

# ***Composition of Incremental Costs and Economic Benefit Analysis of Green Buildings***

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**Abstract.** Against the background of China's dual-carbon development goals and the steady advancement of new urbanization, the large-scale promotion of green buildings is currently restricted by two prominent bottlenecks: high one-time construction surcharges and insufficient market recognition of their long-term comprehensive gains. This paper sorts out the sources of extra investment in green construction projects and evaluates their economic performance over the full service life. Five major types of incremental spending are summarized, covering energy-saving transformation, water recycling, low-carbon building materials, indoor environmental upgrading, as well as green design and certification fees. The results also show that such extra costs will rise steadily as the green building star rating goes from one-star to three-star. For benefit measurement, this study separates economic returns into direct and indirect categories and adopts three mainstream evaluation indicators, namely net present value (NPV), benefit-cost ratio (BCR) and dynamic payback period, to carry out a full life-cycle economic assessment. Calculation results show that green buildings can generate stable positive economic gains in long-term operation, and their capital recovery cycle is far shorter than the standard design service life of buildings. Besides, this paper sorts out economic obstacles existing in four key phases including project decision-making, architectural design, on-site construction and post-completion operation, and puts forward targeted cost control strategies. Overall, despite higher upfront construction expenses, green buildings possess sound economic competitiveness if evaluated from a full life-cycle perspective. The paper conclusions can provide practical decision-making references for real estate developers planning to launch green construction projects.

**Keywords:** green building, incremental cost, life-cycle, economic benefits

## **1. Introduction**

As a high energy-consuming and high-carbon-emitting industry, the construction sector has to transform toward low-carbon and eco-friendly development to match China's dual-carbon targets and the ongoing progress of new-type urbanization. Green buildings stand out for their advantages in energy and water conservation, carbon reduction and comfortable indoor living environments, making them a core tool to cut construction carbon emissions, upgrade building quality and ease

resource and environmental pressures. Driven by supportive government policies and growing market demand, green building projects have achieved continuous expansion in recent years.

Different from conventional ordinary buildings, green construction needs extra capital input during design, material selection, construction and operation stages to meet official green evaluation standards, and these additional expenditures are defined as incremental costs. Although energy-saving equipment, renewable energy systems and low-carbon construction materials adopted by green buildings are widely recognized as effective ways to lower overall carbon emissions over decades of use, the heavy initial extra investment often discourages developers from participating in green projects [1].

At present, market participants hold divided views on whether green buildings can bring sound economic returns. Most investors only focus on the extra spending at the construction stage while ignoring long-term comprehensive operating gains. This cognitive bias slows down the large-scale popularization of green buildings, especially high-star projects that face more complex implementation difficulties.

Based on the above practical background, this paper mainly addresses two core research questions: first, to clarify the specific composition of incremental costs for green buildings; second, to calculate the payback cycle and long-term revenue generated by early extra investment across the whole building life cycle. By sorting out cost components and quantifying life-cycle economic gains, this paper intends to assist developers in scientific investment judgment and accelerate the wider application of green construction technologies.

## 2. Composition of incremental costs of green buildings

### 2.1. Connotations of green buildings and incremental costs

Green buildings prioritize resource conservation, emission reduction and comfortable indoor conditions throughout design, construction, operation and demolition, so as to realize harmonious coexistence between human living activities and natural ecology. The incremental cost of a green building refers to all extra construction funds compared with standard ordinary buildings, which are spent to satisfy green building assessment standards. Such extra investment runs through the whole building lifespan, covering architectural design, construction, operation maintenance and demolition phases. The core reason for extra costs is that green buildings adopt energy-saving, water-recycling, low-carbon and environment-improving technologies, materials and equipment that exceed the minimum requirements of conventional construction codes [2].

### 2.2. Main sources of incremental costs in green buildings

The extra spending of green buildings mainly falls into five categories: energy-saving equipment investment, water recycling system construction, low-carbon eco-material premium, indoor living environment upgrading, plus green design and certification service charges. In addition, new innovative construction technologies applied in design and construction links will also produce additional expenses [3]. Detailed items of each cost type are listed in Table 1.

Table 1. Main sources of incremental costs in green buildings

| Cost Category                           | Specific Inclusions                                                                                        |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------|
| Energy-efficiency technology investment | Costs for procurement and installation of energy-saving envelope structures and renewable energy equipment |

Table 1. (continued)

|                                                      |                                                                                                                                                                                |
|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Water-conservation technology investment             | Construction costs for rainwater harvesting systems, reclaimed water reuse facilities, water-efficient fixtures, and landscape water-saving supporting facilities              |
| Material-saving and eco-friendly material investment | Premium costs of low-carbon building materials (e.g., recycled concrete, eco-friendly panels, recyclable building materials) over conventional materials                       |
| Indoor environment enhancement investment            | Costs for fresh air purification systems, sound insulation and noise-reduction structures, and supporting engineering for improved indoor temperature/humidity and air quality |
| Design and certification fees                        | Fees for specialized green building scheme design, third-party testing, star-rating assessment, and green technology consulting services                                       |

### 2.3. Incremental cost variations across different star-rated green buildings

Green buildings are classified into one-star, two-star, and three-star ratings according to the assessment standard, which evaluates performance across six dimensions: safety and durability, health and comfort, convenience in living, resource conservation, environmental livability, and innovation enhancement. Higher star ratings entail stricter index requirements, greater technological integration, and consequently higher incremental costs. Detailed star-rating criteria are shown in Table 2.

One-star buildings adopt only routine and simple green technologies, with limited use of high-cost specialized equipment, thus incurring the lowest incremental costs. Two-star buildings employ a combination of multiple green technologies, but with limited application frequency, resulting in moderate incremental costs. Three-star buildings, subject to the most stringent assessment criteria, must integrate multiple supporting systems for energy efficiency, water conservation, and indoor environment optimization. The stacking of these costs makes their incremental costs substantially higher than those of one-star and two-star buildings.

Table 2. Star rating criteria for green buildings

| Build<br>ing<br>Star<br>Rating | Minimu<br>m Total<br>Score<br>Require<br>d | Core Assessment Rules                                                                                                                                                                                                                           | Mandatory Basic Requirements                                                                                                                                                                                        |
|--------------------------------|--------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| One-<br>Star                   | 50<br>points                               | Only basic green measures are required; high-end technologies such as renewable energy and reclaimed water reuse are not mandatory                                                                                                              | No mandatory high-cost green systems; basic energy-saving and water-efficient fixtures suffice to meet the standard                                                                                                 |
| Two-<br>Star                   | 60<br>points                               | Must achieve certain scores in both resource conservation and health/comfort categories; mandatory installation of basic energy-efficient envelopes and simple rainwater harvesting systems                                                     | At least two dedicated green engineering measures are required; renewable energy may be optionally deployed as needed                                                                                               |
| Three-<br>Star                 | 80<br>points                               | Sub-scores in each category must not be too low; high requirements for resource conservation and innovation bonus points; multiple low-carbon technologies, renewable energy systems, and indoor environment optimization systems are mandatory | Must integrate multiple high-cost green facilities including solar energy, reclaimed water reuse, high-efficiency fresh air, and high-performance insulation; innovation technologies may be added for bonus points |

### 3. Economic benefit analysis of green buildings

#### 3.1. Direct economic benefits

Direct economic benefits come from lasting cuts in resource consumption expenses brought by energy-saving and water-recycling facilities, which can be calculated based on annual operating data. In terms of energy saving, adding external sun-shading structures can reduce air conditioner operating loads and lower cooling power consumption by up to 16%. Solar hot water systems replace traditional gas or electric heating equipment, greatly cutting long-term daily energy expenditure during building operation. For water conservation, rainwater collection and reclaimed water recycling facilities supply treated water for landscape irrigation, cutting the total water usage for greening by 20% and largely reducing municipal tap water fees [4].

To clearly display the one-time extra investment and annual operating savings of mainstream green construction technologies, the input-output data of typical technologies are sorted into Table 3.

Table 3. Comparison of initial investment and annual savings for representative green technologies

| Green Technology                      | Initial Incremental Investment (one-time)  | Annual Savings                                 | Core Benefit Source                                                |
|---------------------------------------|--------------------------------------------|------------------------------------------------|--------------------------------------------------------------------|
| Building external shading system      | Premium cost for envelope retrofitting     | 16% reduction in air-conditioning energy costs | Reduced electricity consumption for summer cooling                 |
| Solar water heating system            | Equipment purchase and installation costs  | Long-term reduction in gas/electricity bills   | Substitution for conventional hot water energy sources             |
| Rainwater harvesting and reuse system | Cost of storage tanks and filtration units | 20% savings on landscape water bills           | Reclaimed water replacing municipal water for landscape irrigation |

#### 3.2. Indirect economic benefits

Indirect economic gains cannot be directly reflected in water and electricity bills, yet they can offset early incremental costs and raise the overall long-term value of construction projects. Such benefits fall into three types: policy subsidies, property market premium and intangible added value.

Policy incentives refer to tiered financial subsidies, land charge discounts and tax reductions released by local governments for one-star, two-star and three-star green buildings. These policy supports can directly reduce project extra investment and ease developers' short-term capital pressure. Generally speaking, higher star-rated green buildings can enjoy larger subsidy amounts and more favorable tax policies.

Market premium originates from market preference for low-carbon, healthy construction products. Green buildings in the same area usually carry higher rental prices than ordinary buildings, bringing steady asset appreciation income for owners.

Intangible benefits include lower overall water and energy consumption, corresponding carbon and pollutant emission reduction, and decreased external environmental governance costs. Besides, developing high-star green building projects helps developers build a low-carbon corporate brand, and reduces credit threshold and loan interest rates when enterprises apply for financing [5].

#### 3.3. Life-cycle economic benefit assessment

Judging the economic efficiency of green buildings merely through construction-stage cost comparison cannot reach objective conclusions. The full life-cycle evaluation system covers

construction, long-term operation and demolition phases, and adopts three core indicators: net present value (NPV), benefit-cost ratio (BCR) and dynamic payback period.

This paper takes a new office building located in the core urban development zone as a research case. The project is equipped with complete green supporting facilities including external sunshades, solar hot water equipment and rainwater recycling systems, which generates certain incremental costs during construction. After being put into operation, energy and water-saving facilities create stable positive cash inflows every year. The evaluation results show that the project's full life-cycle NPV is positive, its BCR exceeds 1.0, and the dynamic payback period is around 10 years—far shorter than the standard 50-year design service life of buildings. After recovering the early extra investment, the project can continuously create stable economic gains for decades, which fully reflects its outstanding long-term economic advantages [6].

Sensitivity test results show that energy and water price fluctuations exert obvious influences on project returns, while the evaluation indicators have relatively stable resistance to discount rate changes, proving the overall reliability of green buildings' economic feasibility [7].

#### **4. Key influencing factors and optimization pathways for green building cost-effectiveness**

##### **4.1. Key factors influencing green building cost-effectiveness**

From the perspective of full life-cycle management, four phases including project decision-making, architectural design, construction and daily operation all affect the economic returns of green buildings. Improper management at any single stage will weaken the project's overall economic performance [8].

In the decision-making stage, unreasonable project positioning or blind pursuit of high star ratings will sharply raise incremental investment, making it impossible for later operating income to cover extra costs. During the design phase, unreasonable building shape coefficients or illogical envelope layout may require additional equipment investment, producing ineffective extra spending. In construction links, if green materials and energy-saving construction techniques fail to reach design standards, eco-friendly facilities cannot achieve preset energy and water saving targets, leading to lower-than-expected operating gains. In the operation stage, rough property management, long-term idle energy-saving equipment and lack of regular maintenance will make green systems unable to operate normally, resulting in total loss of long-term resource-saving benefits.

Moreover, regional climate differences and the fact that local green building star evaluation standards focus on qualitative indicators without matching economic constraints will also affect the actual input-output performance of construction projects.

##### **4.2. Feasible pathways for incremental cost control and comprehensive benefit enhancement**

Star rating selection and technology deployment should be aligned with regional climatic conditions; a higher star rating does not necessarily guarantee better economic outcomes. In hot and rainy southern regions, priority should be given to external shading and rainwater harvesting systems to reduce air-conditioning energy consumption. In severely cold northern regions, the focus should be on strengthening external wall and roof insulation to lower winter heating costs, with technologies deployed on a demand basis to avoid unnecessary cost increases from irrelevant equipment.

Moreover, promoting integrated collaborative design across architecture, heating, ventilation, and air conditioning (HVAC), water supply and drainage, and landscaping, with unified planning of

energy- and water-saving supporting systems, can avoid equipment duplication caused by separate disciplinary designs and thus reduce extra costs at the source. In procurement, two strategies can be adopted to control material and equipment costs. First, prioritize locally sourced low-carbon materials such as recycled concrete or eco-friendly panels to reduce long-distance transportation costs. Second, aggregate procurement volumes across multiple projects in the same area, and establish long-term cooperation with local suppliers to lower material premiums [9].

In the early planning stage of projects, operation and maintenance plans for green equipment should be formulated simultaneously, and standardized energy and water management procedures should be set for property management teams to prevent energy-saving facilities from being left unused. Meanwhile, developers can actively apply for local financial subsidies and tax reduction policies for green buildings to offset early incremental investment with policy funds. At the same time, taking advantage of green building brand premium and lower financing interest rates can further enlarge indirect economic benefits [10].

## 5. Conclusions and outlook

### 5.1. Conclusions

Against the dual-carbon strategic background and the trend of new urbanization, this paper systematically sorts out the composition of green building incremental costs and completes full life-cycle economic benefit calculation and analysis. The extra investment of green buildings mainly comes from five modules: energy-saving facilities, water recycling systems, low-carbon eco-materials, indoor environment upgrading and green building certification. Incremental costs rise significantly along with higher star ratings; three-star projects need to configure multiple mandatory low-carbon supporting systems, so their extra investment is much higher than one-star and two-star projects.

Green buildings can create both direct and indirect economic gains: energy and water-saving equipment continuously cut daily utility expenses, while policy subsidies, property premium and reduced financing costs can offset early extra construction spending. Single comparison of construction-stage costs has obvious limitations. Through NPV, BCR and dynamic payback period analysis, the results show that green buildings can produce stable long-term economic gains, and their payback cycle is far shorter than building service life, which proves strong economic feasibility.

Whole-process project management level also directly determines final economic returns. Blind pursuit of high star ratings, separated fragmented design and inadequate post-operation maintenance will all reduce comprehensive benefits. Effective control of incremental costs can be realized through climate-adaptive technology matching, cross-discipline integrated design, bulk centralized material procurement, standardized operation and maintenance systems, and active application for policy support.

In short, although green buildings need larger upfront construction investment, their comprehensive returns over the full life cycle are considerable. Scientific whole-process management can keep incremental investment within a reasonable range and guarantee the realization of long-term life-cycle benefits.

## 5.2. Outlook

This paper systematically sorts out incremental cost components and quantifies life-cycle economic gains, yet there still exist several limitations. The study fails to carry out differentiated analysis for different climate zones such as severe cold areas and hot-summer cold-winter regions, and lacks quantitative comparison of green technology input-output performance under diverse climatic conditions. The economic evaluation is based on a single urban office building case, with limited sample data that does not cover residential, commercial and other building types, which weakens the universality of research conclusions. Besides, the current evaluation model does not fully include implicit costs such as equipment replacement and long-term maintenance expenditure, leading to idealized deviation in calculation results.

Future research can be expanded in the following directions: collect long-term measured operation data of green projects in different cities and climate zones to form regional economic reference indicators for green buildings; expand research samples to cover residential and public buildings, and compare cost-benefit gaps between different building types; add equipment maintenance and replacement costs into the evaluation model, and carry out multi-scenario simulation under fluctuating energy and water prices to improve evaluation accuracy. Moreover, future work can develop big-data intelligent evaluation tools to provide data support for developers to select green star ratings and compare technical schemes, further optimize the green building economic evaluation system and help the construction industry achieve dual-carbon development targets.

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