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Keppel Bay Tower: Valuing What a Green Retrofit Delivers

SGFIN-Keppel Case Study

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The Sustainable and Green Finance Institute:
The Sustainable and Green Finance Institute (SGFIN) is a research institute established by the 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 aims to help companies embed sustainability as a key pillar in their business decisions.

Keppel:
Keppel is a global asset manager and operator with strong expertise in sustainability-related solutions across infrastructure, real estate, and connectivity. Headquartered in Singapore, Keppel operates in more than 20 countries worldwide, providing critical infrastructure and services for renewables, clean energy, decarbonisation, sustainable urban renewal and digital connectivity. Its Real Estate Division is an innovative urban space solutions provider that leverages technology to deliver sustainable and customer-centric solutions that enrich people and communities. It is focused on the areas of sustainable urban renewal, senior living, urban living, retail and large-scale integrated developments.

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I. Introduction

Keppel has more than 40 years of experience in real estate development, investment, and fund management across Asia and other markets. Building on this rich experience, **Keppel Real Estate Services** (KRES) was formed to extend Keppel's real estate technology- and sustainability-driven operations to help other asset owners meet both operational requirements and financial objectives. Their services include asset visioning and consultancy for sustainable asset enhancement initiatives, adaptive reuse, project management, net operating income-driven property management and leasing.

Keppel Bay Tower (KBT) at HarbourFront was completed in 2002 and stands as the leading waterfront business hub in Singapore. Being a Grade-A office tower, KBT offers a unique experience beyond a conventional business district, combining unobstructed harbour views with transport connectivity. The 18-storey building features floor plates of up to 37,000 square feet, a core-to-perimeter depth of up to 24 metres, and a raised-floor system that enhances space-planning efficiency.

A comprehensive and carefully curated green retrofit[1] of KBT made history in 2020, making it Singapore's first Building and Construction Authority (BCA) Green Mark Platinum Zero Energy-certified commercial building. The green retrofit delivered measurable improvements.[2] On the energy front, KBT achieved a 30% improvement over its 2017 Green Mark Platinum baseline, reducing its Energy Use Intensity (EUI) from 167 kWh/m^2/year to 115 kWh/m^2/year. The retrofit also avoided ~40,000 tonnes of embodied carbon. Financially, the reduced operating costs, combined with the ability to command higher rental rates, contributed to a >30% increase in net operating income per year.

These outcomes were achieved through extensive asset enhancements and the integration of several advanced and emerging energy-efficient technologies. They include smart LED lighting with daylight autonomy and occupancy-based controls, intelligent workspace solutions featuring user detection and plug load management, an integrated building management system, high-efficiency chillers, and solar photovoltaic panel arrays to offset the building's energy consumption.[3]

Embodying Keppel's sustainability commitments, the green retrofit of KBT served as an example of how sustainable real estate investments may create value beyond operating and rental income. Most traditional financial tools do not account for the outcomes green buildings generate, including lower carbon emissions, better indoor environmental quality, and improved public health. The Sustainable and Green Finance Institute at NUS (SGFIN) has developed the Integrated Return on Investment (IROI) framework to address this gap, providing a systematic approach to measure the integrated value of green buildings.[4] The framework has been applied to several projects in Singapore, including the SDE4

[1] Keppel Ltd. (n.d.). *Keppel Bay Tower*. Keppel Real Estate. Retrieved May 18, 2026, from https://www.keppel.com/realestate/sg/Work/Keppel-Bay-Tower.
[2] Sustainable Urban Renewal Pte. Ltd. (n.d.). *KBT*. Retrieved May 20, 2026, from https://sustainableurbanrenewal.com/our-sur-properties/kbt.
[3] ibid.
[4] Jefferson, Zhang, W., Mueller, A., & Yang, C. (2024). *Integrated Impact Valuation Framework for Green Buildings* (SGFIN Whitepaper Series #4) [White paper]. Sustainable and Green Finance Institute (SGFIN). https://sgfin.nus.edu.sg/sgfin_white_papers_04/.

building in NUS[5], the Dover Campus owned by United World College South East Asia (UWCSEA), and the Jurong East precinct[6].

This case study presents the collaboration between SGFIN and Keppel to apply the IROI framework to KBT's retrofit. The central question we seek to answer is: ***What is the value of KBT's retrofit when evaluated through an integrated valuation lens?***

II. Beyond Utility Bills: The Valuation Issues in Green Buildings

To understand the value creation from a green retrofit, the first challenge is to pin down the causality. Green retrofits are rarely implemented as a single, standalone investment. Instead, they are typically a bundled package of interventions/levers, such as chillers, lighting, controls, landscaping, and engagement programs, which are financed and implemented together. Once in place, the outcomes are measured in aggregated metrics, such as a lower electricity bill or a green building certification. Costs and savings are likewise compounded into capital expenditure (CapEx) and operating expenses (OpEx), making it **hard to isolate the contribution of any single green intervention**.

Similarly, KBT's green retrofit was achieved through multiple measures, including high-efficiency air distribution, cooling tower water management, air intake control, smart lighting, and intelligent controls, supported by renewable energy production. Without a clear framework that tracks these levers systematically, the retrofit reads as an aggregate success. This bundling creates a "black box" problem: developers can see that the package works, but not which interventions deliver the strongest economic returns, the largest environmental gains, or are best to be replicated in other buildings. Effective capital allocation requires granularity; without it, retrofit planning remains under-optimised.

The second challenge is that retrofits may also generate co-benefits or externalities that are not directly captured in the developer's financial returns. Traditional metrics – such as Net Present Value (NPV) and Internal Rate of Return (IRR) – are built around a single stakeholder's cash flows and therefore systematically understate the broader value created by sustainability investments. However, **much of the value generated by sustainability levers does not accrue solely to developers**.

At KBT, energy savings translate into lower operating costs and carbon emissions, but the value of these outcomes is not bound to KRES's financial ledger only. Tenants and occupants may benefit from lower utility bills and improved indoor environmental quality; government from lower system-wide emissions and progress towards national decarbonisation and building-efficiency goals; and the public from avoided emissions and the knowledge sharing of successful models for retrofitting existing buildings that support market transformation.

These co-benefits are evident in the KBT case because its retrofit sits within a broader public-interest transition in Singapore's built environment. The Building and Construction Authority (BCA)

[5] Zhang, W., Cossu, C., & Jefferson. (2026). NUS Green Bonds: Integrated Valuation of SDE4, *IVEY Case Publishing*, Accepted for publication.
[6] Zhang, W., Or, F. X., Zhang, F., & Jefferson. (2025, November 1). Rethinking Value Creation in Building Sustainable and Regenerative Cities. *Urban Solutions,* (27), 82–91. https://isomer-user-content.by.gov.sg/50/4219c964-8255-4fd4-8ffa-c0c2340285f8/Issue27%20-%20Essay_Cross-System%20Relationships_Weina%20Zhang.pdf

reported that the KBT building achieved annual energy savings of over 2.2 million kWh.[7] KBT has also been positioned as an exemplary project under the Green Buildings Innovation Cluster (GBIC) programme, demonstrating how developers can retrofit their existing high-rise commercial assets towards net-zero performance. These achievements carry value beyond the building asset itself: they contribute to sectoral learning, validate emerging green retrofit pathways, and support policy ambitions for greener buildings.

The third challenge lies in the **lack of a standard method to translate intangible outcomes into monetary terms**. These outcomes include better indoor air quality, biodiversity, and improved occupant wellbeing**.** Even when these outcomes are recognised and measured, many of them arrive in forms which stakeholders do not know how to value. Hence, the intangible outcomes are often reported in their own metrics, making it difficult to compare, scale or even communicate clearly to stakeholders.

Taken together, the challenge of bundling effect, co-benefits, and intangible outcomes results in a structural under-estimation of sustainability benefits. The IROI framework addresses these issues by decomposing new built or retrofit interventions into individual green levers and assigning a monetary value to each outcome across different stakeholders.

Overall, the IROI framework answers a question conventional financial metrics cannot fully address: ***For every dollar invested, what is the integrated value created, and who benefits from it?***

III. IROI: A Framework for Seeing the Full Picture

Theory of Change — connecting sustainability levers to outcomes

The IROI framework establishes a direct link between the interventions and the outcome to be achieved. It ascertains the current and desired states of a building, identifying the gaps between them and how the planned interventions could bridge them.

In KBT's case, the Theory of Change mapped out how the retrofit can transform the building from its current state into its desired state of a green building with improved sustainability performance. It draws the direct link between specific interventions and the outputs and outcomes, such as energy savings, emissions reduction, and occupant wellbeing. The mapping allows for a holistic valuation of KBT's retrofit, which provides a comprehensive account of long-term sustainability value creation.

Specifically, we identified four key stakeholders in the built environment affected by the interventions: owners and developers, occupants and tenants, the public and government. Identification of stakeholders is critical to the IROI valuation because the benefits from green buildings do not just benefit the developers but also other stakeholders.

As a result of the levers, our IROI method presented four categories of long-term impacts generated:

(1) stronger economic resilience via lower operating costs and green premiums;

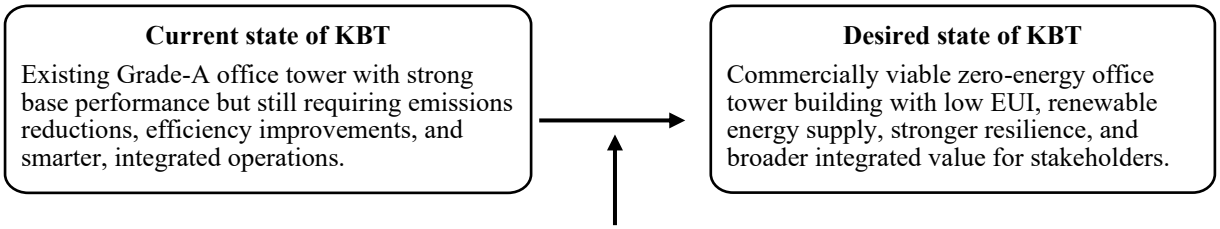
[7] Building and Construction Authority. (2020, December 9). *Keppel Bay Tower certified as Singapore's first Green Mark Platinum Zero Energy commercial building*. Retrieved May 18, 2026, from https://www1.bca.gov.sg/resources/newsroom/keppel-bay-tower-certified-as-singapore-s-first-green-mark-platinum-zero-energy-commercial-building/#_ftn2

(2) greater natural capital resilience through reduced carbon emissions;
(3) building a net-zero pathway through energy-efficient design and retrofit; and
(4) contribution to more liveable cities through better indoor environmental quality, community wellbeing, and urban biodiversity.

Taken together, these value drivers showcase the broader value creation by strategic green interventions beyond the simple measurement of reduced utility bills.

Figure 1 presents the details of the Theory of Change in our IROI framework.

Figure 1. Theory of Change of KBT



Green retrofit interventions in KBT				
Feature	**Description**	**Supporting Evidence**	**Outcomes**	**Stakeholders**
Danfoss-Novenco air distribution system	Implements an innovative air distribution system which consumes less energy than other units in the market.	A 12-month unit test run achieved 46.8% energy savings and 3–17% lower noise level than a pre-retrofitted system.	• Reduced environmental footprint • Improved indoor environmental quality • Lower OpEx	• Keppel • Occupants and tenants • Government • The public
Demand-control fresh air intake system	Uses smart sensor arrays to optimise energy use, while improving indoor thermal comfort and air quality.	A 6-month test run on KBT's level 12 showed 12% energy use reduction from air conditioning.	• Reduced environmental footprint • Better indoor environmental quality • Lower OpEx	• Keppel • Occupants and tenants • Government • The public
Smart building control system	Uses a high-precision model to predict, monitor, and minimise energy consumption.	The model's predicted 10% energy saving after six months closely trailed the actual 7% energy saving.	• Reduced environmental footprint • Lower OpEx	• Keppel • Government • The public
Cooling tower water management system	Deploys an innovative system to minimise water use and avoid chemical treatment.	Average chiller plant system efficiency during the 12-month test run rose by 7%.	• Reduced environmental footprint • Lower OpEx	• Keppel • Government • The public
Smart lighting system	Adjusts lighting levels depending on live building occupancy, reducing energy use.	A 12-month trial run across 270 localised zones on 7 floors on KBT showed 13.4% energy reduction.	• Reduced environmental footprint • Lower OpEx	• Keppel • Government • The public
Solar PV panel arrays	Installed over 400 m^2 of KBT's roof and adjacent podium block to harness solar energy.	The arrays generate ~100,000 kWh of clean energy every year. This is equivalent to 22 4-room HDB flats annually.	• Reduced environmental footprint • Lower OpEx	• Keppel • Government • The public
Green Mark Platinum certification	Implementation of the above features and other measures (e.g., waste reduction and Renewable Energy Certificates / RECs).	For 12 months from March 2021 to February 2022, KBT saved 30.2% of energy compared to pre-retrofit conditions.	• Reduced environmental footprint • Improved indoor environmental quality • Lower OpEx	• Keppel • Government • The public

Logic Model — turning outcomes into measurable indicators

Logic Model is used to further map how inputs and activities of interventions generate outputs, and how outputs lead to short- to medium-term outcomes and eventually long-term impacts. It also provides specific metrics to track, measure, and evidence. The impacts would be consistent with the desired state outlined in the Theory of Change, demonstrating that they can be achieved through the implementation of green interventions.

Developing the Logic Model is critical because the outcomes of sustainability interventions may unfold across different time horizons and stakeholder groups. Some are immediate and measurable, such as electricity and water savings. Others are indirect, delayed, or dependent on better data collection, such as impacts on human health and well-being, behavioural change, and biodiversity. The IROI framework maintains these direct connections before computing the integrated value. By linking the interventions to measurable outputs and outcomes that can be quantified over time and monetised, the Logic Model creates the bridge between building features and investment-relevant analysis.

The SGFIN team developed this model by harmonising 1,141 indicators from existing building certification standards and impact measurement frameworks (e.g., BCA Green Mark, LEED, and WELL) into a structured set of value drivers across the EESG pillars.[8] The harmonisation is especially crucial in the built environment, where performance assessments are often fragmented within or across different standards. By building these standards and frameworks into a harmonised framework, the SGFIN team established a common analytical language. Note that the framework does not eliminate the differences across standards but uses them to build a coherent, decision-useful valuation model.

We applied the IROI framework to the KBT case using the operational and performance data provided by KRES, monetising a subset of outcomes that are financially material. Our computational results also revealed the data gaps that can be improved in the future. Our results are presented in the next section.

IV. Keppel Bay Tower: The Retrofit Up Close

Through the retrofit, Keppel sought to reposition KBT as a flagship of its long-term sustainability strategy rather than treating sustainability as a peripheral feature of the building. As both KBT's landlord and major corporate tenant, Keppel has a direct stake in reducing KBT's carbon footprint and operating it as a high-performance asset aligned with a net-zero trajectory. The retrofit also served as a measure to protect asset value, where green-certified, high-performance buildings in the market would command measurable rental premiums and attract more first-class tenants. As such, KBT's enhancement was framed as part of its Sustainable Urban Renewal initiative and supported by BCA's Green Buildings Innovation Cluster (GBIC) programme. Energy-efficiency measures and services upgrades could also lead to long-term efficiency gains, lower operating costs, and stronger appeals to tenants. Together, these considerations reinforce the view that delaying retrofit could expose the asset to competitive, occupancy, and valuation risks in a market increasingly attentive to green performance.

[8] Jefferson, Zhang, Mueller, & Yang (2024).

The retrofit package

The green retrofit of KBT took two years to complete in a few phases. Certified Green Mark Platinum Zero Energy after the retrofit, KBT's green retrofit features can be classified into two categories: the energy levers and the amenities.

The first category comprises six energy levers that form the interventions and cost roughly S$1.5M:

- First, the **smart lighting system** replaced conventional fixed-output fixtures with a sensor-integrated network which adjusts lighting levels in response to occupancy and ambient daylight conditions. Such an intelligent system reduces unnecessary energy use across different zones.
- Second, the Air Handling Unit (**AHU**) **fan system** as part of the Heating, Ventilation, and Air Conditioning (HVAC) system improved air distribution efficiency through high-performance axial flow fans, high-efficiency IE6-class motors, and frequency-regulated variable speed drives. This combination of technology dynamically matches air output to actual operational demand.
- Third, the **cooling tower water management system** introduced an electrochemical process which removes scale deposits, strips dissolved oxygen, and disinfects cooling tower water without chemical dosing, improving system performance while reducing maintenance-related inefficiencies.
- Fourth, the **air-conditioning fresh air intake control system** deployed a multi-sensor network to model indoor activity levels and dynamically regulate air intake. This innovation helps to maintain occupant comfort while eliminating the energy penalty associated with over- and under-ventilation.
- Fifth, the **Intelligent Building Control System** functions as KBT's optimisation layer, integrating real-time operational data, digital twin modelling, predictive scheduling, and automated fault correction to improve overall system performance.
- Finally, Keppel installed **solar photovoltaic (PV) panels** on 400 m^2 of KBT's roof and adjacent podium block, which produce ~100,000 kWh of clean energy annually.

Beyond the energy levers, the retrofit revitalised existing amenities and introduced new services that contribute to intangible benefits that KBT provides. Level 1's main lobby and arrival area underwent architectural enhancements, including a redesigned reception counter, ceiling, new stone and timber finishes, and integrated digital wayfinding. Lift lobbies across Level 1, the podium, and tower floors were also refurbished with upgraded wall, floor, and ceiling finishes. In addition, selected office floors received a complete interior retrofit, while Level 1, the podium, and toilets received new sanitary fittings, tiling, and finishes. Rounding them up were bespoke architectural lighting in lobbies and common areas, as well as the makeover of the lower-level corridor into an activated space with bold tenant branding and curated retail and food-and-beverage offerings. Together, these upgrades enhanced KBT's spatial quality, appearance, and user experience in ways that are not easily captured through conventional financial metrics, but which nonetheless form part of the broader integrated value created by the retrofit.

With the scope of KBT's retrofit established, the insights of its integrated valuation are fourfold.

Insight #1 — Electricity levers are doing the heavy lifting

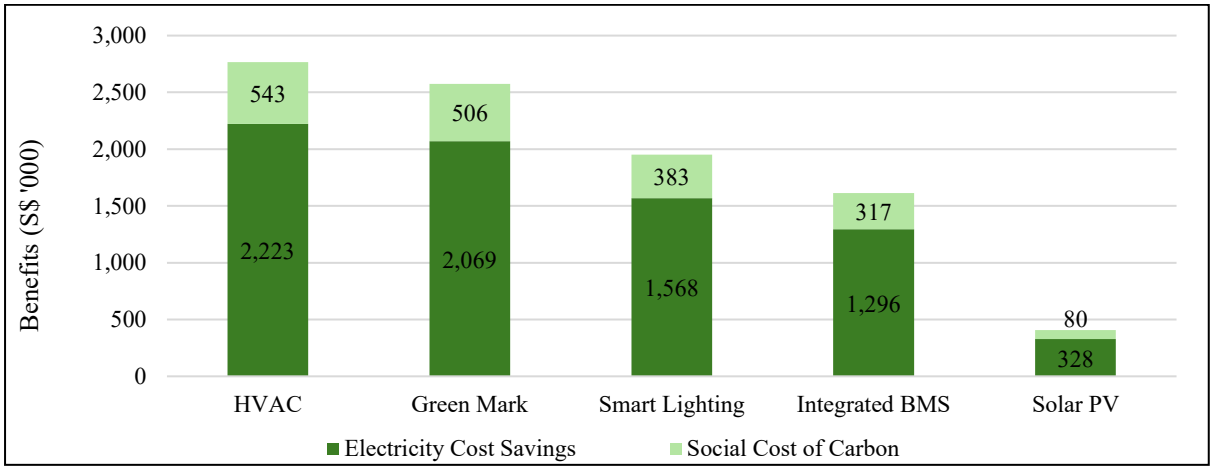
The decomposition of KBT's retrofit features revealed a clear concentration of value in electricity-related interventions. The HVAC system, smart lighting, and BMS together account for most measurable benefits, reflecting their direct impact on reducing energy consumption and improving operational efficiency.

In present value terms over a period of 20 years, electricity cost savings from these interventions amount to approximately **S$7.5 million (S$179/m^2)**. The HVAC system alone contributes over **S$2.2 million (S$52.50/m^2)**, with smart lighting and BMS each generating more than **S$1 million** in electricity bill savings. As illustrated in Error! Reference source not found., the distribution of benefits is heavily concentrated in HVAC and Green Mark certification-related outcomes, which together account for more than 50% of the integrated benefits. On the other hand, solar PV systems contribute the least share. These results confirmed that operational efficiency is the primary driver of financial returns in this context.

In addition to cost savings, reduced electricity usage lowers the operational carbon emissions. When valued using the social cost of carbon, these avoided emissions contribute an additional **S$1.8 million (S$43/m^2)** in integrated value. The social cost of carbon contributes to a sizable share of the integrated value created, but electricity cost savings still generate the highest value.

This insight is significant because it grounds the sustainability discussion in operational reality. In KBT's case, the retrofit creates value primarily through core levers embedded in the building's day-to-day operations, which reduce electricity consumption. For existing commercial assets, the pathway towards integrated value may therefore begin with the fundamentals of energy performance, the core levers that shape a building's day-to-day electricity demand.

Figure 2. Present Value of Benefits by Interventions



Insight #2 — IROI turns an opaque retrofit into a line-item view

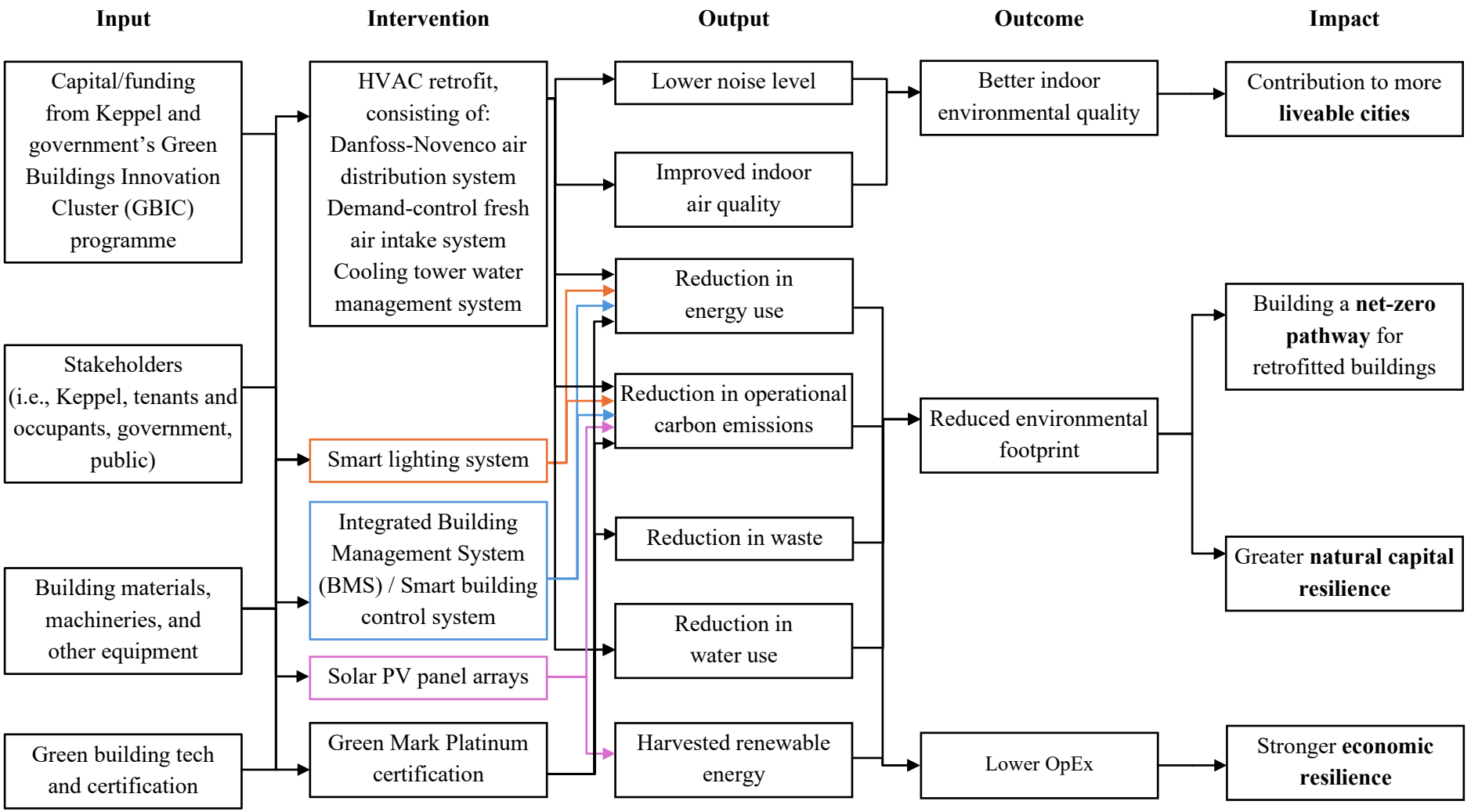
One of the most immediate contributions of the IROI framework is not the production of a single summary metric, but a transformation in visibility. Each retrofit intervention can now be evaluated individually, with its investments, costs, and benefits clearly identified.

Before this analysis, the performance of green retrofit was usually observed at an aggregate level, such as through reductions in overall utility costs. The IROI framework assigns a value chain to each lever, enabling Keppel to assess the levers as a portfolio of distinct sustainability interventions. This shift also helps Keppel better understand which interventions implemented at KBT are driving most of the integrated value and how that value is distributed among the building's stakeholders. In doing so, the

IROI framework supports a more targeted capital allocation and a more systematic approach to future retrofit decisions.

The Logic Model for KBT's green retrofit in **Figure 3** was adapted from the Theory of Change in **Figure 1**. The levers/interventions were rearranged according to the IROI framework's nomenclature for the integrated valuation.

Figure 3. Logic Model of KBT



Insight #3 — Integrated value is larger and more broadly shared

While the financial implication of the retrofit is already strong based on operational savings alone, the inclusion of environmental externalities in the form of the reduced social cost of carbon significantly increases the total value created. Error! Reference source not found. shows that the total integrated value of financial and environmental benefits reaches approximately **S$9.3 million (S$223/m^2).** This value translates into a net integrated value of more than **S$7.4 million (S$178/m^2)** after accounting for retrofit costs. This represents an IROI of **4.83X**. This means that $1 of investment generated a total return of $4.83 for the developer.

Figure 2. Summary of KBT's valuation line items

Line Item	Present Value (S$)	Present Value (S$/m^2)
Electricity cost savings	7,484,595	179
Social cost of carbon (Reduction)	1,829,637	44
Integrated Benefits	**9,314,232**	**223**
OpEx	(1,902,604)	(45)
Net Integrated Benefits (= Integrated Benefits – OpEx)	**7,411,628**	**178**
CapEx	(1,533,739)	(37)
IROI (= Net Integrated Benefits / CapEx)	**4.83X**	

Compared with a conventional financial assessment, the inclusion of environmental value significantly increases the integrated returns generated by the retrofit. It also showed the importance of accounting for externalities in valuation. The result is conceptually crucial because it shows that traditional investment analysis captures only a portion of what the green retrofit delivers. Once environmental outcomes are translated into monetary terms, the investment case becomes materially stronger.

Importantly, a major portion of this value accrues outside of the developer's financial accounts. Of the total integrated value created, approximately $115/m^2 is captured by the developer through grant funding and operational electricity savings. Meanwhile, $44/m^2 accrues to the public through avoided social cost of carbon, and $18/m^2 flows to tenants through lower electricity bills. The government effectively bears a cost of $9/m^2 through the forgone carbon tax revenue associated with lower carbon emissions. The retrofit, therefore, creates a set of holistic values enjoyed not only by developers but also by other stakeholders. This insight also helps explain why green investments may be systematically undervalued by building users if the green assessment is only performed by developers.

The KBT example makes visible a trend in the broader sustainable real estate. Financial returns and integrated returns are not necessarily equivalent. A project may generate substantial value, and a meaningful share of that value may accrue to other stakeholders. Integrated valuation does not eliminate this distributional gap but makes it visible. In doing so, it carries crucial implications for public awareness, providing the right incentives, funding design, and institutional investment frameworks aimed at accelerating sustainable retrofits.

Insight #4 — Where the frontier lies

Not all aspects of KBT's retrofit are fully captured in the current integrated valuation framework. Interventions related to tenant engagement and other green initiatives were not monetised due to data constraints, rather than a lack of meaningful impact. These performance improvements require more granular measurement – such as detailed sensor-based operational data and tenant experience surveys – which are not yet available. Nevertheless, the IROI framework is designed to incorporate these additional layers once data availability and measurement capabilities improve over time.

Therefore, the net integrated benefit quantified in this study should be viewed as a conservative estimate. The full integrated value of KBT's green retrofit is likely higher, suggesting that the true returns on green investments may be understated under current measurement practices. This limitation does not reflect a weakness of the IROI framework, but rather the current reality of data measurements and collection. Certain sustainability outcomes are easier to quantify because they are already tracked through operational systems. Others depend on richer and more complex forms of evidence, including behavioural data, occupancy feedback, or ecological monitoring.

Therefore, the KBT case marks both an achievement and a frontier for integrated valuation. It demonstrates what can be measured and monetised today, while highlighting where improved data collection and monitoring systems could expand the scope of integrated value assessment in the future.

V. From One Building to An Industry-wide Tool

The KBT case demonstrates that sustainability investments can generate substantial value when evaluated comprehensively and therefore carries relevance beyond KBT itself. The insights suggested that a main barrier to scaling sustainable real estate investment is not simply the absence of impact, but the absence of frameworks capable of recognising, organising, and quantifying that value. If building owners, investors, and policymakers are to make informed decisions, they need suitable tools that can capture sustainability outcomes across stakeholders. Our IROI method is one such tool.

For developers, the IROI framework provides a more granular understanding of which interventions deliver the greatest impact, enabling more targeted capital allocation and more strategic planning. **For investors**, the framework offers a consistent way to compare the sustainability performance and trade-offs of different interventions using a common valuation lens. **For policymakers**, the gap identified between financial and integrated returns underscores the role of policy in aligning private incentives with public benefits. The KBT case provided a quantitative basis and an early demonstration of this dynamic, revealing visible and significant externalities.

Moving forward, we expect continuous expansion of sustainability-related data collection to capture more value from sustainability interventions. As data coverage and quality improve, the IROI framework can be evolved into a more standardised and scalable tool for evaluating sustainable real estate investments. In this respect, the KBT case serves not only as an assessment of a single retrofit project, but also as an illustration of how integrated valuation may support the broader transition towards a sustainable built environment.