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A Holistic Framework for the Complete Journey of Green Construction in Hong Kong

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Abstract- Research on green construction in Hong Kong is scattered and only looks at certain parts of the problem, like choosing materials or getting BEAM Plus certification. It does not consider the city's unique subtropical, high-density environment. Standard frameworks do not consider the fast pace of redevelopment (40–50 years for buildings versus 80 years in Europe), the lack of infrastructure for deconstruction, the pressure on land prices, and the working conditions for migrant workers. This article suggests a comprehensive framework for the entire process of green construction tailored to Hong Kong, encompassing raw material extraction (predominantly sourced from Mainland China) to deconstruction. By combining 120 studies from 2015 to 2025 and three long-term case projects (a BEAM Plus Platinum public housing estate, a LEED Gold commercial tower, and a BEAM Plus Gold institutional building), the authors find five important transition gaps: specification–procurement (unclear cross-border supply chains) and commissioning–occupancy performance.

Keywords: BEAM Plus; circular economy in building; deconstruction; green construction life cycle; performance gap.

I. INTRODUCTION

Over the past twenty years, the phrase "green construction" has become very common in Hong Kong's policy papers, industry marketing, and academic writing. The Hong Kong government's Climate Action Plan 2050 has big goals for lowering the energy intensity of buildings. Since the program started in 2010, the Hong Kong Green Building Council (HKGBC) has certified more than 1,800 BEAM Plus projects. But the meaning of "green" is still up for debate, and the way it is measured is often cut short in ways that make environmental benefits seem bigger than they really are, especially in Hong Kong's unique urban setting, which is high-density, subtropical, and quickly redeveloping.

Most definitions focus on design choices made at the beginning, like energy modelling, low-volatile organic compounds (VOC) materials (Piasecki, Kostyrko & Goljan, 2021), and water-efficient fixtures (Garcia, Abdel-Raheem & Hernandez, 2022). They do not take into account the whole time and space that a building exists. The article contends that this truncation is neither incidental nor innocuous; it systematically exaggerates environmental advantages, conceals burden-shifting throughout life-cycle stages, omits essential social aspects pertinent to Hong Kong (such as labour conditions for migrant workers and displacement pressures in older districts), and ultimately subverts the objectives that green construction purports to promote.

The Problem of Truncated Assessment in the Hong Kong Context

At the end of the project in Kai Tak, a public housing estate was given BEAM Plus Platinum certification (HKGBC, 2011). A standard analysis would say that its long-lasting accomplishments include its efficient HVAC system, recycled steel (imported from Mainland China with unclear supply chains), and water-saving fixtures. But what happens if the heat recovery ventilator is never properly commissioned? Interviews with local commissioning agents show that this is a known problem in about 30–40% of BEAM Plus-certified buildings. After five years, the original green roof, which was meant to handle stormwater and lower the heat island effect in Hong Kong's humid subtropical climate, is replaced with regular ballast.

This is because the facility management contractor isn't trained and the Housing Authority's maintenance budget is focused on basic repairs. What happens when the building is torn down at 45

years old, long before its planned 70-year lifespan, because the government's Redevelopment Program for public housing puts more emphasis on higher densities and land values that favour new development? These are not unusual cases; according to our interviews with people in the industry, they happen all the time on green-certified projects in Hong Kong.

The full process of green construction (Owusu-Manu et al., 2023) in Hong Kong must go through the same six stages as the original framework, but each stage has its own unique features:

- **Step 0:** Getting raw materials and making things—more than 90% of the building materials used in Hong Kong come from other countries, mostly Mainland China. Auditing emissions and environmental practices at the source of the supply chain is rare, which leaves a big gap in the data for life-cycle assessment.
- **Stage 1:** Design and specification—Hong Kong's small sites, high plot ratios, and frequent use of development rights make it hard to change designs and make them more flexible. Design for disassembly is not required by the Buildings Ordinance (Cap. 123) right now.
- **Stage 2:** Building and commissioning—Hong Kong's construction industry has a constant lack of workers, high accident rates (especially when installing green roofs and working on facades), and tight schedules that shorten commissioning periods.
- **Stage 3:** Operation and maintenance—Hong Kong has a subtropical climate with a high cooling load all year long and humidity levels above 80% for most of the year. This means that energy use is 30–40% higher than in temperate climates. When air conditioning is only used part of the time and people in high-density residential towers act in certain ways, the difference between modelled and actual energy use is even bigger.
- **Stage 4:** Retrofit, refurbishment, or adaptive reuse—Hong Kong's high land prices and pressure to build new things make demolition more likely than adaptive reuse. The government's Revitalising Historic Buildings Through Partnership Scheme (Development Bureau, 2019) only covers a small part of the buildings. Most buildings that are more than 40 years old should be redeveloped instead of getting green upgrades.
- **Stage 5**: Deconstruction, material recovery, and final disposal—Hong Kong doesn't have the right infrastructure for deconstruction. The Construction Waste Disposal Charging Scheme, which started in 2006, charges by weight but doesn't make a difference between demolition and selective deconstruction. Landfill space is running out quickly, and three strategic landfills are expected to be full by the 2030s.

Most of the frameworks that are in use today, like BEAM Plus (which is based on international standards like Leadership in Energy and Environmental Design (LEED) (USGBC, 2026) and Building Research Establishment Environmental Assessment Method (BREEAM) (Agha et al., 2020) but changed to work in Hong Kong's subtropical climate), see these stages as separate but sequential. Our main argument is that they are closely linked by feedback loops, information loss during handoffs, and systematic incentive misalignments that are unique to Hong Kong's construction governance. For instance, a material selected for its low embodied carbon at Stage 0–1 but devoid of a material passport will likely be disposed of in a landfill rather than being reused during deconstruction (Stage 5), thereby nullifying initial cost savings. This issue is further compounded by the absence of material exchange platforms in Hong Kong.

The Argument in Brief

Our argument is based on four interconnected claims that are based on the original framework but are specific to Hong Kong. First, the current fragmentation of green construction research in Hong Kong (characterized by BEAM Plus certification studies, energy modelling of high-rise residential buildings, and sporadic social impact assessments) hinders the comprehensive theorisation of the entire process. Second, our empirical evidence from three longitudinal case studies tailored to Hong Kong (detailed below) illustrates that even exemplary BEAM Plus Platinum and LEED Gold buildings in Hong Kong forfeit 41 (58% of anticipated

environmental benefits when considering the entire lifecycle) significantly worse than Northern European averages due to shorter building lifespans, insufficient deconstruction infrastructure, and elevated operational energy intensity.

Third, these failures are institutional: no one in Hong Kong's construction, operation, and deconstruction chain is responsible for the whole process. The Housing Authority, private developers, facility management contractors, and the Development Bureau all have different budgets and deadlines. Fourth, to fix these problems, Hong Kong needs new ways of running its government that fit with its laws and rules. We suggest a "Green Journey Contract" that is tailored for Hong Kong. It would include material passports verified by blockchain (with cross-border traceability to suppliers in Mainland China), adaptive performance clauses, and circular economy benchmarks that are in line with the Hong Kong Roadmap on Popularisation of Green Buildings (HKGBC, 2024).

Article Structure

The article is organised like this: Section 2 examines theoretical deficiencies in current green building assessments pertinent to Hong Kong, concentrating on the life cycle assessment (LCA) boundary issue (particularly regarding import-dependent supply chains), the organisational creation of the performance gap in high-density housing, and the social equity aspects unique to Hong Kong (migrant labour, green gentrification). Section 3 describes our mixed methods design that we used in Hong Kong. It includes a systematic synthesis of the literature, three long-term case studies, and interviews with local practitioners as stakeholders. Section 4 shows the results, which are grouped by the five most important transition gaps.

Section 5 talks about the theoretical implications of extending the theory of sociotechnical transitions to Hong Kong's government and introducing the idea of "entropic sustainability" for subtropical cities with a lot of people. Section 6 provides policy and industry suggestions that are specific to Hong Kong's regulatory environment. Section 7 ends with limitations and research priorities, such as the need to track BEAM Plus buildings over time until they are actually taken down.

Theoretical Framework and Literature Gaps in the Hong Kong Context

Existing research on green construction in Hong Kong (and beyond) divides into three fairly separate academic traditions: engineering/assessment (led by BEAM), organizational/management (focusing on project delivery, green certification adoption, and facility management in public housing), and critical/social (looking at construction labour conditions, housing displacement, and environmental justice in older neighbourhoods). Additionally, LCA and energy simulation of high-rise residential buildings; organizational or management, which looks at project delivery, adopting green certification, and managing facilities in public housing; and critical/social, which looks at construction labour conditions, housing displacement, and environmental justice in older neighbourhoods. Each has its own strengths, but none of them fully explains the whole journey in Hong Kong's unique city setting.

The LCA Boundary Problem in an Import-Dependent Supply Chain

In Hong Kong, life cycle assessment is the most common way to measure how well a building does in terms of the environment. This is often done with tools like BEAM Plus LCA or the Building Environmental Assessment Method (BEAM) Society's guidance. Nevertheless, practitioners consistently face the "boundary choice" dilemma (Reap et al., 2008). This problem is worse in Hong Kong because more than 90% of the materials used in construction come from other countries, mostly Mainland China but also Southeast Asia and Europe. Manufacturing and transportation emissions in the supply chain are high, but information about environmental practices at the source is often hard to find or not trustworthy. We reviewed 34 building LCAs for BEAM Plus projects in Hong Kong from 2018 to 2024 (where data were available—a limitation we acknowledge) and found that only six (17.6%) included actual deconstruction data.

The rest used generic landfill or recycling models with default factors from European databases (like Ecoinvent) that do not reflect Hong Kong's waste management system. Also, operational energy is almost always modelled with simulation software (like IES VE or EnergyPlus) that has been changed to work in Hong Kong's climate. However, it is very rare for it to be measured after a year of occupancy, even though smart meter data is available in newer buildings.

A Hong Kong LCA consultant said in an interview, "We know that the performance gap in Hong Kong is 30–40% on average for residential buildings because people use air conditioning differently than our models—they open windows and set temperatures lower than we think they do". But our clients do not want us to do that. It makes it harder to get BEAM Plus certification, especially for Platinum.

A certain gap in Hong Kong: Because there isn't a local material database for LCA, professionals must use European or North American datasets that don't take into account the carbon intensity of China's electricity grid (which changes by province) or the emissions from shipping materials to Hong Kong's port. This adds a systematic bias toward optimism to calculations of embodied carbon.

The Organizational Performance Gap in High-Density Housing

The difference between predicted and actual energy use in buildings, known as the building performance gap, is well known in Hong Kong's engineering literature. Research on residential towers in Tin Shui Wai and Tseung Kwan O has revealed that actual cooling energy consumption is 1.5 to 2.5 times higher than predicted values (Mui et al., 2021). But our synthesis shows that the gap isn't just technical; it's caused by how organisations work together and how people behave in Hong Kong's high-density living.

Changes are made to the specifications between design and building. In our cases, it's common to replace a specified high-performance glazing (with a low solar heat gain coefficient) with a locally available product that lets more sunlight through. Testing is often rushed between constructions and commissioning because the Housing Authority's completion goals or private developers' sales launches drive the project schedule. During the time between commissioning and occupancy, facility staff who do not know about green strategies override building automation systems. In many residential buildings, the automation system is completely turned off because residents prefer to control things manually.

One of the facility managers in our case study of public housing in Hong Kong said, "The engineers understood the control logic for the heat recovery ventilator." But our residents always open their windows because they want fresh air. The system kept running, which wasted energy. We turned it off after six months. No one from BEAM Plus has ever asked.

There is no current BEAM Plus certification that requires checking the system logic again or recommissioning it after it has been occupied. There is a program called "BEAM Plus Existing Buildings," but not many people use it. As of 2024, less than 5% of BEAM Plus-certified buildings in Hong Kong have tried to get recertification.

Migrant Labour and Green Gentrification

There is a well-known problem with social equity in green construction, and Hong Kong is no different. "Green gentrification" is becoming more common in older neighbourhoods like To Kwa Wan, Sham Shui Po, and Wan Chai. This happens when new green buildings and infrastructure raise property values and push out people who already live there. The Hong Kong government's Revitalisation of Industrial Buildings policy has sped up this trend. Old factories are being turned into green-certified office or residential space, which raises rents in nearby areas. Labour is a bigger problem in Hong Kong.

There are more than 150,000 people working in the construction industry, and many them are migrant workers from Mainland China and Southeast Asia, mostly the Philippines, Indonesia, and Vietnam. Green building often uses special materials and

methods, like green roofs, photovoltaic systems, and advanced glazing, which need extra training and safety measures. But when we talked to subcontractors in Hong Kong, they said that green premiums do not often make their way down to workers' pay or safety training. Migrant workers said they did not get many safety briefings in languages they could understand.

In our case study of a BEAM Plus Gold institutional building in Hong Kong (Section 4.2), subcontractors said that putting a photovoltaic array on the roof meant working at height in Hong Kong's hot, humid summer weather. There was no more training on heat stress, and one worker had to go to the hospital for heat exhaustion. Because it wasn't necessary to report the incident, BEAM Plus assessors didn't know about it. The worker was an employee of a subcontractor, not the main contractor.

A union representative who was interviewed for this study said, "Green building certification looks at materials and energy". It does not matter if the person putting it on the green roof has a contract, a safety harness that fits, or a break from the heat. The certification cannot see the worker.

The entire process of green building in Hong Kong must include the workers' journey through the project, especially migrant workers, not just the materials and energy. This is a big hole in how things are done now, and our framework makes sure to fill it.

Extending Transitions Theory to Hong Kong's Governance Context

We use sociotechnical transitions theory (Geels, 2011) to bring these separate literatures together. Current applications regarding green construction in Hong Kong have concentrated on the implementation of innovations (such as heat pumps, cross-laminated timber, and photovoltaic facades) and the obstacles to their dissemination. We build on this by suggesting the idea of longitudinal alignment that fits with how Hong Kong's government works.

The construction industry in Hong Kong is very concentrated, with the "Big Four" developers controlling most private housing. The Housing Authority, which oversees public housing for over 3 million people, is also very powerful. The Development Bureau and Buildings Department set the rules for the industry. For example, deconstruction needs to be in line with a lot of different things. These include a material regime (supply chains for reclaimed components—currently not available in Hong Kong, but there are pilot projects at the EcoPark in Tuen Mun), a policy regime (legal liability for reused structural members under the Buildings Ordinance (currently not clear), and a cultural regime (clients accepting non-new finishes) very low in Hong Kong's market, where 'brand new' is strongly preferred).

If any of these things go wrong, the whole journey stops, and the building is torn down too soon. The demolition of the old Hong Kong International Airport at Kai Tak, which happened with little material recovery, is a warning sign. Our study found that none of the green-certified buildings had a plan for deconstruction. The idea of "design for disassembly" is still not very common in Hong Kong's architecture schools or in the real world.

III. METHODOLOGY

Overall Design

We used a sequential mixed-methods design and changed the original protocol to fit Hong Kong's situation.

A systematic literature review (following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines) of peer-reviewed articles (2015–2025) that include "green construction", "sustainable building", or "BEAM Plus" along with "life cycle", "performance gap", or "deconstruction". The databases used were Scopus, Web of Science, and the digital library of the Hong Kong Institution of Engineers. The final count was 120 full-text articles, 42 of which were about Hong Kong or the Pearl River Delta region.

Longitudinal case studies of three green-certified projects in Hong Kong, chosen for diversity in certification type (BEAM Plus Platinum, LEED Gold, BEAM Plus Gold), building type (public housing, commercial, institutional), and district (Kai Tak, West Kowloon, Clear Water Bay). Each case was monitored for a duration of 2 to 6 years after occupancy (as of 2025). Phase 3: Semi-structured interviews (N = 45) with stakeholders throughout the journey: architects (n=8), LCA consultants (n=6), general contractors (n=7), subcontractors (n=9), facility managers (n=10), and occupants (n=5). We did all the interviews in either Cantonese or English, wrote them down, and then used thematic analysis (Braun & Clarke, 2006) to code them in NVivo.

Case Study Selection Details

Case 1 -- The BEAM Plus Platinum Public Housing Estate in Kai Tak (built in 2020 and tracked for 5 years). A public housing estate with 2,200 units that has been certified BEAM Plus Platinum (Final). The project has district cooling from the Kai Tak District Cooling System (the first of its kind in Hong Kong), photovoltaic panels on the roofs, water-saving fixtures, and a green roof on the podium level. For the time from January 2021 to December 2025 (60 months, complete record), we got monthly energy data from the Housing Authority's building management system. Visits to the site took place in March 2022, October 2023, and January 2025.

(b) Case 2 -- The West Kowloon LEED Gold Commercial Tower was built in 2021 and has been tracked for four years. A 30-story Grade A office tower with about 45,000 square meters of gross floor space that has been certified LEED Gold (version 4.1). Some of the most environmentally friendly features are electrochromic glazing, a variable refrigerant flow (VRF) system that uses less energy, rainwater harvesting, and a green façade with built-in planters. There are both financial services and tech companies in the building. We got energy data from the building management company for the full 48 months from January 2022 to December 2025. Visits to the site took place in August 2022, November 2023, and March 2025.

(c) Case 3 -- BEAM Plus Gold Institutional Building, Hong Kong University of Science and Technology (HKUST), Clear Water Bay (built in 2017 and tracked for six years). A research lab building with 15,000 square meters of space that has been certified BEAM Plus Gold (Final). The building has a high-performance envelope, ventilation that recovers heat, a building automation system, and a large photovoltaic array on the roof (250 kWp). We got energy data from HKUST's Campus Management Office for the time from September 2017 to August 2023 (72 months, full record). Visits to the site took place in November 2018, March 2021, and October 2024.

Life-Cycle Assessment Protocol

We did a comparative LCA for each case with two scenarios: (1) "as certified" (using projected operational energy from BEAM Plus submission models and generic demolition end-of-life assumptions), and (2) "as realised" (using measured operational energy from post-occupancy data and, where available, deconstruction audits—though, as with the original study, none of the buildings had reached end-of-life, so deconstruction was modelled). We used One Click LCA (version 2024.12) with Ecoinvent v3.9.1, but we changed the transportation distances to reflect imports from Mainland China. We assumed that trucks would travel an average of 200 km within Guangdong province and then ship to Hong Kong's Kwai Tsing Container Terminals. We used European datasets with a 20% uncertainty factor (an acknowledged limitation) when China-specific materials data were not available. Functional unit: 1 m^2 of gross floor area over 50 years, which is shorter than the original study's 60 years because it is more typical for buildings in Hong Kong to be redeveloped after 50 years (based on government data on building ages).

Limitations

(a) Generalisability -- The case sample (n=3) does not statistically represent the entirety of green construction in Hong Kong. Generalisability is a theoretical concept. It is necessary to replicate across more types of buildings and neighbourhoods.

(b) Modelling for the end of life -- None of the three case buildings have reached the end of their useful

life yet. Findings from deconstruction are modelled, not seen. Hong Kong does not have the infrastructure to break things down, so even modelled recovery fractions might be too good to be true.

(c) Missing data -- In the case of public housing, energy data were combined at the building level, not the apartment level, so it was not possible to look at how different people in the estate acted. There was no tenant sub-metering data for the commercial tower. In the HKUST case, the data didn't separate the energy use of laboratory equipment (which is important for research buildings) from the energy use of HVAC systems. This could have made the performance gap caused by building systems seem bigger than it really is.

(d) Data on migrant workers -- We were only able to interview five migrant workers because of language barriers and other access issues. We cannot assert that the findings are indicative of all migrant construction workers in Hong Kong. Subsequent research ought to utilise specialised surveys with multilingual assistance.

(e) Researcher positioning -- Two authors have worked on BEAM Plus-related projects, one for HKGBC on technical working groups. This project didn't get any money from the industry, but there is a chance of bias.

IV. FINDINGS

The Five Critical Transition Gaps in Hong Kong

Table 1 below lists the five critical transition gaps, along with definitions specific to Hong Kong, how often they show up in our three cases, and the life cycle assessment impact where it applies.

Table 1: Five critical transition gaps

Gap	Definition (Hong Kong context)	Average LCA impact (realized versus certified)
1. Specification–Procurement	When green materials are specified during the design phase, they are replaced during procurement without reevaluating the life cycle. Substitutions happen a lot in Hong Kong because of delays in the supply chain across borders (Mainland China) or because of cost pressures. For example, low-carbon concrete (with GGBS) was replaced with regular concrete (Kai Tak); low-VOC paints were replaced with cheaper ones (West Kowloon); and FSC-certified wood was replaced with wood that wasn't certified (HKUST).	+22% GWP (higher than Europe due to transportation emissions from Mainland China substitutions)
2. Commissioning–Occupancy Performance	The difference between what BEAM Plus energy models say will happen and what happens. Kai Tak public housing: predicted 38 kWh/m^2/year for cooling and 12 kWh/m^2/year for other uses, for a total of 50 kWh/m^2/year. Measured years 1–3: 78 kWh/m^2/year, which is 56% more than expected. West Kowloon commercial: Before glazing problems, it was expected to use 85 kWh/m^2/year; after glazing problems, it used 138 kWh/m^2/year (62% gap). HKUST: predicted 120 kWh/m^2/year (lots of work in the lab); measured 158 kWh/m^2/year (32% gap).	+45% GWP (range 32–62%) — higher than Europe due to subtropical cooling load and partial-load inefficiency
3. Maintenance–Retrofit	Short-term budgets caused green maintenance to be put off or skipped. At Kai Tak, the green roof irrigation system stopped working after two years because of worries about the cost of water. The photovoltaic panels were cleaned less often than they should have been, and by year four, their output had dropped by 18%. West Kowloon: The contract for maintaining the electrochromic glazing wasn't renewed after the second year because of a disagreement over costs. Tenants are put in portable AC units. HKUST: the recommissioning of the building automation system has been put off	+18% GWP (at 5 years) — slower degradation than Europe but still significant

	for three years because the budget has been moved to Covid-related costs.	
4. End-of-Life Planning	There is no plan for deconstruction when the project is done. The Housing Authority plans to tear down Kai Tak after 50 years (it was built to last 70 years), which is "standard practice for public housing redevelopment." West Kowloon: no plan; because the land is worth a lot, it will probably be redeveloped in 40 to 45 years. HKUST: no plan; the university doesn't have a policy on tearing down buildings. There are no material passports for any of the three.	+58% GWP if demolished vs. deconstructed — worse than Europe due to lack of deconstruction infrastructure
5. Social Equity Blind Spot	The conditions of migrant workers and gentrification. Kai Tak: The project made rents go up in nearby To Kwa Wan (median rent +85% from 2018 to 2024), forcing long-term residents to move. West Kowloon: migrant workers who put up green facades said they didn't get any Cantonese safety training and there were two cases of heat stress. HKUST: no signs of gentrification (the campus is in a remote area), but the working conditions for subcontractors are the same.	Not applicable (qualitative)

Qualitative Findings by Case

(a) Case 1 -- The BEAM Plus Platinum Public Housing Estate in Kai Tak was built in 2020 and has been tracked for five years.

The Housing Authority's Kai Tak estate is a model green public housing project. The district cooling system (DCS) was supposed to use 35% less energy to cool than regular air-cooled chillers. Estimated total energy consumption: 50 kWh/m^2/year. Real years 1–3: 78 kWh/m^2/year (56% gap). The main reason found through interviews was that the district cooling system was only partially loaded and that people opened their windows. The DCS was meant to be used by all the buildings on the network, but in the first few years of the estate, only 60% of them were occupied (phased handover), and the DCS didn't work well at low loads. In the meantime, residents opened windows for natural ventilation, which is common in Hong Kong public housing. This let conditioned air out and made the need for cooling go up.

The manager of the facility said, "The DCS works well when everyone uses it." But the people who live here don't trust central systems. They open windows to let in fresh air. The BEAM Plus model didn't take into account any windows that could be opened. That doesn't make sense for Hong Kong.

In year 3, the green roof stopped working. The Housing Authority's maintenance contractor discovered that the cost of watering the plants was higher than planned and that the roof membrane needed repairs after Typhoon Chanthu in 2022. There was no new calculation for the LCA. A Housing Authority officer said about the end of life: "We assume demolition at 50 years and redevelopment for higher density." That's how things usually work. The BEAM Plus certification is only for the new building, not for what happens after it is built.

The project helped To Kwa Wan become more upscale, which is bad for the people who live there. Rating and Valuation Department data show that rents in the area around the estate rose by 85% between 2018 (before construction) and 2024. A 68-year-old retiree who had lived in To Kwa Wan for 30 years said in an interview, "The new estate is very nice." They say green. Last year, my landlord raised my rent by 40%. I don't know how much longer I can stay here. "Green is for rich people."

(b) Case 2 -- West Kowloon's LEED Gold Commercial Tower (built in 2021 and tracked for four years).

The West Kowloon tower is similar to the German case in the original study, but it has some differences that are specific to Hong Kong. A European company made the electrochromic glazing system, which was chosen for solar control. But the dispute over the maintenance contract happened earlier (in year 2 instead of year 3) because the building owner (a local developer) didn't want to pay the manufacturer's extra fee for specialised technical support. By the third year, the system was run by hand, and office tenants put in portable air conditioners. This is

common in Hong Kong offices because central air conditioning is thought to be not good enough.

There was a big difference in performance: it was supposed to be 85 kWh/m²/year, but it was 112 kWh/m²/year (32% gap) in years 1–2 and 138 kWh/m²/year (62% gap) in years 3–4. One manager of the building said, "LEED certification was important for getting international tenants to rent the building." But after the building is rented out, no one checks to see if the green systems still work. By not renewing the maintenance contract, the developer saved money. The people who live there pay more for electricity. No one puts those pieces together.

Interviews with subcontractors who put up the green facade brought up labour issues. Eight of the twelve workers were migrant workers from the Philippines and Mainland China. None of them got safety training in Cantonese or Tagalog; instructions were given in English, which not all of the workers understood. During the summer of 2022, two workers said they were feeling stressed out because of the heat. Neither of these reports was put in official incident logs. A union representative said, "The green building premium goes to the main contractor and the developer." The person on the scaffold can't see any of it. If he gets hurt, he won't get any green credit for keeping workers safe.

(c) Case 3 -- The BEAM Plus Gold Institutional Building at HKUST (built in 2017 and tracked for six years).

The HKUST case is the best of the three when it comes to keeping up green performance, but there are still big gaps. Expected energy use intensity: 120 kWh/m²/year (high because of lab equipment). The average for years 1–6 was 158 kWh/m²/year, which is a 32% gap. The main reason for the gap was that laboratory equipment (like fume hoods and freezers) that ran all the time was not modelled correctly in the BEAM Plus submission.

After a special grant from the University Grants Committee, the building automation system (BAS) was put back into service in year 5. Before it was put back into service, laboratory managers had turned off the BAS because they thought the temperature setpoints were too high for delicate experiments. After recommissioning (which included changing setpoints and giving users more training), energy use dropped to 142 kWh/m²/year. This was still 18% higher than expected, but it was better.

The HKUST case had the most advanced approach to maintenance. For example, in 2022, the university created a position for a dedicated green building manager, and in 2026, it will be recertified for BEAM Plus Existing Buildings. But there is no plan for deconstruction. The university's Estate Management Office said, "This building should last for 50 years." We don't think about tearing things down. That's an issue for the next generation.

The working conditions were a little better at HKUST because the university made sure that subcontractors had proof of safety training. But migrant workers still said that language was a problem. Safety training was given in English and Cantonese, but some workers only spoke Tagalog or Bahasa Indonesia. There wasn't always an interpreter available.

Cross-Case Synthesis

For all three Hong Kong cases, the full journey cut the net environmental benefit by 41% to 58% compared to what was expected from certification. This is worse than the original study's range of 37% to 52% for Northern Europe. The main cause was not one specific gap, but rather a lot of uncoordinated decisions that made things worse by three Hong Kong-specific factors: (1) shorter building lifespans (50 years instead of 60–80 years in Europe), (2) no infrastructure for deconstruction (no selective demolition market), and (3) higher operational energy intensity (subtropical climate, partial-load AC inefficiency, and occupant behaviour). Hong Kong does not have any official way to keep track of or fix these accumulations. The "BEAM Plus Existing Buildings" pathway is not often used, but BEAM Plus gives a snapshot of a project at the end.

"We spent HK$50 million on green features for this estate", said one facility manager in the Kai Tak case. We received the platinum plaque. After that, the

budget for maintenance was cut. The green roof is no longer alive. Residents' open windows, which makes the distributed control system (DCS) work poorly. There is dust on the photovoltaic panels. And no one from BEAM Plus has ever come back to see. That is not a trip. That is a chance to take a picture.

V. DISCUSSION

Entropic Sustainability in Subtropical High-Density Cities

Our results contradict the static equilibrium presumption inherent in BEAM Plus and similar green building evaluations. Buildings are not machines that can be optimised once and left to run; they are sociotechnical assemblages that drift over time—and in Hong Kong's subtropical, high-density context, they drift faster and further. We propose the notion of entropic sustainability (Tolstykh et al., 2020) for tropical and subtropical urban areas: the intrinsic propensity of green building performance to deteriorate more swiftly than in temperate regions, attributable to elevated mechanical system loads, humidity-induced material degradation, occupant behaviour (such as window opening and a preference for cooler temperatures), and pressures for redevelopment.

This is not just a technical issue (better sensors, automated controls); it is also an institutional one. No one person in the construction, operation, and deconstruction chain in Hong Kong oversees the whole thing. The Housing Authority builds and designs public housing, but a different division oversees keeping it up. Private developers build and sell green-certified buildings (Chen & Gou, 2023), but they do not run them. The Buildings Department makes rules for building but not tearing down. The Development Bureau makes rules, but it doesn't make sure that long-term performance is met.

We contend that the stability of green construction regimes in Hong Kong is contingent upon enduring alignment over decades, a condition that is presently unfulfilled. In the Kai Tak case, design, policy, and market were in sync for a short time during construction (2018–2020), but they were not in sync for operation (maintenance budget cuts, occupant behaviour), and they will almost certainly not be in sync at the end of their lives (demolition at 50 years with no material recovery). For Hong Kong to have a "successful" green transition, all six stages would need to be in sync at the same time. This is unlikely to happen without intentional governance mechanisms.

The Green Journey Contract

To fill these gaps, we suggest a new way of governing that works for Hong Kong: the Green Journey Contract (GJC-HK). This would be a legally binding agreement between the client (like the Housing Authority, a private developer, or a university), the designer, the contractor, the facility manager, and a new role called the Journey Verifier (who is accredited by the Hong Kong Green Building Council or a similar group). The agreement would say:

- For each of the six stages (0–5), there are specific performance goals that are measured by GWP, energy, water, and social indicators (for example, hours of labour safety training and support for migrant workers). Real-time monitoring (smart meters, sensors) keeps targets up to date.
- Adaptive performance clauses that set up actions to take when performance goes beyond certain levels (for example, if cooling energy goes over what was predicted by more than 30% for two years in a row, the roof must be replaced with a green roof, not regular ballast).
- Financial alignment tools that include penalties and rewards based on 50-year LCA goals. For instance, the Housing Authority could give contractors a bonus for reaching 30-year operational energy goals and a fine for tearing down a building without showing that they recovered materials.
- A material passport system (verified by blockchain) for all major parts, with the ability to trace them back to suppliers in Mainland China. The passport would list the materials used, how toxic they are, how to connect them, how to take them apart, and how much they are worth in Hong Kong's material markets (like EcoPark in Tuen Mun).

- A deconstruction bond or circular deposit that makes sure there is money available for the recovery of materials at the end of their life. Because Hong Kong does not have the tools for deconstruction, this bond could help pay for the development of selective demolition capacity. The bond would only be paid back if the recovery rate is more than 60% by mass (which is lower than in Europe but possible soon).

The GJC-HK would not replace BEAM Plus; instead, it would add a longitudinal governance layer on top of it. We need pilot projects. The Housing Authority's new projects in Tung Chung East and the West Kowloon Cultural District could be good candidates.

Policy and Industry Recommendations for Hong Kong

(a) For people who make decisions (Development Bureau, Housing Authority, Buildings Department):

1. Require all public-funded projects that are larger than 1,000 m^2 to have plans for deconstruction and material passports. This could be done by changing the rules of the Public Works Programme. The EU's new Construction Products Regulation (which will go into effect in 2025) is a good example.
2. For all BEAM Plus-certified buildings that get government money (like public housing, government offices, and subsidised schools), they must have a post-occupancy evaluation (POE) and make their actual energy use public. We should think about penalties for gaps that stay open for more than 30% of the time, taking into account Hong Kong's weather.
3. Set up a "circular demolition bond" plan according to the Construction Waste Disposal Charging Regulation (Cap. 354N). If the material recovery is more than 60% by mass, the bond would be refundable. Money from unclaimed bonds could be used to build infrastructure for tearing down buildings at Tuen Mun's EcoPark.
4. Change the Buildings Ordinance (Cap. 123) so that new buildings that are taller than a certain height or have a certain amount of gross floor space must be designed to be taken apart. This would be in line with current rules for barrier-free access.

(b) For the industry (Hong Kong Green Building Council, contractors, and facility managers):

1. Facility managers must get mandatory training on green systems (paid for by the Construction Industry Council), and they should have the right to stop automation overrides that hurt green performance.
2. As part of the as-built documentation, contractors should give "life-cycle bills of materials" that include instructions for taking things apart and how long they are expected to last. Using BIM (building information modelling) tools, this is already possible.
3. Architects should plan for reversibility by putting mechanical connections ahead of adhesives, making service layers (like raised floors and accessible ceilings) easy to get to, and using modular assemblies. The Hong Kong Institute of Architects should change its rules for how professionals should do their jobs.

(c) For HKGBC and BEAM Society, which are certification bodies:

- Add a "longitudinal verification" track to BEAM Plus. Every five years, based on measured performance and maintenance records, the certification should be renewed. You could call this "BEAM Plus Ongoing Performance," which is similar to LEED O+M.
- To get certification points, you need to do social equity assessments. These include records of training for migrant workers on how to stay safe, plans to prevent heat stress, and assessments of the effects of moving people to new communities (using data from Hong Kong's Rating and Valuation Department).

VI. CONCLUSION

The full history of green building in Hong Kong is longer, more fragile, and has more social effects than current frameworks recognise. By following the performance of buildings from the extraction of raw materials to their operation and then to the end of their lives—over two to six years in our real-world cases—we have shown that even the best BEAM Plus Platinum and LEED Gold buildings lose between 41% and 58% of their expected environmental benefits when the whole process is taken into account. These losses are worse than the average for Northern Europe because of things that are unique to Hong Kong, such as shorter building lifespans, a lack of

deconstruction infrastructure, higher operational energy intensity in a subtropical climate, and a lack of coordination between the Housing Authority, private developers, and facility management contractors.

One possible institutional fix is the Green Journey Contract (Hong Kong adaptation), which changes governance from certification-as-achievement to certification-as-process. But there are still big problems to solve. How do you set the price for future decommissioning today when land prices are higher for redevelopment than for keeping the land? How to get tenants in public housing to act in ways that are good for the environment (like opening windows and setting up the AC) that are in line with the Housing Authority's green investments? How can we make sure that green buildings do not turn into green gentrification, which would push out long-term residents of To Kwa Wan, Sham Shui Po, and Wan Chai? And most importantly, how to keep the migrant workers who build Hong Kong's green buildings safe and make sure that green premiums go to the scaffold and not just the developer's bottom line?

Three areas of research must be given priority in the future. First, we really need longitudinal studies of BEAM Plus-certified buildings that are being torn down. But in Hong Kong's current redevelopment path, that means following buildings built today until they are torn down in the 2070s. The time frames for research funding don't match up well with the life cycles of buildings. Second, we need to come up with strong ways to do social life-cycle assessment (S-LCA) that are specific to Hong Kong's construction industry. These should include validated measures of migrant worker welfare, heat stress, and safety training that is appropriate for their language. Third, the pilot implementation of the Green Journey Contract should be checked to see if it is possible, cost-effective, and influences performance gaps. The Housing Authority's new buildings in Tung Chung East and the West Kowloon Cultural District's ongoing projects are good places to test things out. Until such research is conducted, assertions regarding "green buildings" in Hong Kong must be accompanied by temporal and spatial qualifiers: green in relation to which baseline, over what duration of journey, and for whom? A building that gets BEAM Plus Platinum when it is finished but loses 58% of its expected benefits by year five, contributes to gentrification in To Kwa Wan, is built by migrant workers who do not speak the language of safety training, and is torn down after 50 years with no material recovery is not, in any meaningful way, green. The plaque on the wall is not the trip. It's time for Hong Kong to start measuring the journey, which is what matters.

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