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Future Banking: An Innovative Credit Product Linking Green Consumption to Carbon Emission Reduction

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Abstract

Against the backdrop of global carbon neutrality goals and the accelerating green economic transition, green finance has become a critical strategic direction for financial institutions worldwide. However, existing green financial products remain predominantly enterprise-oriented, leaving a significant gap in individual and household green consumption financing. The product features a dual-incentive mechanism whereby users earn green points proportional to their verified carbon emission reductions from purchasing electric vehicles, energy-efficient appliances, and residential photovoltaic systems. These points can be applied to offset loan interest or principal, redeemed at partner merchants, or traded on carbon exchanges. We formalize the green credit scoring model, the carbon-to-points conversion algorithm incorporating machine learning-based dynamic green factors, and the compound interest-adjusted loan deduction framework. A comprehensive financial projection over a five-year horizon demonstrates that the product achieves accounting break-even by Year 2 with approximately 833 active borrowers, yields an internal rate of return (IRR) of approximately 20.5%, and attains a static payback period of 5.83 years. Market analysis confirms strong demand driven by China's dual-carbon policy, rising consumer environmental awareness, and the expanding green finance ecosystem projected to exceed CNY 3 trillion in individual green consumption by 2030. The proposed framework bridges the "last mile" of green finance by transforming personal carbon reduction into quantifiable financial assets, establishing a sustainable closed loop of "green consumption-carbon reduction-financial reward."

Keywords

Green Finance; Carbon Emission Reduction; Green Consumption Loan; Carbon Credit Scoring; Blockchain; Big Data Analytics; Machine Learning; Sustainable Banking; Carbon Trading; IoT-based Carbon Tracking.

1. Introduction

Under the global "dual carbon" objectives and the overarching green economic transformation, financial systems worldwide are undergoing profound structural changes. Green finance, serving as a critical bridge between environmental protection and capital markets, has emerged as a key strategic direction for governments and financial institutions pursuing sustainable development [1–3]. China has explicitly committed to achieving carbon peaking by 2030 and carbon neutrality by 2060, continuously issuing policies to guide green financial innovation. Regulatory bodies including the People's Bank of China (PBOC) and the China Banking and Insurance Regulatory Commission (CBIRC) have incorporated green credit, green bonds, and

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green funds into the core development indicators of the financial system, providing institutional guarantees and policy space for green consumption finance innovation [4, 5].

From a market perspective, green finance is experiencing rapid growth. In 2024, China's green credit balance was projected to reach CNY 10.3 trillion (a 10.8% year-on-year increase), green bond issuance reached CNY 770 billion (a 24.2% increase), and green fund assets reached CNY 260 billion (a 23.8% increase) [6]. Globally, total green financial assets exceeded CNY 29.5 trillion, with compound annual growth rates consistently in the double digits. These figures indicate that green finance has evolved beyond policy directives to become a significant force driving economic restructuring and green industrial upgrading [7].

However, the current supply of green finance remains predominantly focused on the enterprise sector. Green financial products targeting individuals and households are still in their nascent stages. Although consumers purchasing electric vehicles (EVs), energy-efficient appliances, or installing photovoltaic (PV) systems demonstrate significant carbon reduction potential, they lack quantifiable economic incentives and financial support. Existing consumer loans and credit card installment products fail to reflect users' environmental contributions or incorporate carbon reduction outcomes into credit systems [8].

In this context, the "Green Consumption Loan" has been developed. Through carbon footprint tracking, big data computation, and blockchain technology, this product quantifies users' green consumption behaviors into tradable carbon credits, endowing personal carbon reduction with financial attributes and market value for the first time. Users can not only offset loan interest or principal through green points but also participate in carbon trading for additional returns, realizing the innovative paradigm of "green behavior as an asset" [9, 10]. This mechanism effectively addresses the insufficient incentives for individual green consumption and extends the application boundaries of green finance.

The main contributions of this paper are as follows:

– We propose a comprehensive Green Consumption Loan framework that integrates IoT-based carbon footprint tracking, blockchain-secured carbon credit management, AI-driven credit scoring, and dynamic loan pricing into a unified green financial product.

– We formalize the carbon-to-points conversion algorithm with machine learning-based dynamic green factors, and design a compound interest-adjusted deduction model for loan interest and principal offsets.

– We present a detailed five-year financial projection demonstrating commercial viability, including break-even analysis, IRR computation, and payback period estimation.

2. Product Design and System Architecture

2.1. System Overview and Core Mechanism

The Green Consumption Loan comprises three interconnected subsystems: the User Interface Module, the Carbon Footprint Tracking System, and the Financial Services Platform. Their coordinated operation ensures that green consumption behaviors are precisely tracked, rewarded, and financially realized.

The User Interface Module serves as the product entry point, typically operated through a mobile application or online platform. Users can complete loan applications, select green products, view green point balances and redemption status. The platform provides a user-friendly interface that simplifies the loan process and offers comprehensive product information, including various preferential policies and loan conditions.

The Carbon Footprint Tracking System is the core technical component of the mechanism. It leverages Internet of Things (IoT) technology, big data analytics, and artificial intelligence (AI) algorithms to monitor and calculate the carbon emission reductions associated with users'

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green consumption in real time. For example, when purchasing an electric vehicle, the system obtains energy efficiency and carbon emission data from the manufacturer, analyzing the vehicle's contribution to emission reduction. Similarly, when users purchase energy-efficient appliances or PV equipment, the system tracks their energy-saving performance and calculates corresponding carbon reductions based on environmental standards.

The Financial Services Platform executes core business operations. Beyond processing loan applications and approvals, it manages green point issuance and redemption. The platform calculates and distributes green points based on users' green consumption behaviors and resulting carbon reductions. These points are stored in the user's "Carbon Account," from which they can be applied to offset loan interest or principal, or redeemed for other green products and services. The platform's intelligent risk control system also dynamically adjusts loan interest rates and repayment conditions based on the user's application, credit score, and carbon reduction data.

2.2. Carbon Footprint Tracking and Green Point Generation

2.2.1. Data Collection and Interface Integration

When users purchase green products, the system automatically retrieves carbon reduction information through integration with merchants, suppliers, and service providers. For electric vehicles, vehicle-mounted sensors monitor and transmit energy consumption and driving mileage data in real time. For smart home appliances and PV systems, IoT sensors continuously track energy usage and automatically upload data to the platform. The data collection architecture is illustrated in Figure 1.

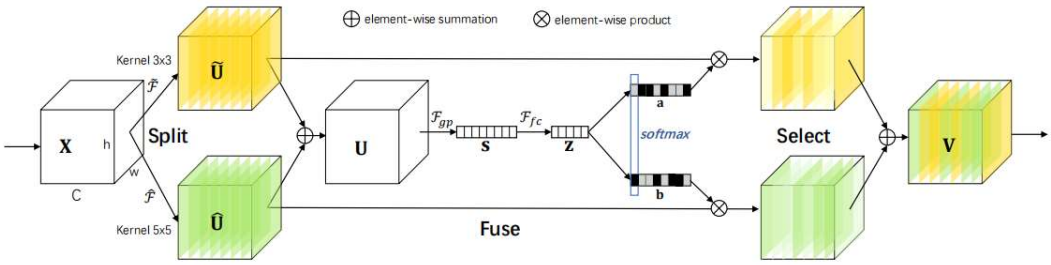

Figure 1. Data collection and interface integration architecture

2.2.2. Carbon Reduction Calculation Model

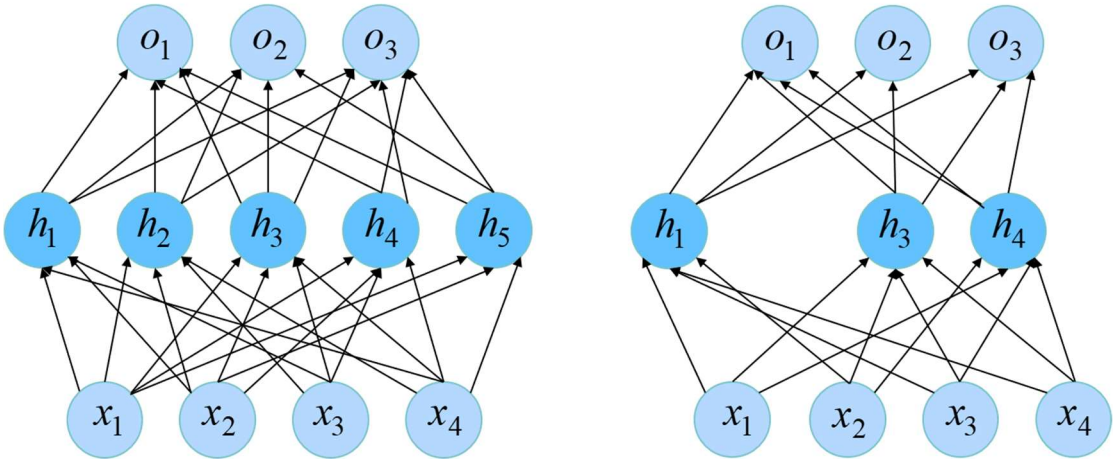

Figure 2. Neural network model for carbon reduction calculation.

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The system employs a neural network-based carbon reduction calculation model (Figure 2) that integrates multiple data sources through big data analysis. Using regression analysis, predictive modeling, and association analysis, the system accurately computes the carbon reduction attributable to each green consumption behavior.

2.2.3. Green Point Generation Algorithm

Green points represent the financial embodiment of carbon reduction behavior. Each green consumption activity generates carbon reduction data that is converted into green points using the following base formula:

$$G=C\times f_g\times w \tag{1}$$

where G denotes the generated green points, C represents the carbon reduction quantity (kg CO_2), fg is the green factor measuring the product's environmental contribution, and w is the behavioral weight reflecting the user's consumption pattern. For example, purchasing an EV that reduces emissions by 2,000 kg CO_2 with a green factor of 1.5 yields G = 2000 × 1 × 1.5 = 3,000 points.

The green factor is dynamically adjusted using a machine learning model:

$$p_{predicted}=ML(X_{user},X_{product},t) \tag{2}$$

where X_{user} represents the user's historical behavioral features, $X_{product}$ represents product characteristics, and t is the current time window capturing market changes and technological progress. The model is implemented using Random Forest or Gradient Boosted Decision Tree (GBDT) algorithms and iteratively updated to ensure fairness and flexibility.

User behavioral weighting is applied as follows:

$$G_{user}=G_{raw}\times(1+w_{user}) \tag{3}$$

where w_{user} is computed via a neural network model trained on the user's feature vector and target behavior:

$$w_{user}=NN(X_{user},Y_{user}) \tag{4}$$

The dynamic adjustment mechanism for green point calculation is illustrated in Figure 3.

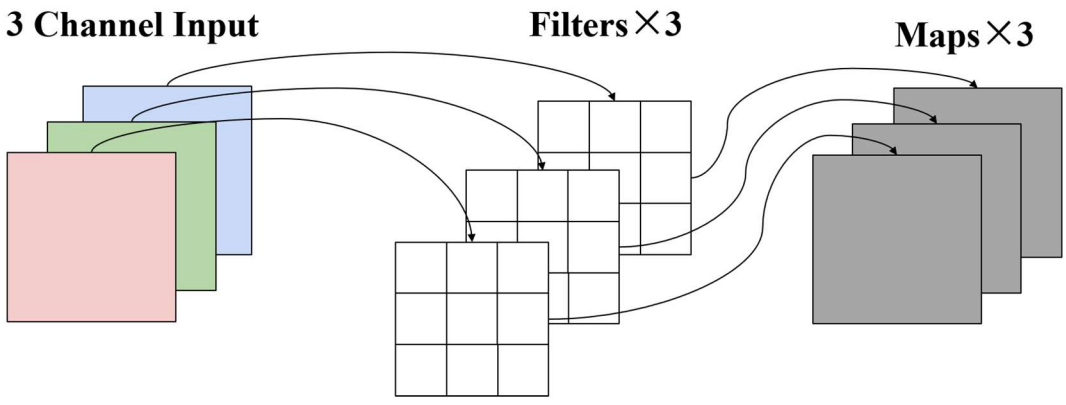

Figure 3. Dynamic adjustment mechanism for green consumption point calculation

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2.3. Loan Deduction Computation Model

2.3.1. Interest Deduction

Green points can be applied to offset loan interest. The deductible interest amount is calculated as:

$$I_{discount} = \frac{G}{100} \times r_{interest} \tag{5}$$

where $I_{discount}$ is the deductible interest amount and $r_{interest}$ is the monetary value per 100 points (typically CNY 1). For a user with 3,000 green points, the deductible interest equals 3000/100 × 1 = CNY 30.

2.3.2. Principal Deduction

Green points may also offset loan principal. The deductible principal is:

$$P_{discount} = \frac{G}{100} \times r_{principal} + \alpha \tag{6}$$

where $r_{principal}$ is the base principal deduction rate per 100 points (typically CNY 10), and α is an adjustable coefficient reflecting the user's Green Credit Score (GCS) or promotional incentives.

2.3.3. Comprehensive Loan Balance Calculation

The final loan balance after green point deductions is computed as:

$$L_{final} = L_{total} - P_{discount} - I_{discount} \tag{7}$$

For example, with a total loan of CNY 20,000, a principal deduction of CNY 3,050, and an interest deduction of CNY 30, the final balance is L_{final} = 20,000 − 3,050 − 30 = CNY 16,920.

2.4. Green Credit Scoring Model

The Green Credit Score (GCS) integrates traditional credit metrics with environmental behavior indicators:

$$GCS = w_1 \cdot \frac{C}{C_{max}} + w_2 \cdot \frac{G}{G_{max}} + w_3 \cdot \frac{t}{T_{max}} \tag{8}$$

where C is the user's cumulative carbon reduction, G is the total green points, t is the duration of green consumption participation, w_1, w_2, w_3 are weight coefficients, and C_{max}, G_{max}, T_{max} are normalization parameters. The GCS directly influences loan interest rates and credit limits, enabling a differentiated pricing logic where "green equals credit".

2.5. Compound Interest Integration

Considering the compound interest effect on loans, the total repayment amount is calculated as:

$$A = P \times \left(1 + \frac{r}{n}\right)^{nt} \tag{9}$$

where A is the final repayment amount, P is the initial principal, r is the annual interest rate, n is the compounding frequency per year (typically 12), and t is the loan term in years. The green point deductions are applied before compound interest calculation, reducing the effective principal and thereby generating cascading savings over the loan lifetime.

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2.6. AI-Powered Intelligent Loan Approval

The intelligent loan approval system comprises four layers: Data Collection, Data Processing, AI Decision Engine, and Blockchain Certification. The AI Decision Engine employs a logistic regression-based default probability model:

$$P(\text{default}) = \frac{1}{1 + e^{-(w^T x + b)}} \tag{10}$$

where x is the user's credit and carbon reduction feature vector, and w and b are model parameters. The system integrates the GCS with the default probability to implement dynamic loan pricing, enabling low-carbon, low-risk users to enjoy lower interest rates while high-risk users bear appropriate premiums.

2.7. Blockchain-Based Carbon Credit Management

The system employs a consortium blockchain to manage the full lifecycle of carbon credits. Each carbon point generation, transfer, and redemption event is recorded on-chain via smart contracts, ensuring data immutability and transparency. The decentralized architecture eliminates single points of failure and prevents data tampering. Smart contracts automate the verification of carbon reduction data and the issuance of green points, reducing human intervention and operational costs.

For carbon trading platform integration, the system uses cross-chain technology to map accumulated user carbon reductions to standardized tradable carbon assets (measured in tonnes of CO_2 equivalent). The conversion process is fully recorded on-chain, ensuring traceability and verifiability. Users can convert their carbon points into marketable carbon assets, providing additional economic returns beyond loan interest deductions.

2.8. Machine Learning-Based Predictive Models

The platform employs LSTM-based time series models for user behavior prediction:

$$y_{t+1} = f(y_t, y_{t-1}, \ldots, y_{t-n}; \theta) \tag{11}$$

where y_{t+1} represents the predicted future green consumption intensity and θ are the model parameters. For carbon reduction prediction, particularly for residential PV systems:

$$R_{year} = E_{gen} \times \gamma \tag{12}$$

where R_{year} is the annual carbon reduction, E_{gen} is the annual power generation (kWh), and γ is the grid carbon emission factor. The prediction results directly influence the scale of green point generation and provide a scientific basis for loan incentives.

3. Market Analysis

3.1. Market Demand Analysis

The development of green finance stands at the intersection of policy momentum and market awakening. On one hand, national "dual carbon" strategic objectives continue to strengthen energy structure adjustment and consumption-side emission reduction requirements. On the other hand, consumer upgrades and rising environmental awareness have significantly expanded the market potential for green products and services [1, 7]. Whether for EVs, energy-

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efficient appliances, or household PV systems, these categories are becoming important entry points for financial service innovation.

3.1.1. Policy Background

China's policy framework for environmental protection and carbon reduction has matured considerably. The "dual carbon" targets have been elevated to national strategy, signaling the transition from high-energy-consumption to high-efficiency, clean, low-carbon economic growth.

3.1.2. Consumer Green Awareness

Consumer green consumption awareness is transitioning from "ideological identification" to "behavioral self-consciousness." Information dissemination, social media influence, and the emergence of younger consumers as the primary consumption force have accelerated this transition. The introduction of economic return mechanisms further strengthens consumer participation, as green consumption is increasingly recognized as both environmentally and economically rational.

3.2. Competitive Analysis

Table 1 presents a comparative analysis of existing green financial products in the market, including green credit, green bonds, green funds, green insurance, green trusts, and carbon financial products.

Table 1. Comparative Analysis of Green Financial Products

Product Type	Definition / Use of Funds	Key Features	Applicable Scenarios	Risks / Limitations
Green Credit	Loans to green-standard projects for energy conservation, clean energy, green buildings	Preferential rates; long terms; project-evaluation bound	Enterprise: renewable energy, green parks; Individual: EVs, PV, energy-efficient appliances	Requires green certification; collateral may be needed; longer approval cycles
Green Bonds	Debt financing for environmental projects with mandated disclosure	Large capital scale; third-party certification; dedicated tracking	Government/Enterprise: renewable energy, green transport, pollution control	Continuous disclosure required; market rate risks; greenwashing concerns
Green Funds	Investment in environmental and sustainable assets via public/private funds	Diversified; thematic; covers clean tech, energy storage	Institutional/Individual: asset allocation and thematic investment	Market volatility; classification inconsistencies; growing ESG reporting requirements
Carbon Finance	Financial instruments related to carbon emission rights and reduction trading	Market-linked pricing; hedging and asset management capabilities	Enterprise compliance hedging; institutional carbon asset allocation	Policy and quota mechanism dependency; high price volatility

3.3. Differentiated Competitive Advantages

The Green Consumption Loan's primary competitive advantage lies in its innovative carbon reduction incentive mechanism. Unlike traditional green financial products that rely on fixed interest rate reductions, this product introduces a green point system ensuring that every green

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consumption behavior translates into tangible financial returns. The integration with carbon markets and trading platforms further enhances competitiveness by enabling users' green points to participate in broader carbon reduction mechanisms. Additionally, blockchain technology ensures the transparency and credibility of the green point system, while the multi-scenario point redemption network extends the product's reach into daily life beyond purely financial applications [9, 10].

4. Business Model and Revenue Structure

4.1. Value Proposition

The product delivers triple value: (1) User Value: users enjoy dual returns of "consumption savings" and "environmental gains"; (2) Industry Value: by partnering with green product manufacturers, the platform provides user carbon reduction data for precision marketing and product optimization; (3) Social Value: by binding individual green consumption to carbon reduction through financial instruments.

4.2. Key Business Operations

The core business extends beyond simple lending to encompass full lifecycle management: pre-loan consulting and AI-driven risk assessment; in-loan real-time carbon footprint tracking and green insurance integration; post-loan value realization through flexible point utilization channels including interest deduction, principal offset, merchant redemption, and carbon trading. The green point circulation operates across three domains: the Financial Endpoint (loan cost deduction), the Consumption Endpoint (merchant goods and services), and the Trading Endpoint (carbon market transactions).

4.3. Revenue Sources

Revenue is structured across three tiers: (1) Base Revenue from loan interest, dynamically adjusted based on user credit status, loan tenure, and green behavioral scores; (2) Value-Added Revenue from green point management fees, carbon trading commissions, and data analytics services provided to government agencies and enterprise partners; (3) Policy Subsidy Revenue from government interest subsidies for green financial products, which can be strategically retained or partially passed to users depending on market conditions [4, 6].

4.4. Partner Ecosystem

Table 2 summarizes the key partnership structure of the Green Consumption Loan ecosystem.

Table 2. Key Partnership Structure

Partner Type	Collaboration Content	Collaboration Value
Green Product Manufacturers	Data interface integration for certified carbon reduction data; channel embedding in online/offline sales processes	Access to green consumption data; brand synergy expanding market reach
Financial Institutions	Joint credit and channel sharing with local banks and trust companies; cross-selling to existing quality customers	Reduced funding costs; enhanced user trust through banking credibility
Carbon Trading Platforms	Strategic cooperation with national/regional carbon exchanges; real-time carbon price data integration	Market-based carbon point monetization; enhanced point value proposition
Green Merchants	Point redemption for goods and services at green retailers, EV maintenance shops, organic restaurants	Enriched point application scenarios; cross-industry traffic exchange
Government / Environmental Agencies	Policy subsidy applications; carbon reporting and compliance data support	Reduced operating costs; alignment with national dual-carbon strategic direction

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5. Marketing Strategy and Implementation Plan

5.1. Three-Phase Implementation Roadmap

5.1.1. Pilot Phase: Campus and Local Bank Collaboration

The pilot phase targets university campuses and local banks as initial channels. Students and young faculty members exhibit high receptivity to novel concepts and genuine identification with green values. Local banks offer regional expertise and flexible community relationships. Joint small-amount green loan products are designed with tiered limits (CNY 5,000–50,000), immediate online approval, and campus-exclusive application channels. The "Carbon Account" function is demonstrated through integration with campus smart card systems, shared bicycle platforms, and online payment systems.

5.1.2. Promotion Phase: Manufacturer and Bank Joint Marketing

The promotion phase expands through partnerships with EV manufacturers and energy-efficient appliance brands, leveraging their established customer bases and brand trust. Joint marketing activities include online campaigns with live-streaming sessions, offline green consumption events in commercial districts, and combined promotional packages featuring loan interest subsidies and manufacturer discounts. The carbon point system is integrated with manufacturer sales platforms, enabling seamless cross-platform point circulation.

5.1.3. Expansion Phase: Government and Carbon Trading Integration

The expansion phase integrates with local government agencies and carbon trading platforms. Carbon accounts are incorporated into regional carbon inclusion systems with defined personal carbon point certification rules. In the credit module, high-accumulation users are automatically whitelisted for preferential loan terms. In the public service module, carbon points are redeemable for urban transportation cards and municipal services. Integration with carbon trading platforms enables users to open "Personal Carbon Asset Accounts" for trading verified carbon reductions.

5.2. Customer Acquisition and Retention

The customer acquisition strategy combines point-based incentives with social media engagement. Upon completing green consumption, the system generates corresponding points that can be visualized through the mobile application. Social media platforms are leveraged for content-driven user transmission through authentic user cases, energy-saving lifestyle recommendations, and themed campaigns aligned with environmental events. In-app community features including green leaderboards, carbon reduction competitions, and gamified membership tiers with escalating benefits strengthen user engagement and retention.

6. Carbon Reduction Effect Projection

Table 3. Carbon Reduction Effect Projections by Product Category

Product Category	Annual Reduction (kg CO_2)	5-Year Cumulative (kg CO_2)	Assumptions
Electric Vehicle	≈ 950	≈ 5,040	12,000 km/year; 15 kWh/100km; grid factor 0.55 kgCO_2/kWh; 3% annual grid decarbonization
Energy-Efficient Appliance	≈ 80	≈ 378	Energy efficiency improvement of 0.4 kWh/day; grid factor 0.55 kgCO_2/kWh
Residential PV (5 kW)	≈ 2,750	≈ 12,949	Average generation 5,000 kWh/year; grid factor 0.55 kgCO_2/kWh; 3% annual decarbonization

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Table 3 presents the carbon reduction projections for the three primary product categories based on standardized emission factors and usage assumptions.

Based on a pilot scale of 1,000 users (40% EV, 40% energy-efficient appliances, 20% PV), the aggregate annual carbon reduction totals approximately 962 tonnes CO_2. These reductions are fully convertible to green points (1 kg CO_2 ≈ 1 point) for loan interest and principal offsets, forming the "environmental behavior-financial incentive" closed loop.

7. Financial Analysis and Projections

7.1. Assumptions

The financial projections are based on the following core assumptions: (1) project cycle of 10 years with a 5-year forecast horizon; (2) staged user growth (400, 1000, 2000, 3000, 4000 users in Years 1–5); (3) average loan amount of CNY 50,000 with a 3-year average term and 6% annual interest rate; (4) comprehensive funding cost of 3.5% annually; (5) credit impairment losses at 1.5% of average loan balance; (6) value-added revenues commencing from Year 2 (data services) and Year 3 (carbon trading); (7) corporate income tax rate of 15% under green finance preferential policies; (8) initial equity investment of CNY 30 million.

7.2. Projected Income Statement

Table 4 presents the five-year projected income statement (all figures in CNY 10,000).

Table 4. Projected Income Statement (CNY 10,000)

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Interest Revenue	60	270	720	1,410	2,250
Data Value-Added Revenue	0	50	200	450	800
Carbon Trading Revenue	0	0	100	300	600
Point Service Revenue	5	40	120	240	400
Funding Cost	35	157.5	420	882.5	1,312.5
Net Operating Revenue	30	202.5	720	1,577.5	2,737.5
Total Operating Expenses	33	155.25	432	862.75	1,398.75
Gross Profit	-3	47.25	288	714.75	1,338.75
Income Tax	0	7.09	43.2	107.21	200.81
Net Profit	-3	40.16	244.8	607.54	1,137.94

7.3. Break-Even Analysis

Setting net profit to zero and simplifying revenue to interest income, the break-even point requires annual interest revenue of approximately CNY 2.5 million, corresponding to a loan balance of CNY 2.5M / 6% ≈ CNY 41.67 million, or approximately 833 active borrowers at an average loan of CNY 50,000. The projection confirms that Year 2 interest revenue (CNY 2.7 million) exceeds the break-even threshold, consistent with the Year 2 positive net profit of CNY 401,600.

7.4. Internal Rate of Return and Payback Period

The Internal Rate of Return (IRR) is defined as the discount rate that equates the net present value (NPV) to zero:

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$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1 + IRR)^t} = 0 \quad (13)$$

With initial investment of CNY 30 million and net profit cash flows of −0.03M, 0.4016M, 2.448M, 6.0754M, and 11.3794M over Years 1–5, applying the Gordon Growth Model for terminal value estimation (3% perpetual growth rate), the computed IRR is approximately 20.5%. This significantly exceeds typical cost of capital benchmarks (8–12%), confirming project viability.

The static payback period is calculated using cumulative net cash flow analysis. Table 5 presents the cumulative cash flow trajectory.

Table 5. Cumulative Cash Flow Trajectory (CNY 10,000)

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
-3,000	-3,003	-2,962.84	-2,718.04	-2,110.50	-972.56

Since cumulative cash flow remains negative through Year 5, projecting Year 6 cash flow at CNY 11,720,800 (3% growth), the cumulative flow turns positive at CNY 1,995,200. The static payback period is approximately 5.83 years, indicating that the initial CNY 30 million investment is fully recovered within approximately six years.

8. Conclusion and Future Work

This paper presents a comprehensive framework for the Green Consumption Loan, an innovative credit product that bridges the "last mile" of green finance by connecting individual green consumption behaviors to quantifiable financial incentives. By integrating IoT-based carbon footprint tracking, blockchain-secured carbon credit management, AI-powered credit scoring, and dynamic loan pricing, the product transforms personal carbon reduction into tradable financial assets.

The proposed carbon-to-points conversion algorithm, incorporating machine learning-based dynamic green factors and behavioral weighting, ensures fair and adaptive reward mechanisms. The Green Credit Score (GCS) model extends traditional credit assessment by incorporating environmental behavior metrics, enabling differentiated pricing that rewards low-carbon lifestyles. The compound interest-adjusted loan deduction framework provides users with direct economic benefits proportional to their environmental contributions.

Financial projections demonstrate strong commercial viability: the product achieves accounting break-even by Year 2, yields an IRR of approximately 20.5%, and recovers initial investment within 5.83 years. These results, combined with the expanding policy support for green finance and rising consumer environmental awareness, suggest significant market potential for green consumption financial products.

Several directions for future work merit investigation. The current framework has been designed primarily for the Chinese market; adaptation to international regulatory environments and carbon trading standards represents an important extension. The integration of advanced privacy-preserving technologies such as federated learning for cross-institutional credit data sharing could enhance the GCS model without compromising user privacy.

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