact value drivers. In other words, the methodology converts the non-tangible impacts into the common unit of dollar values. However, before we could proceed with the monetization, we must first establish the causality between the impact value drivers of a green building with their intended outcomes and long-term impacts. This is the task that Chapter 3 would undertake, using the tools of Theory of Change and Logic Model.

3 Establishing the Impact Causality of Green Buildings

In this chapter, we worked towards filling the gap before we proposed the new framework, namely the causality between the harmonized impact value drivers and indicators of green buildings and the intended outcomes and impacts. Although our proposed framework encompassed the integrated Economic, Environmental, Social and Governance (EESG) impacts of green buildings, it did not immediately come with Specific, Measurable, Realistic, and Time-bound (SMART) metrics. As such, we took a step back and asked, "Why do we need 'green' buildings? What value propositions can green buildings offer to society and the environment?" To answer these questions, we applied the tools of "**Theory of Change**" and "**Logic Model**" on our framework (Nicholls et al., 2012). The former helped us to identify the relevant stakeholders and establish the impact causality of green buildings, while the latter mapped the harmonized impact value drivers and indicators as a sequence of inputs, activities, outputs, outcomes, and impacts.

3.1 Theory of Change

Theory of Change outlined how an **intervention** – in this case, green buildings – could address the present issues and transform the **current state** into the **desired state** over time. It built upon the existing literature and research to substantiate the various outputs, outcomes, and impacts that the intervention's inputs and activities generate. Theory of Change also helped to identify the key stakeholders who would be affected by the intervention and thus must be consulted throughout the planning and implementation of the intervention. (Nicholls et al., 2012)

Building on this concept, we identified five key stakeholders of green buildings and summarized them in **Table 4**.

***Table 4**. Identified Stakeholders of Green Buildings*

Stakeholders	Descriptions
Building owners and developers	Building owners and developers plan, design, construct, operate, and maintain green buildings. These stakeholders directly influence the EESG performance of the buildings, especially the Economic and Governance aspects. How building owners and developers develop green buildings affects other stakeholders in the building value chain, including but not limited to construction companies, utility providers, and material suppliers and manufacturers.
Building occupants, tenants, and visitors	As the end users of green buildings, tenants, occupants, and visitors directly experience the Environmental and Social impacts. Since buildings are designed to fulfil certain functionalities for their intended users, their outdoor and indoor environments directly affect the building users' quality of life and productivity. For instance, green office buildings with good sound insulation features can improve workers' concentration and well-being, boosting their productivity, while a well-ventilated, comfortably lit study area on a university

Stakeholders	Descriptions
	campus can enable students to learn and faculty to teach at optimal conditions. Although they stakeholders vary depending on building uses, they are invariably affected by the built environment which they occupy.
Investors and financial institutions	Investors and financial institutions provide the financing for developing and operating green buildings. Conversely, these stakeholders expect to receive returns proportionate to the risks of the investments. As a well-established long-term investment asset class, buildings as part of real estate made up approximately 10% of the total assets held by institutional investors around the world (Likhachova et al., 2019). Real estate also constituted more than USD 100 trillion on the balance sheets of commercial banks globally in the form of construction finance, mortgages, and home improvement loans (Likhachova et al., 2019). It is thus imperative for financial institutions and investors to assess the EESG performance of green building assets they invest in.
Governments, regulatory authorities, and certification bodies	Governments, regulatory authorities, and certification bodies develop policies, incentives, standards, and codes to promote sustainable building design and practices. These regulations create an enabling environment for green building investments and development, thus contributing to the larger-scale efforts for sustainable development. For example, greening the built environment sector in Singapore is crucial for achieving the nation's emissions reduction targets given buildings account for 20% of national GHG emissions (BCA & SGBC, 2022). Extending Singapore's carbon tax (NCCS, 2023) to buildings may reduce the embodied and operational GHG emissions.
Local communities and non-governmental organizations (NGOs)	Local communities and NGOs drive the demand for concerning green buildings and influence public opinions and related policies. The communities around a green building benefit indirectly from the improved outdoor environmental quality and green spaces it provides, enhancing their health and well-being and fostering stronger societal ties among residents and occupants of local communities. On the other hand, the NGOs advocate for sustainable building practices and may work with local communities to raise public awareness. These stakeholders should be consulted by building owners, developers, and policymakers to ensure that the green buildings developed in the area positively impact the surrounding communities and society at large.

Having identified the stakeholders of green buildings, we reviewed the existing literature to substantiate the value drivers of our integrated framework. In the process, we distinguished four long-term impacts which green buildings can generate to benefit their stakeholders, society, and the environment at large:

- First, green buildings could contribute to long-term **Enhanced Economic Resilience**. Their use of renewable energy sources (e.g., solar panels, wind turbines) can substantially lower long-term operating expenses and reduce dependence on conventional energy sources (Legence, 2024). Moreover, certified green buildings also command more demand and higher lease and occupancy rates from green premium, generating a more consistent and reliable income stream for building owners (Gil-Ozoudeh et al., 2024). As the demand for green buildings continue to rise in the future, it would create more jobs (SGBC, n.d.) across the building and construction value chain.

- Green buildings could contribute to **Natural Capital Resilience**. Buildings heavily rely on natural capitals, which refer to the collective of renewable and non-renewable natural resources that provide services and benefits for society. These resources include land, water, clean air, metal, and ecosystem services (Natural Capital Coalition, 2016). Minimizing buildings' environmental footprint through sustainable design and practices in buildings themselves and across their value chain would build the capacity of natural capital to adapt and recover from disturbances (IFC & Capitals Coalition, 2020). This resilience would ensure the long-term sustainability of natural capital, supporting human well-being and economic activities facilitated by green buildings.
- Green buildings could also play their part in achieving the net-zero emissions targets and become part of the **Net-Zero Pathway** essential for mitigating climate change. International Energy Agency (IEA, 2021) identified buildings as one of the industry sectors that would be decisive in the global attempt to achieve net-zero emissions by 2050. To accomplish this target, IEA's (2021) *Net Zero by 2050* roadmap noted that all newly constructed buildings zero-carbon ready and to retrofit 2.5% of all existing buildings in the world every year to be zero-carbon ready, both from 2030 onwards. Such a projection should provide the impetus for green building stakeholders to incorporate energy-efficient design and technology, renewable energy, and sustainable materials in their buildings to reduce the embodied and operational carbon emissions.
- Finally, green buildings are essential building blocks for **Liveable Cities**. Such buildings can enhance the urban environmental quality through reduced urban heat island (UHI) effect, pollution reduction, and healthier indoor environment. Moreover, green buildings can promote social well-being by providing spaces for community interaction and interaction with local biodiversity. All these features would lead to more inclusive and resilient cities for the present and future generations. (Kawamura & Brady, 2023)

Table 5 presented the result of the literature review to support the proposed Theory of Change for green buildings. Although some components were based on literature relevant to our local context in Singapore, the Theory of Change can be easily adjusted and contextualized for green buildings in other parts of the world.

***Table 5**. Theory of Change for Green Buildings*

Current State	Intervention	Desired State
Many buildings were built with little to no attention to their environmental, social, and governance externalities, exacerbating various issues in the world.	Integrate environmental, social, and governance considerations on top of economic aspects when developing new buildings and retrofitting existing ones as green buildings.	Green buildings create long-term impacts of Enhanced Economic Resilience, Natural Capital Resilience, Net-Zero Pathway, and Liveable Cities for people and planet.

Evidence to Substantiate the Need for Intervention	
Economic	
Building as economic goods must justify their **investment** and account for their integrated **costs** and **benefits**	The built environment is an important economic sector that draws significant investments. In 2017 alone, the world committed more than USD 5 trillion to construct new buildings and retrofit the existing ones, less than 10% of which (approximately USD 423 billion) was dedicated to green buildings (IEA et al., 2018). The investment in buildings would only grow as the number of buildings globally was expected to double to accommodate a population of 10 billion by 2050 (Archer & Langbroek, 2023). Likhachova et al. (2019) from the International Finance Corporation (IFC) estimated a USD 24.7 trillion investment potential for green buildings between 2018 and 2030 in emerging economies like China, Indonesia, and Thailand. The investment in building decarbonization in 2022 was estimated to be more than USD 285 billion, but this value was expected to decline due to increasing costs and less conducive investment environment (UNEP & GABC, 2024). Given these trends, the developers, owners, and investors must break from the traditional profit maximization mindset and start accounting for the ESG impacts of buildings.
Environmental	
Many buildings could do better to consider their impacts on the **ecology** in and surrounding their site	The built environment sector significantly contributed to climate change, which affected 29% of threatened and near-threatened species globally (WEF, 2020). To better integrate ecological considerations into building development and retrofitting, recommended strategies include designing compact and efficient built environments, promoting nature-positive designs, and utilizing nature as infrastructure (WEF, 2020). Locally, Singapore Green Building Masterplan (SGBMP) set the "80-80-80 in 2030" targets to mitigate buildings' contribution to climate change, which include obtaining Green Mark certification for 80% of buildings by gross floor area (GFA) by 2030 (NCCS, n.d.). By the end of 2022, 55% of Singapore's buildings had been Green Mark-certified, with efforts expected to be ramped up in the future (BCA, 2024a). Concerning biodiversity, the latest Green Mark certification standard mandates buildings to consider plant diversity, provide habitats for local species, and restore the ecological balance (BCA, 2024b).
Many buildings have low **energy efficiency** and high **GHG emissions**	Buildings accounted for more than 20% of GHG emissions in Singapore (SGBC, 2015b). Given this high proportion, SGBMP set the target of 80% improvement in energy efficiency compared to the 2005 levels for best-in-class green buildings by 2030 (BCA, 2023a). As of 2022, Singapore had achieved a 70% improvement (BCA & SGBC, 2022), with aims for higher efficiency in more buildings. In September 2024, a new Mandatory Energy Improvement Regime (MEI) in Building Control Act was launched

	to fine the buildings that failed to meet the required energy intensity reduction from 2025 onwards (Lim, 2024). Reducing GHG emissions associated with construction and embodied carbon is also crucial. The ratio of embodied carbon within the total carbon emissions over a building's life cycle in Singapore was 40%, higher than the global average of 30% (SGBC, 2015b). To address this issue, the Singapore Green Building Council (SGBC) launched the Singapore Built Environment Embodied Carbon Pledge, which garnered 100 signatories from the built environment sector. The pledge was based on three principles: selecting building materials with lower embodied carbon, minimizing material usage through collaborative design and optimization, and transforming construction site processes to utilize electricity and renewable energy sources (SGBC, 2015b).
Many buildings have inadequate sustainable **water management**	According to the Public Utilities Board (PUB), daily household water consumption per capita in 2018 was 141 litres. PUB aimed to reduce this figure to 130 litres by 2030 (PUB, 2024a). In the non-domestic sector, which accounted for 55% of Singapore's daily water consumption of 430 million gallons, PUB introduced the *Best Practice Guides in Water Efficiency for Buildings*. These guides were designed to equip engineers, developers, building owners, facilities managers, and managing agents involved in water management, with the essential knowledge needed to design, maintain, and operate water-efficient buildings. The guides emphasized best practices such as leak detection and repair, the use of water-efficient fixtures, optimizing water use in the cooling towers and adopting water-efficient landscape designs (PUB, 2022). Adopting these best practices should create more water-efficient buildings and contribute to Natural Capital Resilience.
Many Buildings have inadequate considerations over **responsible material use** and **waste management**	By 2018, Singapore had achieved an almost 100% recycling rate for construction and demolition (C&D) waste, as well as for ferrous and non-ferrous metals. This success largely owed to the Demolition Protocol introduced by BCA that facilitated demolition planning to maximize C&D waste recycling (MEWR, 2019). In contrast, only 22% of Singapore's domestic waste was recycled, significantly less than the 74% recycling rate for non-domestic waste (MEWR, 2019). Despite government initiatives such as the #RecycleRight campaign in 2019 and the provision of recycling receptacles to new HDB owners, further efforts are needed to enhance the recycling rate of operational waste from buildings.
Social	
Building developments have inadequate considerations over their **direct and indirect social impacts**	Nearly 55% of Singapore's buildings had obtained the Green Mark certification by the end of 2022, with the rest still lagging behind (BCA, 2024a). The Green Mark standard encompassed crucial social elements like indoor environmental quality that, if neglected, could lead to sick building syndrome (BCA, 2023a).

	This gap highlighted the ongoing challenge to ensure that buildings contribute to their users' health and well-being. Recognizing the role that buildings play in human health, the WELL certification by the International WELL Building Institute (IWBI, n.d.) had been increasingly adopted around the world. Beyond just ensuring good indoor environmental quality, the WELL certification focuses on active interventions that encourage healthier lifestyles. Given that people spend about 90% of their time indoors, buildings have the potential to be powerful spaces for health promotion. Although this concept was still nascent in Singapore, with its first WELL certification awarded to SDE4 building in 2019 (NUS, 2019), there is huge opportunity for more buildings to adopt WELL principles. By integrating features which promote healthy eating, physical activity, and overall well-being, buildings can actively contribute to the health of their occupants. The urgency of these efforts was underscored by the looming threat of climate change, which was expected to cause global crop yields to decline by up to 25% by 2050 (URA, n.d.-a). For a nation that imports over 90% of its food, Singapore is particularly vulnerable to the fluctuations in global food market (URA, n.d.-a). In response, the Singapore Food Agency (2022) set the goal of meeting 30% of the nation's nutritional needs through local production by 2030. Achieving this target will require innovative urban farming solutions in buildings that not only bolster food security but also contribute to a healthier, more resilient population.
Governance	
Building developments can do better in terms of the **governance** of **buildings and their environs**	Effective governance in building design requires a forward-thinking approach. Anticipating the impacts of climate change demands the incorporation of resilience into design strategies (URA, 2019), while considering future functionalities necessitates designs that offer flexibility (Ong & Ong Pte Ltd, 2023). In its efforts to enhance productivity, reduce costs, improve safety, and create better jobs, BCA had been driving digital transformation within the built environment. A key focus in building development was the implementation of Integrated Digital Delivery (IDD), which utilizes data and digital technologies to seamlessly connect all stakeholders involved in a project (Co, 2021). As for building operation and maintenance, innovations such as asset information models and digital twins represent data-driven approaches to building management (BCA, 2021a). These technologies automate the manual processes, thereby reducing the cost and complexity of facility management (BCA, 2021b). To further accelerate the development and deployment of cutting-edge energy-efficient technologies in buildings, the Green Buildings Innovation Cluster Programme 2.0 was launched in 2022. This program served as an innovation platform dedicated to advancing green building technologies. (BCA, 2023b)

Building developments can be better integrated with **transportation** and **other supporting infrastructure**	The Land Transport Master Plan 2040 envisioned a Singapore with 20-minute towns, a 45-minute city, and transportation infrastructure which promotes healthy lives (LTA, 2023). To realize this vision, Singapore began expanding its urban transport network, including by completing an additional 150 km of covered linkway connection to mass rapid transit stations, residential areas, and amenities. There were also plans to implement dedicated cycling paths, widen footpaths, extend the cycling path network to over 1,000 km by 2040, and construct additional 20 km of noise barriers on existing expressway flyovers. It is crucial that building stakeholders proactively integrate these considerations into their projects. Furthermore, as part of the Singapore Green Plan 2030, there had been a strong push toward the adoption of electric vehicles (EVs) with the goal of transitioning all vehicles to cleaner energy sources by 2040. To facilitate this shift, it was imperative to ensure that EV charging points are abundant, conveniently located, and easily accessible (Tan & Koh, 2023). The government had also introduced guidelines and incentive schemes that mandate active and passive EV charging infrastructure in building retrofitting projects (URA, n.d.-b), making buildings facilitators of green energy.

3.2 Logic Model

Logic Model is also known in the impact investment literature as "Impact Map". With the Theory of Change as its basis, the Logic Model maps inputs and activities to outputs, outcomes and impacts. **Inputs** are resources (e.g., funding, manpower, equipment, or facility) which are required to implement the **activities** of the intervention. These activities implement the change from the current state to the desired state, generating Specific, Measurable, Realistic, and Time-bound (SMART) **outputs** as well as short- to medium-term **outcomes**. The intervention's outcomes then lead to long-term **impacts** for its stakeholders. (Nicholls et al., 2012)

Having understood these five elements, we proceeded to use the harmonized impact value drivers in Chapter 2 as the components of our Logic Model for green buildings. However, we realized that the value drivers were not yet detailed enough to be mapped as the five elements of the Logic Model. As such, taking reference from the categories in the guideline documents and matching them with the classification of our framework, we specified the harmonized impact value drivers into more detailed indicators.

Table 6 presents the complete list of the EESG aspects, pillars, value drivers, and indicators of our proposed framework for green buildings.

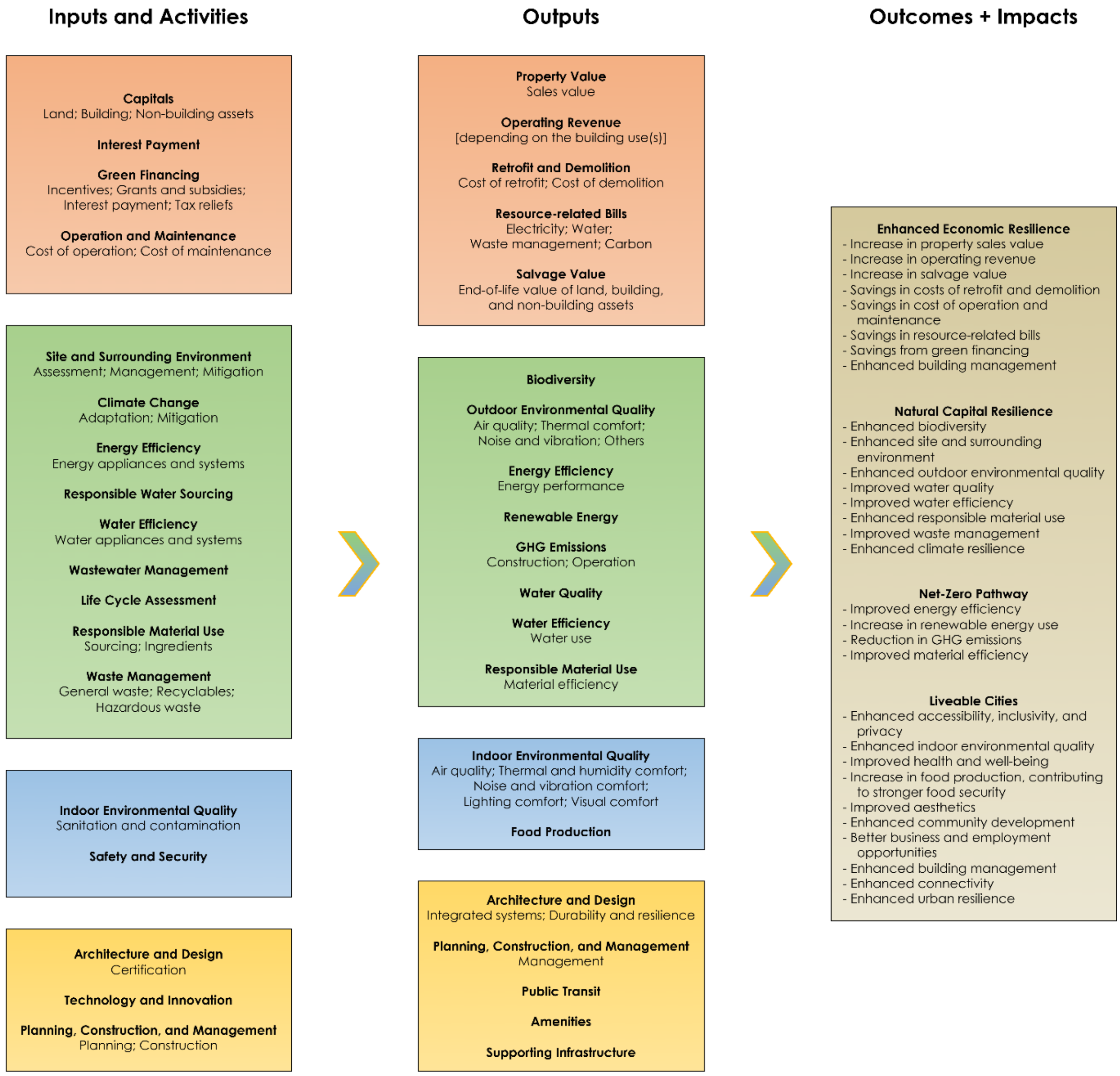
Table 6. *Classification of EESG Impact Components in SGFIN's Framework*

Aspect	Pillars	Value Drivers	Indicators
ECONOMIC	Investment	Capitals	Land
			Building
			Non-building assets
		Interest payment	Loan interest payment
	Cost	Retrofit and demolition	Cost of retrofit
			Cost of demolition
		Resource-related bills	Electricity
			Water
			Waste management
			Carbon
		Operation and maintenance	Cost of operation
			Cost of maintenance
	Benefit	Property value	Sales value
		Operating revenue	Hotel
			Office lease
			Retail lease
			Recreation
			MICE lease
			Others
		Green financing	Incentives
			Grants and subsidies
			Interest payment
			Tax reliefs
		Salvage value	Land
			Building
			Non-building assets
ENVIRONMENTAL	Ecological factors	Biodiversity	Biodiversity
		Site and surrounding environment	Assessment
			Management
			Mitigation
		Outdoor environmental quality	Air quality
			Thermal comfort
			Noise and vibration
			Others
		Climate change	Adaptation
			Mitigation
	Carbon and energy	Energy efficiency	Energy performance
			Energy appliances and systems
		Renewable energy	Renewable energy
		Greenhouse gas (GHG) emissions	Construction
			Operation
		Responsible water sourcing	Responsible water sourcing

Aspect	Pillars	Value Drivers	Indicators
	Water and wastewater	Water quality	Water quality
		Water efficiency	Water use
			Water appliances and systems
		Wastewater management	Wastewater management
	Material and waste	Life cycle assessment	Life cycle assessment
		Responsible material use	Sourcing
			Ingredients
			Material efficiency
		Waste management	General waste
			Recyclables
			Hazardous waste
SOCIAL	Direct user experience	Accessibility, inclusivity, and privacy	Accessibility
			Inclusivity
			Privacy
		Indoor environmental quality	Air quality
			Thermal and humidity comfort
			Noise and vibration comfort
			Lighting comfort
			Visual comfort
			Sanitation and contamination
		Health and well-being	Mental health and well-being
			Active lifestyle
			Healthy lifestyle
		Safety and security	Safety and security
		Food production	Food production
		Aesthetics	Aesthetics
	Indirect externalities	Community development	Communal benefits
			Education
		Business and employment	Business and employment
GOVERNANCE	Building and environs	Architecture and design	Integrated systems
			Durability and resilience
			Certification
		Technology and innovation	Technology
			Innovation
	Planning, construction, and management	Planning	Planning
		Construction	Construction
		Management	Management
	Transportation and other infrastructure	Public transit	Public transit
		Amenities	Amenities
		Supporting infrastructure	Supporting infrastructure

Based on the Theory of Change in **Table 5**, we mapped the harmonized impact value drivers and indicators of our proposed framework in **Table 6** according to the five elements of a Logic Model. **Figure 3** depicts the resultant map, which established the causality between our framework and the intended impacts of green buildings.

Figure 3*. Logic Model for Green Buildings*



Having explained how green buildings could contribute to the long-term impacts of Enhanced Economic Resilience, Natural Capital Resilience, Net-Zero Pathway, and Liveable Cities using the harmonized impact value drivers and indicators of our proposed framework, the next chapter would elaborate the calculation methodology of the framework.

4 Methodology of the Integrated Impact Valuation of A Green Building

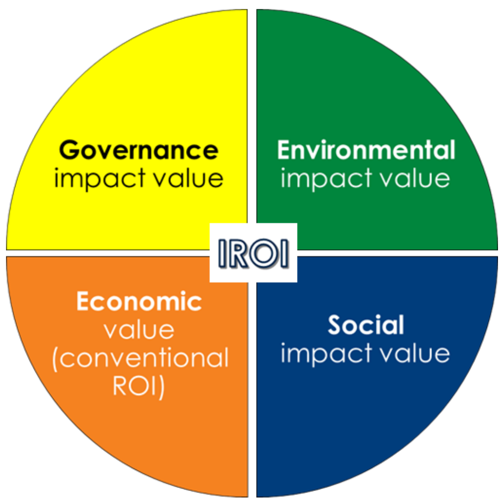
This chapter outlined the methodology of our proposed integrated impact valuation framework, which involved identifying stakeholders of a green building, selecting the relevant impact metrics, and monetizing the metrics using financial proxies. It introduced the concept of the Integrated Return on Investment (IROI), which combined the Economic, Environmental, Social, and Governance (EESG) factors into a unified monetary assessment. The methodology highlighted the importance of adjusting for financial factors such as time-varying parameters and purchasing power parity. Our proposed methodology also employed sensitivity and scenario analyses to refine the valuation process, ensuring a robust and adaptable framework applicable across various contexts and scales in the built environment sector. In light of climate change, the scenario analysis can test how the IROI value of a green building may vary due to different global warming scenarios.

4.1 Introducing the Integrated Impact Return on Investment (IROI) Method

The impact valuation methodology which we touched upon at the end of Chapter 2 is the Social Return on Investment (SROI). It has been used mainly by impact investors and social enterprises since its conception in 1996 by the Roberts Enterprise Development Fund (Corvo et al., 2022). Over time, the use of SROI method has been gaining traction in recent years by private and public institutions to evaluate the economic, social, and environmental impacts of a project in financial terms and vis-à-vis the investment in the project. Such organizations likely started employing the SROI method to ensure that their investment would yield net positive returns (Kang & Zhang, 2023).

With the SROI method as the foundation, we set out to identify the impact metrics of a green building under their respective EESG indicators, value drivers, pillars, and aspects before translating them into the common unit of dollar value. However, because of the additional impact aspects in our application of the SROI method, we renamed it the **Integrated Return on Investment (IROI)** method. A key highlight of the IROI value that this method calculates is that it builds on and includes the conventional Return on Investment (ROI) value, encompassing a more complete picture of the integrated EESG aspects as depicted in **Figure 4**.

Figure 4. *Components of SGFIN's IROI Value*



4.2 Identification of the Relevant Stakeholders of A Green Building

An IROI assessment evaluates the impact values created for the stakeholders of an intervention. Therefore, identifying the relevant stakeholders of green building development is crucial for selecting the outcomes and impacts to be monetized. The IROI calculation must carefully consider the characteristics of these stakeholders to reflect the integrated impact value of the building accurately. For instance, the stakeholders of an office skyscraper (e.g., building developer, tenants, guests) are different from those of a school building (e.g., the school institution, students, teachers).

4.3 The Harmonized Impact Indicators of Green Buildings

As outlined in Chapter 3, our integrated impact valuation framework for green buildings encompasses a comprehensive structure consisting of four EESG aspects: Economic, Environmental, Social, and Governance. Within these aspects, the framework is further divided into 12 pillars, 39 value drivers, and 82 indicators to capture the multifaceted impacts of a green building. The components of our proposed framework reconcile the seemingly contradictory objectives of achieving robust economic returns while maximizing the integrated impact across the building's lifetime. To elaborate on the integrated impact values covered by our proposed framework, we described each of the 39 value drivers depicted in **Figure 5** below.

Figure 5. *The 39 Impact Value Drivers of SGFIN's Framework*

Economic

1. Capitals
2. Interest payment
3. Retrofit and demolition costs
4. Resource-related tariffs
5. Operation and maintenance costs
6. Property value
7. Revenue
8. Green financing
9. Salvage value

Environmental

1. Biodiversity
2. Site and surrounding environment
3. Outdoor environmental quality
4. Climate change
5. Energy efficiency
6. Renewable energy
7. GHG emissions
8. Responsible water sourcing
9. Water quality
10. Water efficiency
11. Wastewater management
12. Life cycle assessment
13. Responsible material use
14. Waste management

Social

1. Accessibility, inclusivity, and privacy
2. Indoor environmental quality
3. Health and well-being
4. Safety and security
5. Food production
6. Aesthetics
7. Community development
8. Business and employment

Governance

1. Architecture and design
2. Technology and innovation
3. Planning
4. Construction
5. Management
6. Public transit
7. Amenities
8. Supporting infrastructure

4.3.1 Economic Impact Value Drivers

Value drivers of this aspect capture the economic and financial impacts of a green building. They are usually reported in monetary terms. We identified nine value drivers in the economic aspect which are monetized by our valuation framework.

1) **Capitals** refer to the investment to develop a green building, such as for acquiring the land, constructing the building, and purchasing non-building assets.
2) **Interest payment** refers to the monetary charge for capitals borrowed from bank loans or debt instruments.
3) **Retrofit and demolition** costs refer to the expenditures for installing new fixtures or equipment or modifying existing ones in previously constructed buildings.
4) **Resource-related bills** refer to the expenses incurred for consumption of natural resources. In our framework, these bills cover electricity, water, waste management, and carbon.
5) **Operation and maintenance** costs refer to ongoing expenses associated with running and upkeeping a green building after its construction.
6) **Sales value** refers to the monetary worth of a green building which may be affected by the market conditions and rates.
7) **Operating revenue** refers to the income arising from the operation of a green building. Examples include revenues from a hotel, office lease, retail lease, recreation, and meetings, incentives, conferences, and exhibitions (MICE) lease.
8) **Green financing** refers to the monetary benefits awarded by the public or private sector for green building project developments. Such benefits include incentives, grants and subsidies, preferential interest rate, and tax reliefs.
9) **Salvage value** refers to the amount an asset is worth at the end of its lifetime, usually when it is fully depreciated.

4.3.2 Environmental Impact Value Drivers

Environmental value drivers capture the impacts of a green building on natural environment and ecosystem. For this aspect, we identified 14 value drivers to monetize.

1) **Biodiversity** refers to the perceived benefits of conserving the biodiversity in and around the area of a green building.
2) **Site and surrounding environment** refer to the costs incurred in assessing and managing the environment in and around the building area as well as the benefits generated by the environmental mitigation plan (e.g., through additional greenery space).
3) **Outdoor environment quality** refers to the perceived benefits generated by a green building on the surrounding outdoor environment, such as the improved air quality, improved thermal comfort, and reduced noise and vibration.
4) **Climate change** refers to the benefits generated from installing and maintaining climate change adaptation (e.g., shadings, permeable

pavements), and mitigation (e.g., green roofs and walls) features in a green building.

5) **Energy efficiency** refers to the electricity cost savings of using resource-efficient appliances and systems that may reduce energy use and improve efficiency.
6) **Renewable energy** refers to the investment and costs from installing a renewable energy system, such as energy storage system (ESS) and solar PV, as well as electricity cost savings from renewable energy.
7) **GHG emissions** refer to the actual tax savings from reducing the embodied carbon from the building construction/retrofit and from reducing the operational carbon emissions.
8) **Responsible water sourcing** refers to the costs incurred for constructing and refurbishing equipment (e.g., rainwater storage tank, rainwater catchment surfaces) needed to source water responsibly.
9) **Water quality** refers to the perceived benefits of improved water quality and the costs incurred for installing, refurbishing, and maintaining a water quality monitoring system.
10) **Water efficiency** refers to the costs incurred for installing, operating, and maintaining water-efficient systems and equipment, as well as the cost savings in water bills.
11) **Wastewater management** refers to the costs incurred for installing and refurbishing the systems and equipment for greywater treatment, wastewater treatment, and water pollution control.
12) **Life cycle assessment** refers to the costs of materials incurred throughout the life cycle of a green building.
13) **Responsible material use** refers to the benefits and cost savings of using responsible materials, such as from using Pulverized Fly Ash and recycled construction materials.
14) **Waste management** refers to the investment and costs incurred for the disposal of construction and demolition waste, as well as cost savings in operational waste management.

4.3.3 Social Impact Value Drivers

Social value drivers reflect the impacts which a green building generates for its human users, local communities, and society at large. For the social aspect, we have identified eight value drivers to be monetized.

1) **Accessibility, inclusivity ,and privacy** refer to the values generated by installing accessibility, inclusivity, and privacy features in a green building. These features include those that accommodate people with disabilities, protect privacy, and cater for breastfeeding mothers.
2) **Indoor environment quality** refers to the perceived benefits of improved environmental quality inside a green building. Parameters include air quality, lighting comfort, noise and vibration comfort, sanitation and contamination management, thermal and humidity comfort, and visual comfort.

3) **Health and well-being** refer to the perceived benefits, healthcare savings, and cost savings of an active lifestyle, healthy lifestyle, and improved mental health and well-being. Examples of the metrics of this value driver include walking in greenery areas and building features which encourage exercises.
4) **Safety and security** refer to the costs incurred from installing safety and security systems and features in the building, including the cost of alteration, application for building materials and fire safety features, and insurance premium.
5) **Food production** refers to the revenue from and cost savings generated by food produced in a green building.
6) **Aesthetics** refers to the perceived benefits of the aesthetic value of a green building. Examples of features of this value driver include green walls and adjoining vegetation which may improve the building's aesthetics.
7) **Community development** refers to perceived benefits from encouraging interaction among building users as well as knowledge sharing with and learning by the local communities.
8) **Business and employment** refer to the values from improved business and employment opportunities in a green building, such as creation of new jobs and establishment of new businesses.

4.3.4 Governance Impact Value Drivers

Governance value drivers capture the impacts of a green building from how its planning, design, construction, operation, and maintenance are managed by its developer. For this aspect, we identified eight value drivers to be monetized.

1) **Architecture and design** refer to the costs incurred in implementing sustainable architecture and design practices – e.g., in the green building's durability, resilience, and integrated systems – and the benefits generated by complying, for example, to green building certification standards.
2) **Technology and innovation** refer to the cost incurred by and benefits from the implementation of building technology (e.g., automated management system), cost savings from avoided consultation service, and the benefits and costs of implementing innovative features and practices in a green building.
3) **Planning** refers to the impact values generated by planning activities, including due diligence, master planning, and efficient work allocation.
4) **Construction** refers to the costs incurred and costs savings from the construction of a green building and retrofitting an existing building into a green building.
5) **Management** refers to the cost incurred and benefits from implementing best management practices in a green building, such as effective engagement with the stakeholders of a green building.
6) **Public transit** refers to the values generated by a green building for being in proximity to public transportation nodes and for providing public transportation services, such as shuttle bus services in a private residential complex.
7) **Amenities** refer to the value generated by a green building for being in proximity to public amenities, such as hospitals, schools, and sports facilities.

8) **Supporting infrastructure** to the investment and costs incurred for constructing such features in a green building (e.g., sheltered walkways, leisure facilities).

4.3.5 Impact Metrics for Green Buildings

Furthermore, we identified 171 impact metrics material to a green building, classified according to the aspects, pillars, value drivers, and indicators developed in Chapter 3. These metrics capture the monetized impacts by multiplying the building data inputs with the financial proxies in our database. Since building inputs are generally non-monetary (e.g., amount of electricity generated by solar panels), financial proxies are needed to convert them to dollar values. Due to this conversion, and for the purpose of IROI value computation explained in Section 4.6, we categorized the metrics into the following types:

- **Investment** refers to resources that enable the impact value of a monetized metric to exist, such as the cost of installing solar panels in a building.
- **Cost** refers to the expenditure required to generate the impact value of a monetized metric, e.g., the maintenance fee of solar panels in a building.
- **Benefit** refers to the positive impact value generated by a monetized metric. An example of a benefit is electricity bill savings from solar panels in a building.

While it seems exhaustive, the metrics are highly customizable to meet the specific needs of an evaluated green building. Stakeholders using our framework can also add their own unique metrics if the metrics are not found on the list, provided they apply the calculation steps of the IROI method described in Section 4.5 to the additional metrics. In the future, we plan to add more impact metrics and enhance the existing ones as we work on projects which leverage our proposed framework. We also welcome any feedback on the metrics from the green building stakeholders.

4.4 Monetization of A Building's Impact Value

Converting the non-monetary value represented by the impact metrics into monetary terms requires financial proxies associated with the impact indicators and metrics. As such, we conducted a literature review of academic research papers, industry reports, and websites of goods and services providers to build our database of financial proxies. We then selected and collated the financial proxies relevant to green buildings.

4.4.1 Understanding the Types of Financial Proxies

From the sources above, we gathered the following types of financial proxies:

- **Direct Proxy** consists of unit prices of tangible goods and services available in the market (e.g., electricity price, water price, carbon tax) and provides information for benchmarking. For example, the proxy of electricity tariff (SP Group, 2024) enables comparison between the electricity uses and bills before and after the installation of solar panels, which stands for electricity savings from renewable energy investment.

- **Indirect Proxy** concerns economic values that society assigns to the intangible impacts of ESG goods and services. This proxy type usually takes the form of Willingness to Pay (WTP) estimates reported in research studies, notably those using the contingent valuation method. An example of this proxy type is the average WTP per household of US$36.86 annually for higher recycling capacity in South Korea (Ko et al., 2020).
- **Incremental Proxy** typically comes from academic papers and research studies which reported the marginal changes from adopting certain green building practices, technology, feature, or certification. For instance is the proxy of property premium for buildings with high walkability at 17% (C. Y. Yiu, 2011).
- **Approximated Proxy** cover proxies from other previous types that originated from another country and/or time different from the geographic and temporal context of the building being assessed. The rule of thumb for choosing relevant approximated proxies is to i) choose proxies from sources geographically nearest to the nation where the building is for closest comparison, and ii) choose proxies closest to the desired year to minimize temporal disparities. Section 4.5.2 and 4.5.4 respectively explain how to contextualize this type of proxy to the country and time of the building being evaluated.

4.4.2 Establishing the Database of Financial Proxies

By leveraging the reference sources, we constructed a comprehensive database of financial proxies for the monetary valuation of the impact metrics of a green building. As of this publication, the database comprised more than 550 financial proxies from various parts of the world for the 39 impact value drivers and 171 impact metrics described in Section 4.3. A list of sample financial proxies is available in Appendix C.

It is important to note that the financial proxy database is not exhaustive. As we apply our proposed framework in future research and projects, we plan to continually expand the database by adding new financial proxies and refining the existing ones. Additionally, we welcome feedback from green building stakeholders to improve the quality and comprehensiveness of the database.

4.5 Computation of the Integrated Impact Value

The integrated impact value of a green building is calculated by the following steps:

- Select the impact metrics relevant to the building;
- Select the financial proxies which correspond to the selected impact metrics;
- Compute the financial value of selected impact metrics as annual cash flow;
- Project the cash flows of impact metrics across the building's lifetime; and
- Discount the future cash flows to arrive at the net present value.

Moreover, during the computation process, the financial value of the impact metrics needs to be adjusted for the time value of money and causality factors to substantiate the impacts of green building development. Impact metrics that rely on financial proxies from international sources must also be adjusted for currency exchange. Overall, this valuation process would provide a better understanding of the impacts of green buildings and further inform investment decisions.

4.5.1 Select the Relevant Impact Metrics and Financial Proxies

The impact metrics we developed encompass various building features and uses (we followed BCA's (2024) building categories) which may be relevant for specific stakeholders. Therefore, in evaluating the integrated impact of a green building, we must select only the metrics relevant to the building from the pool of 171 impact metrics. For example, if a green building has no solar panels, the metrics related to solar panels should be excluded from the impact valuation. Furthermore, we must select the financial proxies relevant to the selected metrics from the proxy database. As an impact metric may have multiple financial proxy options, we have to select the proxy that best represents the building's context.

4.5.2 Adjust by Purchasing Power Parity

Because we collected proxies from literature from various parts of the world, the value of some proxies must be adjusted from the origin country's currency into the currency of the nation where the green building is. In our framework, we used the implied purchasing power parity (PPP) conversion rate from the International Monetary Fund (IMF, 2021) for the currency exchange adjustment. We decided upon this conversion rate over the historical and real-time exchange rates as it enables better comparison of the prices of similar goods and services between different countries (Callen, n.d.).

4.5.3 Annualize the Impact Metrics

Next, the impact metrics are monetized by multiplying their building data inputs with their corresponding financial proxies and subsequently projected as future cash flows across the lifetime of the building. The projection allows the cash flows to be adjusted to reflect the dynamic economic conditions (e.g., inflation, increase in carbon tax). In projecting the impact metrics as future cash flows, we must pay attention to the expected impact value duration of the impact metrics. For example, since solar panels have an expected lifespan of 25 years (Sodhi et al., 2022), impact metrics which concern their maintenance cost and benefit (from electricity bill saving) should be projected only up to Year 25 in the building lifetime. We can then assume another investment impact metric to replace the solar panel in Year 25 and resume the solar panels' maintenance cost and benefit for another 25 years.

4.5.4 Establish the Causality Factors

To ensure that the integrated impacts genuinely originate from the green building, it is essential to determine the specific contribution of the building to those impacts. The following four causality factors help to proportionate the values of monetized impact metrics attributable to the building (Kang & Zhang, 2023):

- **Attribution** refers to the proportion of actual impact values generated by the building instead of by the investments and interventions from other stakeholders. For example, a building's improved indoor environmental quality leads to better health for users, but external programs contribute 30% to this improvement. In this case, only 70% of the impact value is attributed to the building.
- **Deadweight** refers to the impact value that would occur even without the intervention of the green building. For instance, the building manages to reduce water use by 25% but local regulations would have led to a 10% reduction regardless. In this case, the deadweight factor is 10%.
- **Displacement** refers to the extent of the impact values of a green building replacing other (pre-existing) outcomes and impacts. For example, if a building with rooftop farm replaces a farmland, its food production-related impact values must be adjusted to the displacement of the farmland's food production.
- **Drop-off** refers to the potential decrease in impact values over time and in consideration of the duration of their respective metrics. For instance, the effectiveness of an air purifier may decrease over time due to wear and tear.

Adjusting to the causality factors can be challenging due to the need for data beyond the scope of the intervention. These factors are typically estimated based on past experiences with similar projects or through academic research. Deadweight, displacement, and attribution are expressed as percentage of the monetized impact metrics, representing the causality factors' collective adjustment of the metrics. On the other hand, drop-off is calculated by applying a fixed percentage reduction each year to reflect the decreasing impact values over time (Nicholls et al., 2012).

4.5.5 Adjust for Time-varying Parameters

The changing economic conditions can significantly alter the financial proxies and, by extension, the impact value of monetized metrics. These changes generally take the form of inflation rate and increase in resource-related costs due to market rate fluctuations or changing regulations. Inflation refers to the rise in the prices of goods and services over time that reduces the purchasing power of money. For instance, solar panel installation in Year 1 costs $10,000 but due to an annual inflation rate of 2% it would cost approximately $16,400 in Year 26. On the other hand, resource-related costs may increase due to various factors such as resource scarcity and regulatory changes. The growth of Singapore's carbon tax rate is a good illustration of this factor. The carbon tax will be raised from S$25/t$CO_2$e in 2024 to S$45/tCO_2e in 2026 and 2027 and to a range of S$50–80/t$CO_2$e by the end of the decade (NCCS, 2023). Therefore, the future annual cash flows of monetized metrics must be adjusted as follows:

- For metrics with financial proxies that **fluctuate with regulations**: calculate the annual growth rate of the proxy based on its historical data and multiply the future cash flow in applicable years by the growth rate.

- For **all other metrics**: multiply the future cash flow by the average annual inflation rate of the country where the building is in applicable years.

4.6 Computation of the Integrated Return on Investment (IROI) Value

The last step of the computation of integrated impact value involves discounting the projected future annual cash flows of the monetized impact metrics into the present. To obtain the Present Value (PV) of future cash flows, we used the discount rate of the building development. The rate reflects the opportunity cost of the development, accounting for the time value of money and associated risks (Brealey et al., 2023). We then used the PV of the integrated impact metrics to calculate the IROI value. As the ratio between the net integrated EESG impact values generated by a green building – represented by subtracting the total PV of cost items from the total PV of benefit items – and the investment required for the building, the IROI value is computed using the following formula:

$$IROI = \frac{\sum PV\ of\ Integrated\ Benefits - \sum PV\ of\ Integrated\ Costs}{\sum PV\ of\ Investments}$$

where, for example, an IROI of X means every $1 invested in the intervention has generated or will generate a total integrated value worth $X (Nicholls et al., 2012). An IROI below $1 implies the intervention generates negative externality for stakeholders.

4.7 Sensitivity and Scenario Analyses

Using the computed IROI value, we can conduct two further analyses. The first, sensitivity analysis, assesses how the IROI value varies in response to the change in individual elements of the impact valuation model. This analysis helps to identify the parameters which significantly alter the IROI value. The result of this analysis is usually depicted as a football field chart. The commonly sensitized values include financial proxies, causality factors, project discount rate, and the inflation rate. On the other hand, scenario analysis combines multiple sensitized elements into a scenario set to observe how the IROI react to the new scenario. For example, a best-case scenario can assume a better reduction in energy intensity and higher salvage building value, resulting in an IROI value that is considerably higher than the base scenario. In light of the climate change-induced global temperature rise affecting multiple financial proxies such as electricity price and the lease of a green building, stakeholders can test the susceptibility of their IROI value to various climate scenarios in this analysis.

5 Potential Usage of SGFIN's Framework by Stakeholders

A key strength of our proposed framework is its translation of the intangible, non-monetary impact values into financial terms. The conversion enables for comparison between the integrated impacts in the dollar value of different building projects and across development scales. This chapter showcased this strength by exploring the application of the proposed framework in facilitating decision-making at various scales of development: individual building, a portfolio of buildings, and urban development. Where relevant, we substantiated our case by supplementing it with real-life examples.

5.1 Building Project Level

Our framework can be used as a capital budgeting tool to facilitate decision-making for individual building projects, both existing ones and those still at the development stage. For existing buildings, the framework would enable the measuring, tracking, and reporting of the integrated impact value they generate. On the other hand, for planned and ongoing building developments, the framework would allow for comparison between designs, features, and development options that maximize the impact value creation of the building. Altogether, the framework can help building owners and developers identify the primary impact value drivers of their green buildings, thus optimizing the use of their capital and resources.

To this end, we have been testing our proposed framework with our partners and received positive feedback on its application, the most notable of which is the SDE4 building at the National University of Singapore (NUS). The College of Design and Engineering at NUS developed SDE4 with sustainability as the forefront consideration. Its energy-efficient design and building features (e.g., architecture that maximizes natural ventilation, 1,225 rooftop solar panels, hybrid cooling system) enable SDE4 to offset its energy use and even contribute the surplus back to the grid. As a result, SDE4 was among the first buildings in Singapore to be certified Green Mark Platinum (Zero Energy) (NUS, 2021a). Furthermore, recognizing its positive impacts on the occupants' health and well-being, SDE4 was WELL-certified Gold in 2019, the first university campus building and the first building in Singapore to receive this certification (NUS, 2019). Zhang et al (2024) wrote a business case study valuing the integrated impacts of SDE4. By employing the contextualized version of our proposed framework, the case study captured both the tangible impacts of its resource efficiency and the intangible benefits. These non-tangible impacts include health benefits and educational benefits (from knowledge sharing in SDE4).

Going forward, we hope that more buildings in Singapore would adopt such holistic valuation of the EESG impact generated. The standardization of impact metrics, using financial proxies, and reporting and verification of monetary values of green buildings will warrant a consistent portrayal of the integrated impact values across different green buildings and sharpen the accuracy of impact values captured by the IROI method (Kang & Zhang, 2023). More adoption can also help interested developers to set an example for other industry players and asset owners to follow (BCA & SGBC, n.d.) and easier for investors to justify their investment decisions.

5.2 Building Portfolio Level

In the site visit to SDE4, we saw that the excess recycled water was fed into the pond in its landscape balcony. The pond was good for artistic views and educational purposes to teach the building users and visitors about natural purification systems (NUS DoA, n.d.). However, if the excess recycled water can be fed into another nearby buildings, more costs can be saved for the portfolio of buildings especially when the nearby buildings were costly to retrofit to install its own recycling systems.

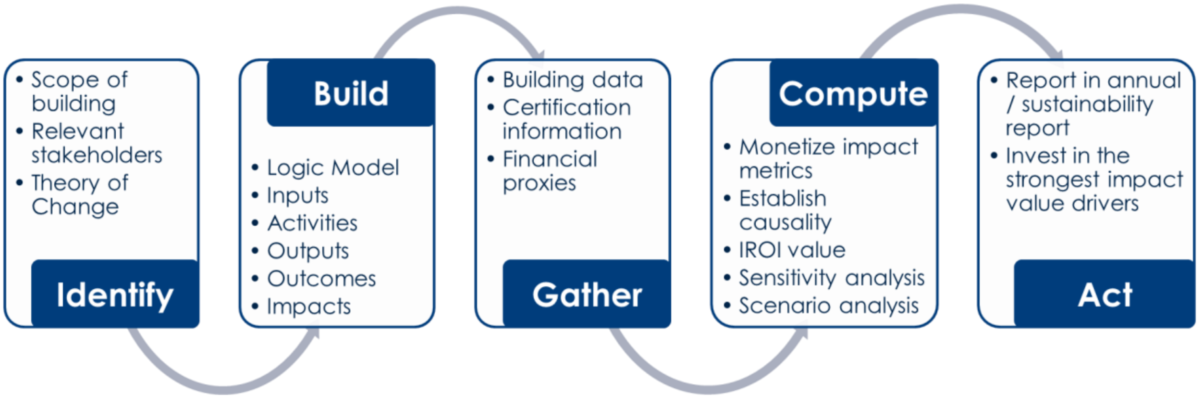
The reflection above provided the basis for applying our proposed framework to a cluster of buildings. Our framework's flexibility extends the systems thinking and integrated impact valuation to a portfolio of buildings. In addition to helping developers, owners, and investors calculate and compare the IROI value of a building portfolio, the framework can analyse the scaling factor from implementing best practices, sustainable design, technology, and features across multiple buildings. This application offers beneficial insights into strategic decision-making for investments and master planning within a vicinity.

To illustrate one specific application of our framework, we took the NUS Campus Sustainability Roadmap 2030 as an example. In the Roadmap, NUS shared the plan to increase energy efficiency by optimizing the individual chiller plants on its three campuses (NUS, 2023). The University Campus Infrastructure office can use the framework to compare the integrated return of alternative options, such as implementing campus-wide district cooling systems, retrofitting its existing buildings to include a hybrid cooling system, or incorporating architectural design that leverages natural ventilation for newly constructed buildings. In the long run, the alternative which minimizes or eliminates the need for cooling may generate the highest net positive impact as building technologies improve and their upfront investment costs decrease. Another aspect of the campus development to which our framework can contribute is related to public connectivity to the campus. As NUS looks into enhancing connectivity among its buildings and to surrounding areas, our framework could incorporate the net valuation of enhanced connectivity in the calculation.

Moreover, by measuring and presenting the integrated impact value created by green buildings in monetary terms, developers can access sustainable finance products to fund their building projects. Such products include loans that seek different levels of financial returns (GIIN, 2023). Therefore, our framework would enable green building stakeholders to assess the prospect of accomplishing their objectives across the return–impact spectrum and throughout the investment lifecycle.

In support of the future adoption of our framework by various stakeholders in the built environment sector, we developed a roadmap outlining how green building stakeholders can implement the framework, as depicted in **Figure 6** below.

Figure 6*. Framework Implementation Roadmap for Green Building Stakeholders*



5.3 Urban Development and Beyond

Going beyond one building or a cluster of buildings, our framework can also be used for urban planning and public financing. The scaling includes communities, neighbourhoods, parks, and districts that maximize positive impacts for residents and align their lifestyle to sustainable development. With the goal of optimal level of economic growth, high quality of life, responsible natural resource management, and efficient infrastructure operation, urban planning necessitates multi-dimensional and complex considerations. Aspects that feed into considerations of urban planning include land use and development, amenities, infrastructure, on-site and surrounding ecosystems, and human population (Bibri & Krogstie, 2017); in other words, elements encapsulated by our proposed framework.

In Singapore's context, the recent agenda of transforming Singapore into a "City in Nature" (SG Green Plan, n.d.) entails developing building-scale greenery (e.g., green roofs), urban-scale greenery (e.g., parks, streetscapes), and non-greenery sustainable features (e.g., landscaping that enhanced wind flow for cooling) (URA, 2023). Using our framework, which can be expanded to include more urban development considerations, public sector agencies can unify various cross-disciplinary considerations in financial terms by computing the integrated impact value of these master planning and urban development features, thus aiding the complex decision-making process.

We witnessed first-hand the potential of this application of our framework in the *Living with Rising Seas* Ideas Competition organized by the Public Utilities Board (PUB, 2024b). More than 110 tertiary students in 32 groups submitted their design ideas for future coastal protection in the southeastern part of Singapore in light of the threatening climate change. The group of students from NUS's MSc in Integrated Sustainable Design and MSc in Sustainable and Green Finance programmes proposed a design solution based on systems thinking called the "Island Chain" (Bhatia et al., 2023). The interdisciplinary team showcased the advantages of their development idea compared to PUB's original "Long Island" plan (Zalizan, 2022), leveraging a multi-functional caisson wall instead of landfill with sea bund. Their proposal would start to protect the coastline within five years after the start of caisson wall construction and showed financial sensibility from the integrated impact value perspective. By constructing five reclaimed islands along the caisson wall in phases, the capital raised from one island can be used to develop the next island, putting less strain on the national budget for this development and allowing the integrated value to be enjoyed earlier than the original plan. The team supported their proposal with the financial valuation of integrated impact metrics used in this framework, including the socio-economic value of exercise and the value of time spent for recreation.

For policymaking, governments and public sector agencies can use our framework to assess the effectiveness of green building incentives and support schemes. For example, Kuckshinrichs et al. (2010) calculated the social benefits of a national subsidy programme to increase buildings' energy efficiency through refurbishment to argue for the continuation of public funding to the programme. Such analysis may be replicated in Singapore to compute the integrated impact value generated by existing green building incentive schemes and assess their effectivity. It also enables the public sectors to compare the additionality that their schemes have generated with green buildings developed purely in reliance on private sector financing.

Finally, our framework can assist policymakers in introducing or updating best practices guidelines and standards in the built environment sector. Government agencies and statutory bodies can leverage on our framework to identify and verify sustainable building features, design, and technology with strong causality and net positive impacts. Subsequently, these building components can be incorporated into the best practice guidelines or certification standards, such as Singapore's Green Mark standard, to encourage their adoption by new building developments, thereby accelerating sustainable building practices across the standard's jurisdiction.

6 Conclusion

To conclude, our proposed integrated impact valuation framework offers a comprehensive tool for assessing the multifaceted value that green buildings provide. At the heart of the framework is the **established impact causality** as the basis for understanding how the intervention of green buildings generates long-term outcomes and impacts. By employing the Theory of Change and Logic Model, our framework maps the complex relationships between building inputs and activities and their eventual impacts, ensuring the thorough accounting of all value drivers involved in a green building.

In addition to evidencing the causality of impacts by green buildings, our framework **harmonized the impact indicators** across various building certification standards and impact measurement frameworks. By consolidating and standardizing the existing indicators according to our classification (i.e., EESG aspects, pillars, value drivers, and impact indicators), the framework provides a unified approach to evaluating the diverse impacts of green buildings. This step closed the gaps in the existing standards and ensured that the integrated impact valuation comprehensively accounts for all relevant economic, environmental, social, and governance impacts.

Another key feature of our proposed framework is the **monetization of impact metrics** using the IROI methodology. This step is critical as it translates both the tangible and intangible benefits of green buildings into quantifiable financial terms. By coupling the appropriate financial proxies to measurable building data in our framework and computing the IROI value, our framework enables stakeholders to understand the impact value generated by green buildings in dollar terms. This process also facilitates more informed decision-making and promotes building investments that align with long-term sustainability goals.

The above-mentioned elements of our framework reinforce the case for **integrating sustainability** into the planning, design, construction, operation, and maintenance of a green building. The framework encourages stakeholders to consider the broader implications of their green buildings, ensuring that buildings contribute positively to the environment, society, and the economy. This integration is crucial for fostering a built environment that contributes to net-zero pathway, enhancing economic resilience, building up natural capital resilience, and creating liveable cities.

Finally, our framework opens the possibilities of **scaling effects through systems thinking**. By applying this holistic approach, the framework not only optimises the impact value at the level of individual buildings but also considers the broader implications across building portfolios and urban planning. The systems-based perspective is essential for driving large-scale changes and maximizing the positive impacts of sustainable building practices across entire communities, cities, and even countries.

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Appendix A – Profile of Selected Standards and Frameworks

BUILDING CERTIFICATION STANDARDS

GM (Green Mark) – Singapore

GM certification standard is a green building rating scheme designed and governed by the Building and Construction Authority (BCA). It was established in 2005 to evaluate the environmental impact and performance of a building with a focus on energy efficiency (MND, 2018). GM certification has since expanded, with the latest iteration GM: 2021 (2nd edition) covering the parameters of Health and Well-being, Whole Life Carbon, Resilience, Maintainability, and Intelligence (BCA, 2023a). GM standard applies to new and existing buildings for residential, non-residential, and other specific purposes (BCA, n.d.-b). GM is used in 16 countries across Asia and Africa (BCA, 2020).

BEAM Plus (Building Environmental Assessment Method Plus) – Hong Kong

BEAM Plus certification standard was developed in 2010 by the Hong Kong Green Building Council (HKGBC) and BEAM Society Limited (BSL) as a voluntary tool to assess the environmental performance of a building (BSL, 2024). The latest BEAM Plus New Buildings Version 2.0 outlines seven performance categories across a building's life cycle: Integrated Design and Construction Management, Sustainable Sites, Materials and Waste, Energy Use, Water Use, Health and Wellbeing, and Innovations and Additions (HKGBC, 2021). It covers various building types, including new and existing buildings, neighbourhoods, interiors, schools, and data centres (BSL, n.d.). BEAM Plus is widely used in Hong Kong and is increasingly gaining traction in mainland China and Macau (GRESB, 2024).

CASBEE (Comprehensive Assessment System for Built Environment Efficiency) – Japan

The Institute for Built Environment and Energy Conservation (IBEC) and Japan Sustainable Building Consortium (JSBC) jointly developed the CASBEE standard in 2001 with an initial focus on evaluating the environmental quality and performance of office buildings (IBECs, 2023). It has since evolved to encompass two major aspects. The first, the *Environmental Quality of Building*, concerns its indoor environment, durability and reliability, and on-site outdoor environment. In contrast, *Environmental Load Reduction of Building* covers a building's energy use, resources and materials use, and impact on off-site environmental quality (IBEC & JSBC, 2014). CASBEE applies to various building types, including new construction, existing buildings, and renovation (JSBC & IBEC, n.d.). The standard for newly constructed buildings was last updated in 2014 (IBEC & JSBC, 2014), with another update in 2021 to align it with the SDGs (IBECs, 2023).

Estidama Pearl Building Rating System – UAE

The Estidama Pearl Building Rating System was introduced by the Abu Dhabi Urban Planning Council in 2010 (Abu Dhabi Urban Planning Council, 2016). Estidama, which means "sustainability' in Arabic, envisions a sustainable way of life in the Arab world and aims to improve the quality of life for residents in four pillars of sustainability: environmental, economic, social, and cultural (DPM, n.d.). It is organized into seven categories fundamental to sustainable development: Integrated Development Process, Natural Systems, Liveable Buildings, Precious Water, Resourceful Energy, Steward Materials, and Innovating Practice. The Pearl Building Rating System applies to all building typologies, their sites and associated facilities, including buildings of various purposes (DMT, n.d.).

BREEAM (Building Research Establishment Environmental Assessment Method) – UK
Established by the Building Research Establishment (BRE) Group in 1990, BREEAM is the world's first sustainability rating scheme for the built environment. The latest BREEAM UK New Construction Version 6.1 was published in 2023 and encompasses aspects such as Management, Health and Wellbeing, Energy, Transport, Water, Waste, Materials, Land Use and Ecology, Pollution, and Innovation (BREEAM, 2023). BREEAM consists of technical standards which apply to the different stages of a building's life cycle, including new construction, refurbishment and fit-out, in-use, and communities (BREEAM, n.d.-a). Increasingly adopted globally, BREEAM is used in more than 75 countries as of 2016, including Germany, Spain, and Singapore (Townsend, 2016).

DGNB (*Deutsche Gesellschaft für Nachhaltiges Bauen*) – Germany
Founded in 2007, DGNB is an independent non-profit association and stands for "German Sustainable Building Council". DGNB certification is a planning and optimization tool for assessing sustainable buildings, interiors and districts. It considers sustainability holistically, accounting for environment, people, and economic efficiency measures. In the latest version published in 2023, the DGNB System Buildings Criteria Set for New Construction encompasses criteria such as environmental quality, economic quality, sociocultural and functional quality, technical quality, process quality and site quality (DGNB, n.d.-a). DGNB certification covers various building types, including new construction, buildings in use, renovation, and districts (DGNB, n.d.-b). DGNB has been adopted in 29 countries, primarily in Europe (DGNB, n.d.-c).

EDGE (Excellence in Design for Greater Efficiencies)
EDGE certification scheme was developed by the International Finance Corporation (IFC) in 2015 (IFC, 2021). By creating a green building certification system for emerging economies, IFC aims to address climate change while simultaneously helping to boost prosperity through the construction of buildings with improved costs (EDGE, n.d.-c). To be EDGE-certified, a project is required to achieve 20% or more savings in energy, water and embodied energy in materials (EDGE, n.d.-b). EDGE is applicable for various building uses and types, including buildings in the concept or design stage, new construction, existing buildings, and renovations. The latest version of the EDGE User Guide was published in 2021 (IFC, 2021). As of 2024, EDGE has certified projects in 103 countries (EDGE, n.d.-a).

LBC (Living Building Challenge) – USA
LBC is a certification program established by the International Living Future Institute (ILFI) in 2006. It defines living buildings as (i) regenerative buildings that connect occupants to light, air, food, nature, and community; (ii) are self-sufficient and remain within the resource limits of their site; and (iii) create a positive impact on the human and natural systems that interact with them. LBC standard covers seven performance categories, also known as "petals": Place, Water, Energy, Health & Happiness, Materials, Equity and Beauty. LBC is applicable for different project scopes and typologies, including new building, renovation, interior, landscape, and infrastructure (ILFI, n.d.). LBC's latest version 4.1 was published in 2024. LBC is currently adopted across North and South America, Europe, Asia, the Middle East, and Oceania (ILFI, n.d.).

LEED (Leadership in Energy and Environmental Design) – USA
LEED is a green building rating system that provides certification for building projects around the world. It provides a framework for healthy, highly efficient, and cost-saving green buildings, which offer environmental, social and governance benefits (USGBC, n.d.-b). For example, the LEED 4.1 Building Development and Construction Scorecard encompasses integrative process, location and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation and regional priority (USGBC, 2024a). LEED covers various building types, including building design and construction, interior design and construction, operations and maintenance, residential, and cities and communities (USGBC, n.d.-c). Adopted across North and South America, Europe, Asia, the Middle East, Africa, and Oceania (USGBC, n.d.-a), LEED is also prevalent in Singapore with more than 250 buildings certified and registered (GBIG, n.d.).

WELL Building Standard – USA
Established by the International WELL Building Institute (IWBI), the WELL certification standard aims to enable building owners and/or building tenants to deliver more thoughtful and intentional spaces that enhance human health and well-being. The latest WELL v2 (Q1-Q2 2024), published in 2024, consists of ten concepts: air, water, nourishment, light, movement, thermal comfort, sound, materials, mind, and community (IWBI, 2024b). WELL v2 is developed for two project groups determined by ownership types: Owner-occupied and WELL Core (IWBI, 2024b). WELL is used in 130 countries across North and South America, Europe, Asia, the Middle East, Africa, and Oceania (IWBI, 2024a; n.d.).

IMPACT MEASUREMENT FRAMEWORKS

GRESB Real Estate Assessment
GRESB Real Estate Assessment is the global standard for ESG benchmarking and reporting for listed property companies, private property funds, developers and investors that invest directly in real estate (GRESB, 2024b). It was introduced by Global Real Estate Sustainability Benchmark (GRESB) in 2009 and most recently updated in

2024. The Assessment evaluates performance against three ESG Components - Management, Performance, and Development. The methodology is consistent across different regions, investment vehicles, and property types, and was adopted in 75 markets as of 2023 (Archer & Langbroek, 2023).

ICMA's *Handbook on Harmonized Framework for Impact Reporting*

The Green Bond Principles (GBP) was introduced by the International Capital Market Association (ICMA) in 2014 to allocate capital to environmentally sustainable projects by fostering the green bond market. Last updated in 2022, the GBP aims to enhance the integrity and transparency of environmental finance, including through recommending impact reporting. The Principles were accompanied by the *Handbook on Harmonized Framework for Impact Reporting*, which outlines the core principles and recommendations for reporting. The Handbook also lists impact reporting metrics and sector-specific guidance for GBP project categories, including green buildings (ICMA, 2024). Green building project types covered in the Handbook are new buildings, retrofitted buildings, and other specific building uses. Under the Green Bond Principles, ICMA has recommended all green bond issuances in the world to adopt, where possible, the guidance and impact reporting templates provided in the Handbook (ICMA, 2022).

WGBC's *Social Impact across the Built Environment* position paper

Issued in December 2023, the World Green Building Council's (WGBC) social impact position paper provides a framework for how the building and construction sector can address social impact throughout the building life cycle. The position paper has threefold purposes: (i) to showcase the diverse range of social impact issues within the sector; (ii) to address the misalignment of social considerations by establishing a centralized framework for the industry; and (iii) to outline initial actions required from all stakeholders across the sector. It outlines a non-exhaustive list of social impact impacts and issues, classifying them into four overarching scopes of i) entity and internal practices; ii) building users and site; iii) community and surroundings; and iv) supply and value chains. (Kawamura & Brady, 2023).

Appendix B – Reviewed Guideline Documents of Selected Standards and Frameworks

Name	Reviewed Guideline Documents	Source
Building certification standards		
GM	• GM:2021 Certification Standard • GM:2021 Energy Efficiency • GM:2021 Carbon Section • GM:2021 Resilience Section • GM:2021 Intelligence Section • GM:2021 Health & Wellbeing Section • GM:2021 Maintainability Section o Framework for New Non-Residential Buildings o Framework for New Residential Buildings o Framework for Existing Non-Residential Buildings	(BCA, 2024b) (BCA, 2024c) (BCA, 2024k) (BCA, 2024j) (BCA, 2024e) (BCA, 2024d) (BCA, 2024i) (BCA, 2024g) (BCA, 2024h) (BCA, 2024f)
BEAM Plus	• New Buildings Version 2.0 (10.2023) • Existing Buildings (Global Version) Version 1.0 (2024.05) • Interiors – Non-Residential Version 2.0 (2023.11) • Interiors – Residential Version 2.0 (2023.11)	(BSL, 2023c) (BSL, 2024b) (BSL, 2023a) (BSL, 2023b)
CASBEE	CASBEE for Buildings (New Construction) (2014 edition)	(IBEC & JSBC, 2014)
Estidama	The Pearl Rating System for *Estidama* Version 1.0 (2010)	(Abu Dhabi Urban Planning Council, 2016)
BREEAM	• BREEAM UK New Construction V6.1 (2023) • BREEAM International New Construction V6 (2021) • BREEAM In-Use International V6 Commercial (2020) • BREEAM In-Use International V6 Residential (2020)	(BREEAM, n.d.-b)
DGNB	• DGNB Criteria Set New Construction Buildings, Version 2023 • DGNB Criteria Set New Construction Buildings, Version 2020 International • DGNB Criteria Set Buildings in Use, Version 2020	(DGNB, n.d.-b)
EDGE	EDGE User Guide for All Building Types (Version 3)	(IFC, 2021)
LBC	Living Building Challenge 4.1 Program Manual (Jul 2024)	(ILFI, 2024)
LEED	• LEED v4.1 Building Design and Construction (Jul 2024) • LEED v4.1 Interior Design and Construction (Jul 2024) • LEED v4.1 Operations and Maintenance (Feb 2024)	(USGBC, 2024a) (USGBC, 2024b) (USGBC, 2024c)
WELL	WELL v2, Q1-Q2 2024	(IWBI, 2024b)
Impact measurement frameworks		
GRESB	2024 Real Estate Standard and Reference Guide	(GRESB, 2024c)
ICMA	*Handbook on Harmonized Framework for Impact Reporting*	(ICMA, 2024)
WGBC	*Social Impact Across the Built Environment* position paper	(Kawamura & Brady, 2023)

Appendix C – Sample Financial Proxies of SGFIN's Framework

Financial Proxies	Unit	Value	Proxy Year	Source
Economic				
Annualized average value of operation cost of green building in Singapore	S$/m^2	130	2020	(Li et al., 2020)
Environmental				
Construction cost of rainwater storage tank [commercial]	S$/m^3	275.52	2018	(Lani et al., 2018)
Cost of installing solar PV system in a residential building	S$/kWp	1,540	n.d.	(NSR, 2014)
Cost of operating and maintaining solar PV system in a residential building	S$/kWp	19	n.d.	(NSR, 2014)
Social				
Healthcare savings from office breastfeeding support	S$/employee /year	598.25	2009	(Slavit et al., 2009)
Monetary value of aesthetics from adjoining vegetation	S$/person /year	2~25	2014	(Wang et al., 2014)
Decrease in sick leave hours taken per person from improved lighting quality	hrs/person/ year	7.24	2011	(Elzeyadi, 2011)
Governance				
Percentage premium of BREEAM construction cost	%	31	2019	(Chegut et al., 2019)
Rental premium of healthy buildings (as proxy of WELL certification)	%/m^2	4.4~7.7	2020	(Sadikin et al., 2021)
Property premium for buildings with high walkability	%	17	2011	(C. Y. Yiu, 2011)