

Life Cycle Cost Analysis of Conventional versus Green Buildings

Azan Mohammad Yousaf

Department of Civil Engineering, Eastern Mediterranean University

Email: azanyousaf119@gmail.com

ABSTRACT

Buildings account for a large and growing share of global energy consumption, resource use, and greenhouse gas emissions, which has made the economic comparison of conventional and green construction a central question for owners, investors, and policymakers. This paper reviews and synthesises published literature on Life Cycle Cost Analysis (LCCA) as applied to conventional and green buildings, using the net-present-value framework codified in ISO 15686-5 to structure the comparison across capital, operating, maintenance, and end-of-life cost stages. Evidence from case studies, hedonic real-estate models, and large-sample energy-benchmarking studies is synthesised to show that green buildings generally carry a modest capital cost premium, most often reported between roughly 0 and 12 percent, but tend to deliver lower operating, maintenance, and disposal costs over the building life cycle, together with rent and sale-price premiums in commercial markets. At the same time, the review highlights substantial heterogeneity: several large empirical studies find that measured energy savings fall well short of design projections, and that a meaningful minority of certified buildings perform no better than conventional stock. The paper concludes that life cycle cost analysis, rather than first-cost comparison, is the appropriate basis for green-building investment decisions, and it proposes practical recommendations for improving the reliability of LCCA in the construction sector, particularly in developing-country contexts such as Pakistan.

Keywords: Life Cycle Cost Analysis; Green Building; Conventional Building; Sustainable Construction; Net Present Value; LEED; Building Economics

Introduction

The construction sector is one of the largest consumers of raw materials and energy in the world economy, and buildings are commonly estimated to be responsible for roughly one-third to forty percent of primary energy use and a comparable share of energy-related greenhouse gas emissions in many national economies. This scale of impact has driven three decades of policy and market interest in “green” or “sustainable” building practices, certified through systems such as LEED (Leadership in Energy and Environmental Design), whose current reference guide sets out the certification criteria used throughout this review (U.S. Green Building Council, 2024), BREEAM (BRE Global, 2016), and various national green-rating schemes. Despite this interest, the decision to build green is still frequently evaluated using first-cost comparisons alone, which compare only the upfront capital outlay of a conventional design against that of a green design.

This narrow framing is problematic because construction cost represents only one stage of a building's economic life. A building also incurs costs for energy, water, maintenance, component replacement, and eventual demolition or disposal, and it generates value through occupancy, rental income, and resale. Life Cycle Cost Analysis (LCCA) is the economic technique developed to capture this full picture: it converts all present and future costs (and, where relevant, revenues) associated with an asset into a single present-value figure using a discount rate, so that alternative designs can be compared on a like-for-like basis over an agreed period of analysis.

The purpose of this paper is to review and synthesise the published literature that applies LCCA, or closely related economic methods, to the comparison of conventional and green buildings. The paper addresses three questions. First, how large is the capital cost premium commonly associated with green construction, and how consistent is this premium across contexts? Second, what do empirical studies show about the operational savings, in energy, water, and maintenance, that green buildings deliver over their service life? Third, when these cost streams are combined using an LCCA framework, does the evidence support the claim that green buildings are more cost-effective than conventional buildings over the long run? The paper also considers the methodological standards that govern LCCA, the principal barriers to its wider adoption in the construction industry, and directions for future research, including in developing economies such as Pakistan, where sustainable-construction adoption remains at an early stage.

The remainder of the paper is organised as follows. Section 2 sets out the review methodology, including the search strategy and inclusion criteria used to identify the literature synthesised in this paper. Section 3 reviews the published literature under five thematic headings: the concept and standards of life-cycle costing, the evidence on capital cost premiums, evidence on operational savings, evidence on market value and non-energy benefits, and critical perspectives that qualify the overall pattern. Section 4 sets out the net-present-value framework used to structure the comparison and defines the cost categories compared across studies. Section 5 presents the results: the principal quantitative findings drawn together in tabular form. Section 6 discusses these results, including the barriers that limit the reliability and uptake of LCCA in practice, and proposes recommendations. Section 7 concludes.

Methodology

This paper follows a narrative-synthesis review approach, appropriate for a body of literature that spans multiple disciplines, engineering economics, real-estate finance, and building science, and that reports outcomes using heterogeneous metrics that are not well suited to formal meta-analysis. The review does not claim to be a systematic review in the PRISMA sense, but it applies an explicit and reproducible search and selection strategy, described below, so that its coverage can be assessed and extended by future work.

Sources were identified through structured searches of Google Scholar, Scopus, and ScienceDirect using combinations of the terms “life cycle cost analysis,” “life-cycle costing,” “whole-life costing,” “green building,” “sustainable building,” “LEED,” and “BREEAM,” together with the economic outcome terms “cost premium,” “operating cost,” “energy savings,” and “market value.” The search was supplemented by

backward citation tracking from key studies, most notably Kats et al. (2003) and Scofield et al. (2021), and by consulting the reference lists of the relevant ISO, ASTM, and RICS standards documents.

Sources were included if they (a) reported quantitative or standards-based evidence on the capital cost, operating cost, market value, or life-cycle cost of green buildings relative to conventional buildings; (b) were published in a peer-reviewed journal, a recognised standards body, or a widely cited government or industry report; and (c) were available in English. Sources were excluded if they addressed green-building design or engineering performance without any cost or economic outcome, or if they were opinion pieces, trade-press articles, or marketing material without an underlying empirical or standards basis. Applying these criteria yielded the thirty sources synthesised in Section 3 and summarised in Tables 1 and 2, comprising empirical case studies, large-sample benchmarking studies, hedonic market-value studies, and the governing standards and methodological literature.

Because the underlying studies report savings and premiums using different metrics, different analysis periods, and different baselines, no attempt is made to pool the reported figures into a single quantitative estimate. Instead, the review synthesises the findings narratively, organised by cost category and evidence type, and presents the reported ranges and their sources transparently in Tables 1 and 2 so that a reader can judge the strength and consistency of the underlying evidence for each claim.

Literature Review

Life-Cycle Costing: Concept and Standards

Life-cycle costing is formally defined and standardised in ISO 15686-5, which provides requirements and guidelines for performing life-cycle cost analyses of buildings and constructed assets, whether new or existing (International Organization for Standardization, 2017). The standard specifies that life-cycle costing takes into account relevant cash flows arising from acquisition through operation to disposal, performed over an agreed period of analysis, and that it typically supports a comparison between design alternatives or an estimate of future portfolio-level costs. In the United Kingdom, this framework is supplemented by RICS professional guidance, which similarly defines life-cycle costing as a methodology for the systematic economic evaluation of life cycle costs over a period of analysis, and distinguishes it from the broader concept of whole-life costing, which also incorporates income, externalities, and non-construction costs (Royal Institution of Chartered Surveyors, 2016).

A generic LCCA formulation used across this literature expresses total life cycle cost as the sum of the initial capital cost and the present value of all subsequent cost streams, discounted at an agreed real discount rate, minus any residual or salvage value recovered at the end of the analysis period. This basic structure is common to ASTM E917, the standard practice for measuring the life-cycle costs of buildings and building systems in the United States (American Society for Testing and Materials, 2017), and to the ISO 15686-5 framework internationally, and it underlies nearly every empirical LCCA study of green versus conventional buildings reviewed in this paper. A companion standard, ASTM E1185, guides the selection of the appropriate economic evaluation method, among life-cycle costing, payback, and other

techniques, for a given building investment decision (American Society for Testing and Materials, 2016). Building on these standards, the U.S. National Institute of Standards and Technology's Building for Environmental and Economic Sustainability (BEES) methodology combines life-cycle assessment with ASTM-consistent life-cycle costing into a single multi-attribute decision tool for building products (Lippiatt, 2002; Helgeson and Lippiatt, 2009), illustrating one route by which environmental and cost performance can be evaluated jointly rather than separately.

A related strand of standards work extends life-cycle costing beyond new construction to retrofit decisions. Bleyl et al. (2019) apply a cash-flow-based life-cycle cost-benefit framework to deep energy retrofits of office buildings, arguing that retrofit decisions should be evaluated using the same discounted cash-flow logic as new-build comparisons, but with the added complication that retrofit projects must be benchmarked against a counterfactual of continued operation of the existing building rather than against a hypothetical new conventional building. This distinction matters for the present review because several of the operational-savings studies discussed in Section 3.3 combine new-build and retrofit evidence without always making this counterfactual explicit, which is a source of some of the heterogeneity in reported savings percentages.

Cost Premiums of Green Construction

The earliest and most widely cited quantification of the green construction cost premium is the report by Kats, Alevantis, Berman, Mills and Perlman (2003) prepared for California's Sustainable Building Task Force, which examined more than thirty LEED-registered buildings and found an average construction cost premium of roughly two percent above conventional buildings of comparable type, alongside financial benefits that the authors estimated at more than ten times this premium when energy, water, waste, and other savings were capitalised over twenty years. Kats (2003) reported similar findings in a parallel study prepared for the Massachusetts Technology Collaborative.

Subsequent research has generally confirmed that a premium exists but has found it to be more variable than the earlier two-percent estimate. Hwang, Zhu, Wang and Cheong (2017) studied green building construction projects in Singapore and defined a green construction cost surcharge to capture the additional capital cost directly attributable to sustainable design features; they found that the surcharge varies considerably with building type, certification level, and contractor experience, and that it tends to narrow as firms accumulate experience with green building techniques. Regional case studies report a wider range still: a life-cycle cost study of an industrial manufacturing building in Sri Lanka found a construction cost premium of approximately twenty-eight percent for the green-certified building relative to its conventional counterpart, a considerably larger premium than the Kats-era estimates, reflecting the smaller and less mature green-construction market in that context (Weerasinghe, Ramachandra and Thurairajah, 2017).

Taken together, these three studies illustrate that the reported capital premium is not a fixed technical parameter but depends heavily on market maturity, the scope of green features included, and the baseline against which the comparison is made. In mature markets with established green-supply chains, such as California in the Kats et al.

(2003) study, the premium is close to the lower end of the reported range; in smaller or less mature markets, such as the Sri Lankan case documented by Weerasinghe, Ramachandra and Thurairajah (2017), the premium can be an order of magnitude larger. This pattern is consistent with the market-diffusion evidence discussed in Section 3.4, and it is directly relevant to the discussion of developing-country barriers in Section 6, since it implies that early adopters in markets such as Pakistan should expect to face a capital premium closer to the higher end of the reported range until local supply chains and contractor experience mature.

Operational Savings: Energy, Water, and Maintenance

The economic case for green buildings rests principally on the claim that lower operating costs offset the initial premium over time. In the Sri Lankan case study noted above, Weerasinghe, Ramachandra and Thurairajah (2017) found that although construction cost was substantially higher for the green building, operating costs were 35 to 41 percent lower, maintenance costs were 26 to 30 percent lower, and end-of-life costs were 6 to 18 percent lower than for the conventional building, so that total life-cycle cost was ultimately 24 to 28 percent lower for the green building over the analysis period.

Energy performance evidence is more contested. Early studies commissioned by the U.S. Green Building Council, including the New Buildings Institute analysis by Turner and Frankel (2008), reported that LEED-certified buildings saved between roughly twenty-five and thirty percent of energy on average relative to conventional buildings, a figure broadly consistent with the eighteen to thirty-nine percent range reported by Newsham, Mancini and Birt (2009) in their re-analysis of the same underlying dataset. However, both studies also found little correlation between the energy savings projected by design teams and the energy savings actually measured after occupancy, and Newsham, Mancini and Birt (2009) noted that roughly one-third of the LEED buildings in their sample used more energy than comparable conventional buildings.

More recent, larger-sample studies present a more moderate picture. Scofield, Brodnitz, Cornell, Liang and Scofield (2021) analysed municipal energy-benchmarking data for 551 LEED-certified office buildings and roughly 3,600 comparable non-LEED offices across ten major United States cities, and found that LEED offices achieved an aggregate site-energy saving of about eleven percent and a source-energy and greenhouse-gas saving of about seven percent relative to non-LEED offices, considerably below the twenty-five to thirty percent savings commonly asserted for green buildings. The same study found that only buildings certified at the Gold level demonstrated statistically significant savings across most metrics, and that measured savings for individual buildings correlated only weakly with the energy-optimisation points awarded during certification. Scofield's earlier, smaller studies of New York City office buildings similarly found no significant source-energy or greenhouse-gas savings associated with LEED certification (Scofield, 2009; Scofield, 2013), and a subsequent 2015 Chicago benchmarking study by the same author reported comparable results (Scofield and Doanes, 2018). Smaller, single-portfolio studies present a similarly mixed picture: an evaluation of United States Navy LEED-certified buildings found wide variation in measured energy consumption relative to

conventional Navy facilities of similar type (Menassa et al., 2012).

The retrofit literature offers a complementary perspective on operational savings. Bleyl et al. (2019) find that deep energy retrofits, evaluated using a life-cycle cash-flow approach rather than simple payback, can be economically justified even where the simple payback period exceeds typical investment thresholds, because the cash-flow approach captures avoided maintenance and component-replacement costs that a payback calculation ignores. This finding reinforces a broader methodological point that recurs throughout the literature reviewed in this paper: studies that use a full life-cycle costing framework tend to find a more favourable economic case for green measures than studies that rely on simple payback or first-cost comparison alone, independent of the underlying energy-savings percentage.

Market Value and Non-Energy Benefits

A separate strand of literature examines whether green certification generates a financial benefit through the property market rather than, or in addition to, operating-cost savings. Using hedonic regression on large samples of United States commercial office properties, Eichholtz, Kok and Quigley (2010) found that green-labelled office buildings command higher effective rents and sale prices than otherwise comparable conventional buildings, a result the authors attribute partly to lower operating costs capitalised into rent and partly to occupier and investor preference for certified space. Fuerst and McAllister (2011) reached a similar conclusion using data from the CoStar database of United States commercial real estate, finding statistically significant rental and sale-price premiums for LEED- and Energy Star-certified buildings after controlling for location and other property characteristics, and attributing the premium to a combination of occupier benefits, lower holding costs for investors, and a lower perceived risk premium. An earlier study by the same authors examined occupancy rates specifically, finding that eco-labelled office buildings achieve higher occupancy than comparable conventional buildings, a result the authors interpret as evidence that occupiers place an independent value on certification beyond any operating-cost saving (Fuerst and McAllister, 2009).

Earlier evidence from national sales and leasing data for Class A offices similarly found that green-labelled buildings achieve superior rents and significantly higher occupancy, which is in turn reflected in a higher selling price (Wiley, Benefield and Johnson, 2010). At the market-diffusion level, Kok, McGraw and Quigley (2011) show that the stock of certified office space has grown rapidly in United States metropolitan areas, driven by local market composition and the availability of relevant professional expertise, while Eichholtz, Kok and Quigley (2013) extend this line of work to demonstrate that the combined rental and sale-price advantages of certified buildings persist after controlling for a wide range of building and location characteristics.

These market-value findings are important for LCCA because they represent an economic benefit stream that is separate from, and additional to, the direct operating-cost savings discussed in Section 3.3. Where an LCCA analysis is extended to a whole-life-cost or investment-appraisal framework that includes rental income and resale value, this literature suggests the case for green buildings strengthens further, even where measured energy savings alone are modest. This is a significant

qualification to the more cautious operational-savings findings of Scofield et al. (2021) and Newsham, Mancini and Birt (2009): an investor who values a building using rental income and exit price, rather than energy cost alone, may still find that certification is financially justified even in cases where the underlying energy performance is unremarkable.

Critical Perspectives and Mixed Evidence

Not all of the literature supports an unqualified conclusion that green buildings are more cost-effective. Several authors caution that the gap between design-stage projections and measured post-occupancy performance is a persistent and significant source of uncertainty in any LCCA that relies on simulated, rather than measured, energy data. Scofield's series of studies, discussed above, is among the most direct expressions of this concern, and more recent systematic reviews of LEED energy performance similarly report inconsistent results across building types and climates, with no clear pattern identifying the conditions under which certified buildings reliably outperform conventional stock. This body of work implies that LCCA outcomes for green buildings should be treated as context-dependent and sensitive to the quality of the underlying energy and cost data, rather than as a fixed percentage saving that can be assumed a priori.

A second critical perspective concerns certification level. Scofield et al. (2021) found that statistically significant savings were concentrated among buildings certified at the Gold level, with Silver- and Certified-level buildings showing weaker or statistically insignificant savings. This finding suggests that treating "LEED-certified" as a single homogeneous category, as much of the earlier literature implicitly does, may obscure important variation, and that LCCA studies conducted at the level of individual certification tiers are likely to be more informative than aggregate comparisons of certified versus non-certified stock.

The Life Cycle Cost Analysis Framework

This section sets out the LCCA framework used to structure the comparative findings summarised in Section 5. The framework follows the ISO 15686-5 approach, adapted to the specific cost categories that recur in the green-versus-conventional building literature reviewed above.

Net-Present-Value Formulation

The standard LCCA model expresses the total life cycle cost, LCC, of a building over an agreed period of analysis of n years as the sum of the initial capital cost, IC , and the discounted present value of all subsequent annual cost streams, C_t , net of any residual or salvage value, RV , recovered in the final year:

$$LCC = IC + \sum [C_t / (1 + d)^t] - RV / (1 + d)^n, \text{ for } t = 1 \text{ to } n$$

where d is the real discount rate and C_t comprises energy cost, water cost, routine maintenance and repair cost, and periodic component-replacement cost incurred in year t . The analysis period, discount rate, and scope of costs included must be stated explicitly and applied identically to both the conventional and green design alternatives, since the comparison is only valid when both scenarios are evaluated on the same basis; ISO 15686-5 identifies this consistency requirement as a core

principle of life-cycle costing (International Organization for Standardization, 2017). The choice of discount rate is one of the more consequential methodological decisions in LCCA, because green buildings typically exhibit a higher initial cost but lower and more stable future costs, so the analysis is sensitive to how heavily future savings are discounted. A low discount rate favours the green alternative by giving more weight to future operating savings, while a high discount rate favours the conventional alternative by weighting the near-term capital cost more heavily. For this reason, ISO 15686-5 and the RICS practice guidance both recommend that LCCA results be reported alongside a sensitivity analysis across a plausible range of discount rates, rather than as a single point estimate (Royal Institution of Chartered Surveyors, 2016). A further methodological refinement, illustrated by Bleyl et al. (2019) in the retrofit context, is to disaggregate Ct into its component cash flows, energy savings, avoided maintenance, avoided replacement, and any non-energy benefits such as improved comfort or productivity, so that the sensitivity of the overall LCC figure to each component can be examined separately. This disaggregated approach is particularly useful for identifying which cost category drives the result in a given study, and it is the approach implicitly used in Table 1 below.

Cost Categories Compared

Table 1 summarises the cost categories used to structure the comparison in this paper, drawing on the categories most consistently reported across the studies reviewed in Section 3.

Cost Category	Conventional Building	Green Building
Initial capital / construction cost	Baseline	Typically 0–12% higher (occasionally higher for advanced systems)
Design & certification cost	Minimal	Additional cost for modelling, commissioning, certification fees
Energy cost (operation)	Baseline	11–39% lower, depending on system and certification level
Water cost (operation)	Baseline	Lower, due to low-flow fixtures and rainwater harvesting
Maintenance & repair cost	Baseline	26–30% lower in several case studies
Replacement cost of components	Baseline	Variable; durable materials can reduce frequency
End-of-life / disposal / residual value	Baseline	6–18% lower disposal cost; higher residual/resale value

Table 1. Life cycle cost categories compared between conventional and green buildings, synthesised from Kats et al. (2003), Weerasinghe, Ramachandra and Thurairajah (2017), Hwang, Zhu, Wang and Cheong (2017), and Scofield et al. (2021).

Period of Analysis and Scope

The studies reviewed in this paper use analysis periods ranging from twenty years, in the Kats et al. (2003) study, to fifty or sixty years in more recent building-scale case studies. Longer analysis periods tend to favour green buildings because they allow more years of operational savings to accumulate against the one-off capital premium, so the reported life-cycle cost advantage of green buildings in the literature should always be interpreted together with the analysis period used. Consistent with ISO 15686-5, the scope of an LCCA should also be stated explicitly: some studies confine the analysis to construction, operation, and maintenance costs, while others extend it to include end-of-life demolition and disposal costs, or, as in the whole-life-costing extension discussed in Section 3.4, rental income and resale value.

Results

Table 2 draws together the principal quantitative findings reported across the literature reviewed in Section 3, organised by study and context. The table illustrates both the consistency of the qualitative pattern, namely a capital premium offset by lower operating and end-of-life costs, and the considerable variation in the size of these effects across contexts and methodologies.

Study / Source	Context	Key LCCA / Cost Finding
Kats et al. (2003)	33 green buildings, California	Average green premium ~2% of construction cost; financial benefits about 10x the upfront premium over 20 years
Weerasinghe, Ramachandra & Thurairajah (2017)	Industrial building, Sri Lanka	Construction cost ~28% higher, but life-cycle cost 24–28% lower than conventional building
Hwang, Zhu, Wang & Cheong (2017)	Green building projects, Singapore	Cost surcharge concentrated in design/MEP systems; premium narrows with contractor experience
Fuerst & McAllister (2011)	US commercial office market	Statistically significant rent and sale-price premiums for LEED/Energy Star buildings
Eichholtz, Kok & Quigley (2010)	US green office buildings	Green-labelled offices command higher effective rents and sale prices than comparable conventional offices
Scofield et al. (2021)	551 LEED offices, 10 US cities	11% site-energy and 7% source-energy/GHG savings versus non-LEED offices; savings well below design projections
Newsham, Mancini & Birt (2009)	121 LEED buildings, USA	18–39% average energy savings, but about one-third of LEED buildings used more energy than conventional peers

Table 2. Comparative summary of life cycle cost and related findings for green versus conventional buildings across the reviewed literature.

Two patterns are apparent from Table 2. First, at the scale of an individual, well-documented building case study, life cycle cost analysis tends to favour the green alternative: the Sri Lankan industrial building example and the Kats et al. (2003) portfolio both report substantial net life-cycle savings despite a higher construction cost. Second, at the scale of large, representative samples of certified buildings, such as the Scofield et al. (2021) study of 551 LEED offices, the average operational saving is smaller and more variable than in individual case studies, and a meaningful share of certified buildings do not outperform conventional buildings at all. This divergence suggests that published LCCA case studies, which are often based on a small number of well-instrumented or exemplary projects, may present a more favourable picture of green-building economics than is representative of the certified building stock as a whole.

The market-value evidence in Table 2 (Fuerst and McAllister, 2011; Eichholtz, Kok and Quigley, 2010) adds a further dimension that a narrow operating-cost LCCA can miss: even where energy savings are modest, certified buildings in mature commercial markets appear to capture a measurable rent and sale-price premium, which a whole-life-cost analysis would record as an additional benefit stream rather than a cost saving.

A further observation follows from comparing the case-study and large-sample evidence side by side. The size of the reported life-cycle cost advantage appears to be inversely related to the size of the sample: the smallest, most detailed case studies, such as the single Sri Lankan industrial building examined by Weerasinghe, Ramachandra and Thurairajah (2017), report the largest life-cycle savings, while the largest samples, such as the 551-building Scofield et al. (2021) dataset, report the smallest average savings. This pattern is consistent with a publication and selection effect in which detailed, resource-intensive case studies are disproportionately conducted on buildings that are already expected, on other grounds, to perform well, while large-sample benchmarking studies are less subject to this selection because they include the full population of certified buildings in a given jurisdiction regardless of expected performance.

Discussion

Barriers to Reliable LCCA

Several barriers recur across the literature and constrain the reliability and uptake of LCCA in practice. First, data availability is a persistent constraint: many LCCA case studies rely on design-stage simulated energy performance rather than measured post-occupancy data, and the gap between the two, documented extensively in the LEED energy-performance literature, means that LCCA results calculated from simulated data should be treated as indicative rather than definitive. Second, the discount-rate and analysis-period assumptions used in published LCCA studies are not always stated or standardised, which limits comparability across studies and across countries; the adoption of a common framework such as ISO 15686-5 partially addresses this problem but has not been uniformly applied, and a systematic review of the wider LCC literature finds that discount-rate treatment remains one of the least standardised aspects of building economic evaluation more generally.

Third, life cycle costing itself is applied unevenly in developing construction markets:

a survey of quantity-surveying practice in Nigeria found that limited technical capacity, poor data availability, and low client demand were the leading barriers to the routine application of LCC on building projects (Opawole et al., 2020), a pattern echoed in the broader review of green-building adoption barriers by Darko and Chan (2016), which identifies cost, lack of information, and the absence of green-building codes as the most frequently reported obstacles across countries. Barriers specific to green-technology adoption, as opposed to LCC practice narrowly defined, have been documented in comparable developing-country contexts, including Ghana, where higher first cost, weak government incentives, and limited access to financing were found to be the most critical constraints (Chan et al., 2018), and Pakistan, where a survey of construction-industry practitioners identified limited public awareness, weak government incentives, and the absence of green-building codes and regulations as the principal barriers to adoption (Azeem et al., 2017). Fourth, in developing-country construction markets generally, the green-building cost premium reported in the literature tends to be higher and less predictable than in mature markets such as the United States and Singapore, reflecting smaller supply chains for green materials, limited contractor experience, and the absence of local benchmarking data of the kind used by Scofield et al. (2021) in the United States.

These barriers interact with one another. Limited local benchmarking data (Barrier 1) makes it harder to demonstrate a robust business case to sceptical clients, which reinforces low client demand (Barrier 3), which in turn limits the volume of green-building activity needed to bring contractor experience, and therefore the construction cost premium, down toward the levels observed in mature markets (Barrier 4). Breaking this cycle is therefore less a matter of any single intervention than of a coordinated set of measures addressing data, standards, and demand simultaneously.

Recommendations

On the basis of this review, three recommendations follow. First, LCCA studies should report results across a range of discount rates and analysis periods, rather than as single-point estimates, so that decision-makers can assess how sensitive the conclusion is to these assumptions. Second, wherever possible, LCCA inputs for the operating-cost stage should be drawn from measured, post-occupancy energy and water data rather than design-stage projections alone, given the well-documented gap between the two. Third, in developing markets, national or regional benchmarking datasets analogous to the municipal energy-benchmarking disclosures used in the United States studies reviewed here would substantially improve the reliability of local LCCA, and their development should be treated as a priority for construction-sector policy.

A fourth, more specific recommendation follows from the certification-tier finding discussed in Section 3.5: where LCCA is used to inform a certification-level decision, such as whether to target LEED Silver or Gold, the analysis should draw on tier-specific rather than aggregate savings estimates, since the Scofield et al. (2021) evidence indicates that aggregate figures may materially overstate the savings achievable at lower certification tiers.

Conclusion

This review of the Life Cycle Cost Analysis literature comparing conventional and green buildings finds a consistent qualitative pattern: green buildings tend to carry a capital cost premium, most commonly reported in the low single digits to low double digits as a percentage of construction cost, but this premium is frequently offset, and in several documented cases more than offset, by lower operating, maintenance, and end-of-life costs over the building's service life, together with measurable rent and sale-price premiums in commercial property markets. At the same time, large-sample empirical studies show that the size of the operating-cost saving is more modest and more variable than early case studies suggested, and that a meaningful share of certified buildings fail to outperform conventional buildings in practice.

The central methodological implication is that life cycle cost analysis, conducted transparently with a stated discount rate, analysis period, and scope, and grounded wherever possible in measured rather than simulated performance data, is a more defensible basis for green-building investment decisions than a comparison of construction cost alone. For developing construction markets such as Pakistan, closing the local data gap that currently limits the reliability of LCCA represents a practical priority for both researchers and policymakers. Future work in such contexts would benefit from locally generated, post-occupancy benchmarking data of the kind that has, in mature markets, allowed the field to move from optimistic early case studies toward the more measured, large-sample assessment reflected in the recent literature.

References

- American Society for Testing and Materials. (2016). ASTM E1185-16: Standard guide for selecting economic methods for evaluating investments in buildings and building systems. West Conshohocken, PA: ASTM International.
- American Society for Testing and Materials. (2017). ASTM E917-17: Standard practice for measuring life-cycle costs of buildings and building systems. West Conshohocken, PA: ASTM International.
- Azeem, S., Naeem, M. A., Waheed, A., & Thaheem, M. J. (2017). Examining barriers and measures to promote the adoption of green building practices in Pakistan. *Smart and Sustainable Built Environment*, 6(3), 86–100. <https://doi.org/10.1108/SASBE-06-2017-0023>
- Bleyle, J. W., Bareit, M., Casas, M. A., Chatterjee, S., Coolen, J., Hulshoff, A., Lohse, R., Mitchell, S., Robertson, M., & Ürge-Vorsatz, D. (2019). Office building deep energy retrofit: Life cycle cost benefit analyses using cash flow analysis and multiple benefits on project level. *Energy Efficiency*, 12(1), 261–279. <https://doi.org/10.1007/s12053-018-9707-8>
- BRE Global. (2016). BREEAM International New Construction: Technical manual. Watford, UK: BRE Global.
- Chan, A. P. C., Darko, A., Olanipekun, A. O., & Ameyaw, E. E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of Cleaner Production*, 172, 1067–1079. <https://doi.org/10.1016/j.jclepro.2017.10.235>
- Darko, A., & Chan, A. P. C. (2016). Review of barriers to green building adoption. *Sustainable Development*, 25(3), 167–179. <https://doi.org/10.1002/sd.1651>

- Eichholtz, P., Kok, N., & Quigley, J. M. (2010). Doing well by doing good: Green office buildings. *American Economic Review*, 100(6), 2494–2511.
- Eichholtz, P., Kok, N., & Quigley, J. M. (2013). The economics of green building. *Review of Economics and Statistics*, 95(1), 50–63.
- Fuerst, F., & McAllister, P. (2009). An investigation of the effect of eco-labeling on office occupancy rates. *Journal of Sustainable Real Estate*, 1(1), 49–64.
- Fuerst, F., & McAllister, P. (2011). Green noise or green value? Measuring the effects of environmental certification on office values. *Real Estate Economics*, 39(1), 45–69. <https://doi.org/10.1111/j.1540-6229.2010.00286.x>
- Helgeson, J., & Lippiatt, B. (2009). Multi-disciplinary life-cycle metrics and tools for green buildings. *Integrated Environmental Assessment and Management*, 5(2), 187–191.
- Hwang, B. G., Zhu, L., Wang, Y., & Cheong, X. (2017). Green building construction projects in Singapore: Cost premiums and cost performance. *Project Management Journal*, 48(4), 67–79. <https://doi.org/10.1177/875697281704800406>
- International Organization for Standardization. (2017). ISO 15686-5:2017 — Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing. Geneva: ISO.
- Kats, G. (2003). Green building costs and financial benefits. Boston, MA: Massachusetts Technology Collaborative.
- Kats, G., Alevantis, L., Berman, A., Mills, E., & Perlman, J. (2003). The costs and financial benefits of green buildings: A report to California's Sustainable Building Task Force. Sacramento, CA: Sustainable Building Task Force.
- Kok, N., McGraw, M., & Quigley, J. M. (2011). The diffusion of energy efficiency in building. *American Economic Review*, 101(3), 77–82.
- Lippiatt, B. (2002). The environmental life cycle. In *Green Building: Project Planning & Cost Estimating* (Chapter 12). Kingston, MA: R.S. Means.
- Menassa, C., Mangasarian, S., El Asmar, M., & Kirar, C. (2012). Energy consumption evaluation of U.S. Navy LEED-certified buildings. *Journal of Performance of Constructed Facilities*, 25, 46–53. [https://doi.org/10.1061/\(ASCE\)CF.1943-5509.0000218](https://doi.org/10.1061/(ASCE)CF.1943-5509.0000218)
- Newsham, G. R., Mancini, S., & Birt, B. J. (2009). Do LEED-certified buildings save energy? Yes, but.... *Energy and Buildings*, 41(8), 897–905. <https://doi.org/10.1016/j.enbuild.2009.03.014>
- Opawole, A., Babatunde, S. O., Kajimo-Shakantu, K., & Ateji, O. A. (2020). Analysis of barriers to the application of life cycle costing in building projects in developing countries: A case of Nigeria. *Smart and Sustainable Built Environment*, 9(4), 503–521. <https://doi.org/10.1108/SASBE-11-2018-0057>
- Royal Institution of Chartered Surveyors. (2016). *Life cycle costing* (RICS Practice Information, 1st ed.). London: RICS.
- Scofield, J. H. (2009). Do LEED-certified buildings save energy? Not really.... *Energy and Buildings*, 41(12), 1386–1390. <https://doi.org/10.1016/j.enbuild.2009.08.006>
- Scofield, J. H. (2013). Efficacy of LEED-certification in reducing energy consumption and greenhouse gas emission for large New York City office

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

- buildings. *Energy and Buildings*, 67, 517–524. <https://doi.org/10.1016/j.enbuild.2013.08.032>
- Scofield, J. H., & Doanes, J. (2018). Energy performance of LEED-certified buildings from 2015 Chicago benchmarking data. *Energy and Buildings*, 174, 402–413. <https://doi.org/10.1016/j.enbuild.2018.06.019>
- Scofield, J. H., Brodnitz, S., Cornell, J., Liang, T., & Scofield, T. (2021). Energy and greenhouse gas savings for LEED-certified U.S. office buildings. *Energies*, 14(3), 749. <https://doi.org/10.3390/en14030749>
- Turner, C., & Frankel, M. (2008). Energy performance of LEED for New Construction buildings—Final report. White Salmon, WA: New Buildings Institute.
- U.S. Green Building Council. (2024). LEED v5.0 reference guide for building design and construction. Washington, DC: USGBC.
- Weerasinghe, A. S., Ramachandra, T., & Thurairajah, N. (2017). Life cycle cost analysis: Green vs conventional buildings in Sri Lanka. In *Proceedings of the 33rd Annual ARCOM Conference*. Association of Researchers in Construction Management.
- Wiley, J. A., Benefield, J. D., & Johnson, K. H. (2010). Green design and the market for commercial office space. *Journal of Real Estate Finance and Economics*, 41(2), 228–243. <https://doi.org/10.1007/s11146-008-9142-2>