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Landscape Design Planning and Research of Renewable Energy Application Projects from a Sustainable Perspective

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Abstract. The substantial emission of carbon exacerbates climate change, posing a threat to human survival and sustainable development. The primary inducement for the carbon emission issue is the excessive dependence of human activities on fossil energy. The construction industry is among the major sectors contributing to carbon emissions, and the low-carbon development within this industry serves as the cyclical engine for the path towards carbon reduction. Currently, there is limited research that integrates low-carbon development with the landscape design of renewable energy projects. Most studies emphasize the application of relevant low-carbon measures, overlooking the landmark effects of building decarbonization. Addressing how to truly achieve landscape design for renewable energy projects from a sustainable perspective based on relevant carbon emission quantification indicators during the architectural design phase is an urgent problem to be solved. This paper takes a sustainable perspective as the starting point and systematically summarizes landscape design concepts from this perspective. It proposes three major design approaches: ecological sustainability, cultural integration, and the application of advanced technology. Using these approaches, the paper tackles the balance between economics, energy, and the environment in landscape design, recognizing it as essentially a high-dimensional multi-objective optimization problem from a methodological perspective. The paper introduces an energy-economy-environment coupling model and utilizes big data. After low-carbon planning and design, both the net carbon footprint and total carbon footprint of the landscape significantly decrease. The Greenfield carbon sequestration per kilogram increases from 301,023.21 to the current 347,856.02, with an increase of 46,832.81.

Key words. Sustainable Perspective, Low-carbon Philosophy, Landscape Design, Renewable Energy, Design Principles.

1. Introduction

Carbon emissions refer to the release of greenhouse gases, primarily CO_2, and the significant increase in carbon emissions exacerbates climate change, leading to the greenhouse effect, global temperature rise, and threats to human survival and sustainable development. The excessive dependence on fossil fuels in human activities is the leading cause of carbon emissions. Currently, global industries' impact on climate change is mainly measured by carbon emissions, with the construction industry being one of the significant contributors. The low-carbon development of the construction industry serves as a driving force for leading China's low-carbon path.

Effective carbon reduction measures for buildings are often based on quantifying carbon emissions. Researchers such as Tarancón Morán and del Río González [2] analyzed the relationship between sectors in the Spanish construction industry and the factors influencing carbon emissions using input-output analysis. Mavromatidis *et al*. [3] evaluated the Swiss construction industry's energy consumption and carbon emissions using the Kaya identity, measuring building performance based on carbon emission targets. Zhang *et al*. [4] conducted statistical analysis on relevant data from the construction industry in Gansu Province over 13 years, identifying carbon emission patterns and influencing factors. Qu *et al*. [5] conducted a regionalized analysis of carbon emissions during the production phase of residential buildings in China from 1982 to 2011. They used the German DGNB assessment system to calculate carbon emission factors and found regional characteristics of fixed emissions in Chinese residential buildings correlated with regional economic development. Chau *et al*. [6] compared three quantification methods: Life Cycle Assessment (LCA), Life Cycle Energy Assessment (LCEA), and Life Cycle Carbon Emission Assessment (LCCO2A), leaning toward LCA and LCCO2A for building carbon emissions analysis. Ju and Chen [7] conducted a literature analysis of relevant domestic studies from 1997 to 2013, dividing building carbon emission calculations under the life cycle theory into macro and micro perspectives. They emphasized the impact of material and energy database choices on related carbon emission indicators and categorized life cycle carbon emission calculation methods into three types: empirical methods, material balance methods, and emission factor methods. Ge *et al*. [8] simulated an on-site Life Cycle Assessment for a museum in Hangzhou, proposing three energy-saving and low-carbon strategies: replacing glass curtain walls with solid walls, adding roof and façade shading, and controlling air-conditioning room temperature, guiding the construction of green museum buildings.

Although there have been relevant achievements in research on low-carbon design in construction, there are still some limitations. Moreover, there is a lack of integration with the landscape design of renewable energy projects, emphasizing the application of relevant low-carbon measures and overlooking the indicative effects of building decarbonization. Addressing how to achieve landscape design for renewable energy projects from a sustainable perspective based on quantifiable carbon emission indicators in the architectural design phase is an urgent problem. This article takes a sustainable perspective as the starting point to systematically summarize the landscape design principles within this framework, providing three major design concepts. Simultaneously, it constructs an energy-economic-environment coupling model for renewable energy projects and applies it to big data. After low-carbon planning, there is a significant reduction in both net and total carbon footprints. The carbon sink of Greenfield increases from 301,023.21 to the current 347,856.02 per kilogram, showing an increase of 46,832.81.

2. Principles of Landscape Design from a Sustainable Perspective

As the research on sustainable design deepens, scholars have finely defined it from various dimensions. In terms of keyword segmentation, the object dimension covers aspects such as humanity, users and consumers, and resources; the attribute dimension includes natural, social, economic, and technological attributes; the means dimension involves integrating products and services, efficient resource utilization, engaging in design practice, and participating in design education and research; the goal dimension includes purposeful outputs, the generation of holistic solutions, reduced energy consumption, environmental protection, and balanced and rational allocation of resources.

The core objective is to achieve comprehensive design, reduce pollution and energy consumption, rationalise resource allocation, and construct a concept that seeks a better quality of life. Figure 1 illustrates the ecological green design approach within this framework. In this context, ecological sustainability is seen as the foundation, economic sustainability as the safeguard, and social sustainability as the ultimate design purpose [9], [10]. That is ecology, humanities, and technology. Based on these discussions, the author has summarized three design approaches: ecological sustainability, cultural integration, and the application of advanced technology.

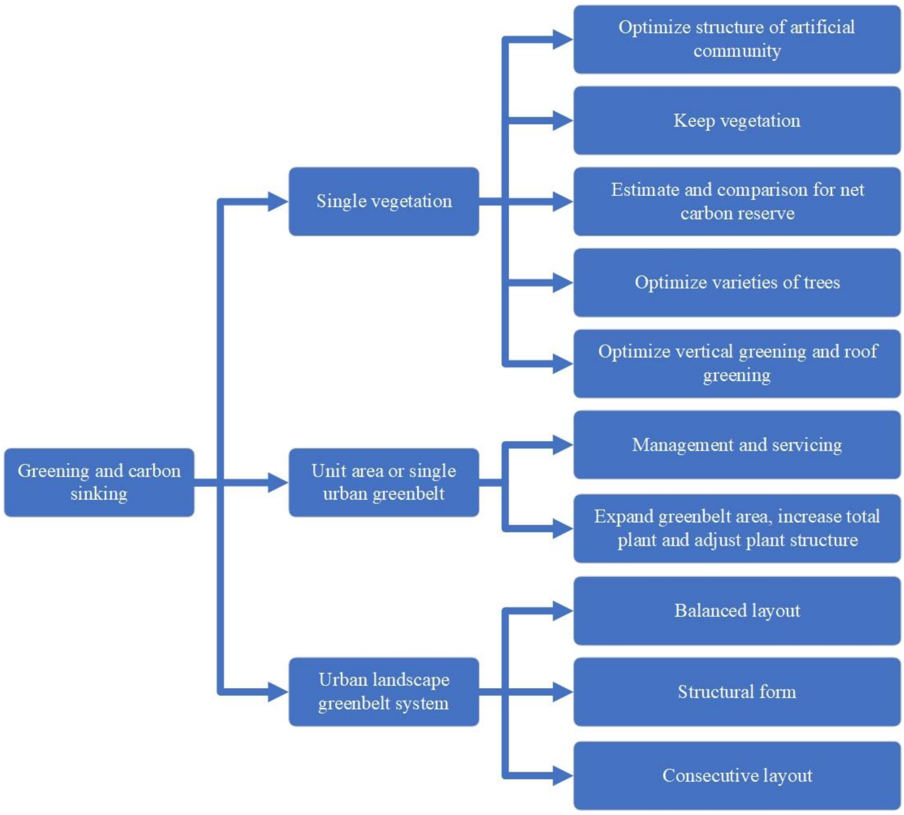

Figure 1. Ecological Green Landscape Design Method

In sustainable landscape design, integrating specific renewable energy technologies is crucial. On the one hand, incorporating solar panels requires the selection of appropriate locations to maximize sunlight exposure while ensuring minimal visual impact on the landscape. Specific strategies include ground-mounted solar arrays and building integrated photovoltaic systems (BIPV). The ground-mounted solar array is suitable for large open spaces and reduces visual interference through a reasonable layout and combination of terrain. Integrating photovoltaic systems integrates solar panels directly into building materials, such as roofs and facades, to generate energy and act as building design elements. Aesthetically, the solar panels coexist harmoniously with the surrounding environment through the design of vegetation, shading structure and material selection.

The integration of wind turbines requires consideration of location choices and scale choices. Selecting a location with abundant wind resources and minimal impact on the surrounding environment requires an assessment of noise, shadow flicker and ecological effects. Small wind turbines are more suitable in urban environments, while giant wind turbines are more efficient in rural or open areas. Mitigate wind turbines' visual and physical effects by designing landscape elements such as wind barriers and vegetation. In addition, the integration of biomass systems utilizes organic waste in the landscape for energy production. The system's layout needs to consider the footprint and process flow to reduce the damage to the landscape. At the same time, potential odour and waste management issues are addressed to harmonize the system with the overall design of the landscape. Regarding aesthetics, the biomass treatment facilities are integrated into the natural landscape through vegetation and structural design.

A. Principle of Ecological Sustainability

With the dissemination of sustainable concepts across different fields, there is an increasing consensus on the coordinated development of society and the environment. Sustainable landscapes have become a new direction and a specific practical strategy in landscape design. In 1993, the American Society of Landscape Architects (ASLA) released the "ASLA Declaration of Environment and Development," presenting the concept of sustainable environments and development from the landscape design perspective. The universal principles outlined include the interconnectedness of human health and happiness, culture, and settlements with the health of other species on Earth and the overall health of global ecosystems; our descendants should inherit an environment of equal or even better quality than ours; long-term economic development and environmental protection are mutually dependent; the harmonious coexistence of humans and nature is the central goal of sustainable development, necessitating the simultaneous preservation of natural and human health.

To achieve sustainable development goals, Figure 2 illustrates the issues involved in regional ecological sustainable development, emphasizing that environmental protection and ecological functionality must be integral components of the development process. Developed countries must recognize and bear the pressure they impose on the global environment to achieve sustainable national and global development [11].

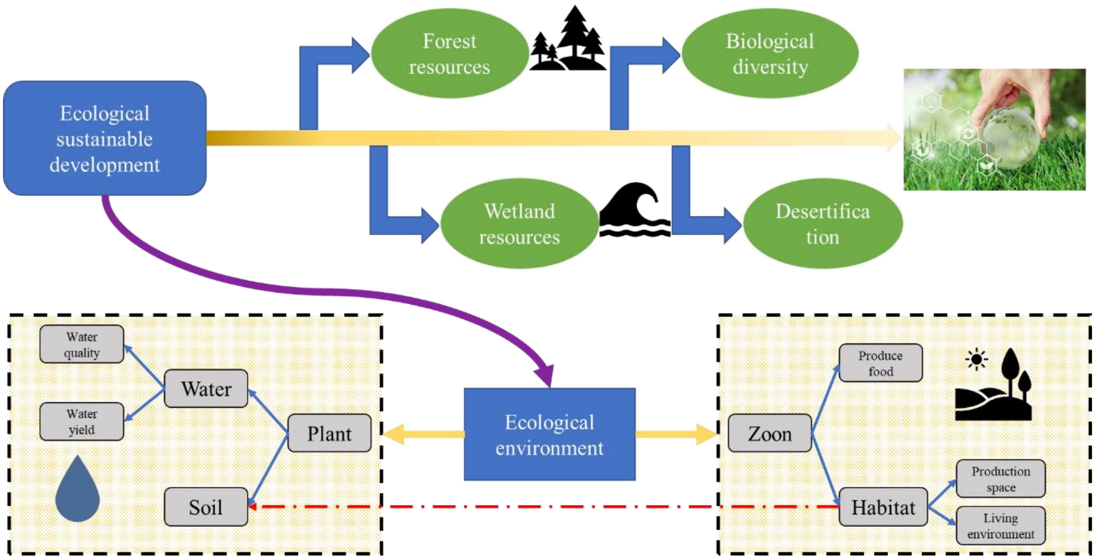

Figure 2. Regional Ecological Sustainable Development Involves Problems

From the declaration proposed by ASLA, we can gain further insight into sustainable landscapes. Firstly, landscapes serve as carriers of natural ecosystems. The existence of landscapes provides an interface for various biological and non-biological processes in the natural world to occur and interact. Landscapes are also ecosystems created by humans. In this ecosystem, health and balance can be maintained only when human survival and development are coordinated with the ecological environment [12], [13]. Secondly, landscapes have certain ecological service functions. Landscapes can provide diverse habitats for organisms, material support for human society, regulate microclimates, resist floods, and maintain dynamic water balance in the environment. They can also provide: 1)Spiritual and cultural support for human society; 2) Meeting people's spiritual and cultural needs; and 3) Serving as educational and scientific venues. The basis for landscapes to provide these ecological service functions lies in the regenerative and sustainability of the landscape system. Therefore, proposing sustainable landscapes makes it necessary for landscapes to have self-renewal and self-organization capabilities. In the design process of sustainable landscapes, we must minimize artificial intervention in the natural regeneration and self-organization processes, leaving maximum space for natural self-regeneration and enhancing the regenerative capacity of the disrupted natural environment [14]. Sustainable landscapes provide an interface for communication in biological and non-biological processes in the natural world and contribute to the inheritance of science and culture in human society. Based on this, sustainable landscapes exhibit three essential characteristics: In non-biological natural processes, sustainable landscapes can fully utilize natural wind and sunlight, maintain the balance of surface and groundwater, ensure soil erosion prevention, and guarantee the renewability and recyclability of materials. In biological processes, sustainable landscapes can help maintain biodiversity in local habitats, ensuring the integrity of biological communities without being invaded by alien species. In human processes, sustainable landscapes can ensure the continuity of site context, inherit historical culture, and create places with a sense of belonging and identity.

Sustainable landscapes provide an interface for biological and non-biological processes, promoting balanced development between human society and the natural environment [15]. Sustainable landscapes can maintain the health of the ecological environment, save economic costs, and contribute to the inheritance of human history and culture.

B. The Design Concept of Local Culture Integration

The accelerating pace of urban construction has led to rapid changes in the urban landscape. While this brings convenience, it is also accompanied by problems. These problems mainly manifest in three aspects: firstly, the advancement of urbanization results in the destruction of local buildings and landscapes, even being directly replaced by high-rise buildings, causing the gradual disappearance of regionally distinctive historical contexts. Secondly, the high integration of informatization and technologization leads to more frequent cultural blending. Domestic architecture and landscape designs are often entrusted to foreign designers, resulting in design elements and styles displaying distinct foreign cultural characteristics. At the same time, some domestic landscape designers attempt to imitate foreign designers' methods, giving the city's landscapes and buildings an exotic feel. Lastly, against cultural innovation, there is a phenomenon of piecing together local cultural symbols, where local cultural content is mechanically applied to design schemes, causing disharmony in architecture or landscape design.

Urban landscape design must be comprehensive in the new era, emphasizing local culture. Traditional culture is the spiritual wealth for the sustainable development of cities and the inspiration for creating culturally renowned cities. Without comprehensive planning and design, the emphasized problems mentioned earlier may arise. Meanwhile, some regions have relatively unique cultural characteristics, requiring more attention to the inheritance and protection of local culture during planning. Simultaneously, it is essential to grasp the characteristics of visual arts to better showcase regional features and create smart cities that embody regional cultural landscapes without losing modern characteristics [16], [17].

Urban development cannot be separated from local culture, and the construction of landscapes similarly requires cultural support. Whether it is Western or traditional Chinese architecture, attempts at imitation, copying, and excessive assimilation have proven unsuccessful. Each region has its corresponding local context, and attention to the inheritance and innovation of local culture is crucial during landscape planning. This ensures that the landscape has more soul while extending the vitality of local culture. Integrating visual artistic techniques into the process of cultural inheritance and innovation can effectively enhance cultural influence, making the cultural connotation of the city more profound.

In landscape planning, various means of expression should be comprehensively utilized and cleverly integrated with local culture. Firstly, symbolism and metaphor should be employed. Landscape art expresses infinite cultural spirits through limited images. By extracting local culture and reshaping the environment through symbolic and metaphorical methods, people are encouraged to seek emotional belonging. The application of this design technique enriches the cultural connotation of the landscape. Secondly, representation and abstraction should be considered. Representation in landscape planning can be achieved by directly applying local culture or using new materials and technologies to reproduce landscape features with local characteristics. For example, representing cultural anecdotes and historical scenes through landscape sketches allows viewers to experience and understand local culture more authentically. Abstraction involves extracting the essence of rich materials and refining local culture through abstract methods, utilizing formal expression techniques to present it in the landscape [18].

C. Application of Advanced Technology in Project Design

In sustainable landscape design, advanced energy management control strategies are essential. Innovative grid technology enables efficient management by monitoring and optimizing energy use in real-time. Specific techniques include real-time monitoring, automated control and optimization of environmental conditions. Real-time monitoring Using sensors and data acquisition systems, real-time monitoring of energy consumption data, identification of high energy consumption areas, and dynamic adjustment. Automated control Optimizes energy distribution through computerised systems, such as energy storage during peak hours and energy storage during off-peak hours. Optimization of environmental conditions dynamically adjusts energy production. It uses strategies based on weather forecasts and environmental conditions, such as maximizing solar energy utilization when the sun is sunny and increasing wind energy utilization when the wind is strong. Innovative grid technology improves energy efficiency and enhances system reliability and sustainability.

Digital media technology is an emerging medium widely applied across various industries. In architectural landscape design and historical monument restoration, digital technology is being extensively utilized [19]. Figure 3 illustrates the application of digital media technology in art. Many cities have begun adopting digital technology for dynamic design work [20]. Simultaneously, digital media technology can provide real-time reflections on urban architectural landscape design progress, comprehensively understand the details of projects, and promptly analyze and address any unique issues during project execution. In the backdrop of increasingly diverse societal ideologies and aesthetic development, the development trend of architectural landscape design is also becoming more varied. By incorporating relevant technologies of digital media art into architectural landscape design, various forms of transformation and timely modifications can be achieved, enabling the possibility of transitioning between different expressive forms. Moreover, this helps enhance the artistic sense of architectural landscape design, as digital media art presents a strong trend towards artistry. Combining it with architectural landscape design will propel the development of art.

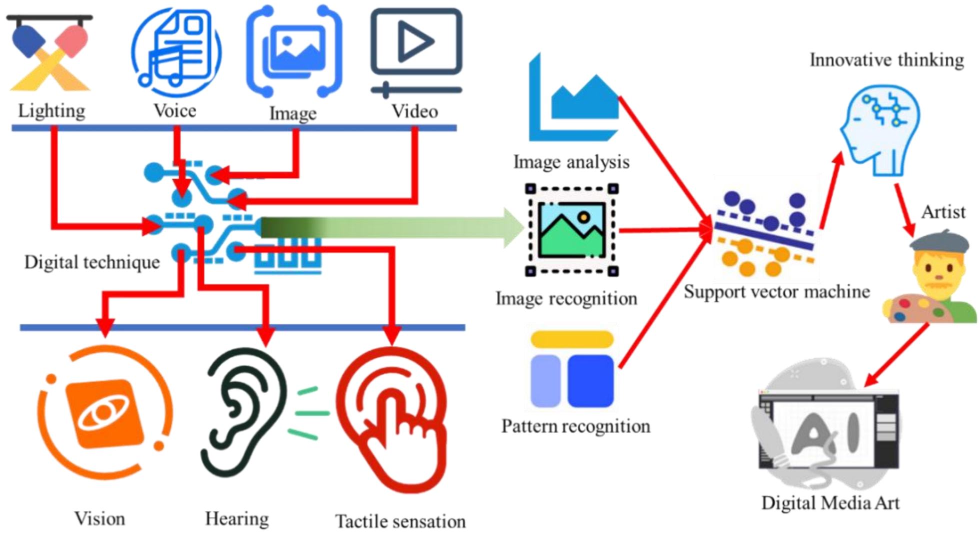

Figure 3. The Application of Digital Media Art

Digital media art in architectural landscape design can drive urban development. Some cities employ digital media art for various commercial advertising promotions, greatly enhancing the company's brand image. This not only boosts the city's visibility through advertising sales but also enhances the overall competitiveness of the city. For instance, LED facades are installed on commercial streets in large cities, using digital technology to facilitate both commercial and public services, enabling citizens to better understand their needs. Applying digital media art in architectural landscape design also facilitates cultural exchange in the city. To allow more citizens to feel the "cultural temperature," creating distinctive buildings with urban characteristics is necessary. By understanding the public mindset, the goal is to resonate citizens' emotions with the city's natural scenery, gradually enhancing the overall strength of significant cities. Digital media art can also effectively improve the city's ecological environment. Diversification in architectural landscape trends presented by digital media art, such as digital lighting and laser projection, reduces excessive use of environmental resources to achieve energy savings and emissions reduction. The demands of architectural landscape design are closely related to designers' thoughts and are closely linked to the development of digital media. The ultimate goal of architectural landscape design is to design for the general public, and therefore, the design should be based on practical situations. In today's era, digital media art has permeated daily work and various fields.

Media architecture is a new product type produced by integrating architecture and digital media. It encompasses knowledge related to architecture and involves forms such as media animation and film and television media, constituting a complex and large-scale art form. For example, as a new decorative material, LED has enriched its colours and connotations through technological advancements. In urban life, people's aesthetic requirements are no longer limited to simple static visual presentations but emphasize communication with people and emotional resonance. In most prominent buildings in China, LED building advertisements use TV animation and image conversion [21], [22]. In the past, 3D technology was used, and today, virtual reality technology is employed. Virtual reality technology achieves the simulated design of buildings. To obtain the most realistic experience regarding hearing, vision, and touch, creating a realistic scene in three dimensions and leveraging software and hardware support to give users an "illusion" of being in the real world is necessary. In practical applications, designers first use virtual technology to construct a landscape of a building, then analyze its spatial environment, and subsequently conceive and design its morphological structure, inspiring designers' creativity and ultimately achieving the desired effect. At the same time, the use of virtual reality technology helps cultivate innovative design thinking in designers. The conceptualization of architectural landscape design mainly falls into two categories: "rational" and "emotional." The purpose of emotional thinking is to inspire creativity, while rational thinking is to deduce and analyze rationality in architectural design, enabling the architectural landscape to embody its unique creativity and achieve the desired landscape effect. In architectural design, virtual technology makes design modelling more intuitive, accurate, and concrete, facilitating designers' revisions to the design.

3. Research on Integrated Landscape Design of Renewable Energy Projects

To limit the global average temperature rise to less than two °C by the end of this century, the Paris Agreement proposes an international framework for achieving emission reduction targets through Nationally Determined Contributions (NDCs). This requires coordinated efforts from various countries and industries to address the challenges [23]. Carbon emissions, primarily in the form of CO_2, contribute significantly to climate change by intensifying the greenhouse effect, leading to a rise in global temperatures. This phenomenon poses threats to human survival and sustainable development. The overreliance on fossil fuels in human activities significantly contributes to carbon emission issues. Currently, industries' impact on climate change is primarily measured by their carbon emissions, and the construction industry stands out as one of the significant contributors. Building energy consumption ranks as the world's second-largest energy-consuming sector, and the energy consumed during its operational phase is a significant factor affecting greenhouse gas emissions, environmental pollution, and resource depletion. It is also a crucial factor threatening global sustainable development and climate change goals [24].

The low-carbon development of the construction industry serves as a driving force for China's path towards a low-carbon future. While there have been relevant achievements in low-carbon design research for buildings, there are still certain limitations. There needs to be more emphasis on the low-carbon development of buildings, and understanding low-carbon design principles is often unclear. Many approaches rely on the accumulation of relevant technologies, emphasizing the application of various low-carbon measures but overlooking the indicative effects of low-carbonization in buildings. This study addresses the critical issue of achieving low carbonisation in public buildings based on relevant carbon emission quantification indicators during the building design phase. The author will explore this by constructing an energy-economy-environment coupled model, combined with big data, to conduct comprehensive landscape design research for renewable energy projects based on a sustainable perspective.

A. Construction of Energy-economy-environment Coupling Model

In managing the lifecycle of solar and wind energy generation, it is essential to comprehensively consider the coupled footprints between energy, the economy, and the environment, with particular attention to the balancing effects. This balancing effect is manifested in two aspects: firstly, there is a need to balance the relationship between carbon reduction benefits and lifecycle carbon emissions, and secondly, there is a need to balance the relationship between energy, environmental, and economic footprints. From a methodological perspective, the balancing effect among multiple footprints (more than three) is a high-dimensional multi-objective optimization problem. However, traditional bottom-up optimization models and standard intelligent algorithms have drawbacks in addressing high-dimensional multi-objective optimization problems (more than three objectives). In practical applications, optimization objectives are often more than one or two but rather exceed three. Existing Evolutionary Multi-Objective Optimization Algorithms (EMO) are inadequate for high-dimensional objective spaces, and the main problems include: 1) A sluggish search process is caused by an increase in the fraction of non-dominated solutions in the population as the number of optimization targets rises; 2) in a high-dimensional objective space, calculating the diversity-maintaining metric is excessively complex, making it challenging to find neighbouring elements of solutions; 3) for a high-dimensional objective space, the search efficiency of recombination operators is too low; 4) due to the large number of objective functions, the Pareto front is challenging to represent, and decision-makers cannot choose the desired solutions; 5) the computational cost of performance metrics is too high to evaluate algorithm results; 6) visualizing results in a high-dimensional objective space is also a challenge.

To address these issues, current research employs improved EMO methods. Apart from the problems above, another obstacle in applying algorithms is that the objective solution set is concentrated in a small region of the Pareto front. The fundamental idea of the Pareto-based method is to use a fitness allocation strategy based on Pareto dominance to find all non-dominated individuals in the current evolving population. Among many Multi-Objective Evolutionary Algorithms (MOEA), those based on Pareto dominance are the most popular. These algorithms first use the Pareto dominance criterion to select non-dominated solutions for good convergence performance. Then, through a density estimate-based selection criterion, they enhance the diversity of selected solutions. However, research has found that objective functions often degenerate into low-dimensional optimization, generally less than 2-3 dimensions, making identifying redundant objectives challenging.

To address the above problems, optimization algorithms that use unique dominance relationships or predefined target search methods, including predefined sets of search directions spanning the entire Pareto front or predefined multiple reference points, can be introduced. The third-generation Non-dominated Sorting Genetic Algorithm-III (NSGA-III) has significantly modified crowding distance sorting by introducing widely distributed reference points to maintain population diversity. NSGA-III follows the same structure as NSGA-II, classifying people in the population into several non-dominated fronts using rapid non-dominated sorting. The fundamental distinction between NSGA-II and NSGA-III is that NSGA-II maintains population diversity through crowding comparison procedures, whereas NSGA-III employs well-distributed reference points. This is because of environmental selection at the critical layer. Unlike the previous genetic algorithm (NSGA-II), NSGA-III introduces a reference point selection mechanism while retaining most functions of NSGA-II. First, a collection of reference points is defined using NSGA-III. Next, given N, the population size, a random beginning population of N people is created. The process then continues until the termination requirements are satisfied. The technique generates offspring populations by random selection in generation t by simulating polynomial mutation depending on the present population. For example, in the objective space, a (M-1)-dimensional standard simplex (e.g., a plane for a 3-objective problem) is considered, with the same slope along all objective axes. If the space along each objective direction is divided into p parts, the total number of reference points H for reference point H can be calculated. For instance, in a three-objective (M=3) problem, reference points are generated on a triangle with vertices at (1,0,0), (0,1,0), and (0,0,1). If each objective axis is divided into four parts (p=4), the number of reference points H is 15, as shown in Figure 4.

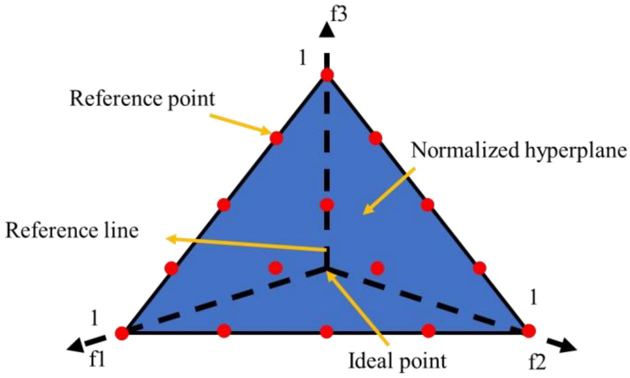

Figure 4. Diagram of 15 Reference Points Under 3D Target

In the normalization process, it first maps the target values and then identifies the extreme points for each dimension. Finding extreme points involves fixing a particular dimension, setting its weight to 1, and assigning a minimal weight to the other dimensions. An adaptive normalization function is used for each solution to calculate its value (with the maximum value on all dimensions representing this solution). The extreme point is selected as the solution with the minimum value of the adaptive normalization function among all solutions. Generally, the extreme points for all dimensions can determine a hyperplane. The calculation involves determining the intercepts of this hyperplane with each coordinate axis and, during normalization, directly dividing by the intercepts. Taking minimization as an example, it begins by obtaining the minimum values of all individuals in each dimension of the target within the population, forming the ideal point for the current population. Then, all individuals' target values, along with the ideal point as a reference, undergo a transformation operation. At this point, the ideal point becomes the origin, and the individuals' target values become the transformed temporary standardized target values. Next, the extreme points on each dimension of the target axis are calculated. These M extreme points form an (M-1)-dimensional linear hyperplane. The intercepts on each target direction can be calculated. Finally, the actual standardised target values are computed using the intercepts and the temporary standardized target values. For the case of a three-objective problem, the process of calculating intercepts and forming a hyperplane from extreme points is illustrated in Figure 5.

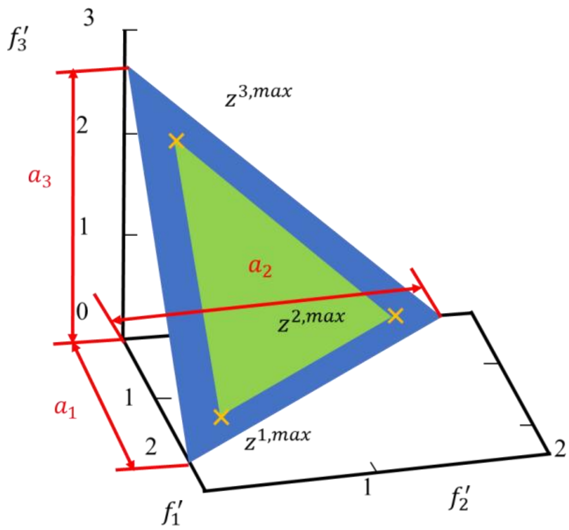

Figure 5. Hyperplane Diagram Under 3D Target

A correlation operation is carried out to link each member of the population with the appropriate reference point following the establishment of the reference points. The line that joins the origin to the reference point in the objective space is known as the reference line, and it must be specified for this purpose. The vertical distance between each member of the population and the reference line is computed once the reference line has been constructed.

Lastly, the reference line closest to each individual is linked to it. Given the advantages of the NSGA-III algorithm in handling high-dimensional multi-objective optimization problems, this paper employs the NSGA-III algorithm to solve the high-dimensional multi-objective optimization problem of the energy-economic-environmental coupling footprint in the life cycle of solar and wind power generation. Implementing NSGA-III involves five steps: initial population, tournament selection, offspring generation, non-dominated sorting, and reference point-based selection mechanism. All steps except for the initial population will be repeated until the termination condition is met. Before adopting the final solution set, we selected the IGD metric to evaluate the algorithm's performance and demonstrate how reliable the results are. The Inverted Generational Distance (IGD) is a comprehensive performance evaluation metric. It assesses the convergence and distribution performance of the algorithm by calculating the minimum distance between each individual on the actual Pareto front and the set of individuals obtained by the algorithm. A smaller IGD value indicates better overall performance, including convergence and distribution. The formula is represented as follows (Equation 1):

$$IGD(P,Q) = \frac{\sum_{v \subset P} d(v,Q)}{|P|} \tag{1}$$

Here, P represents a set of points uniformly distributed on the actual Pareto front, |P| is the number of individuals distributed on the actual Pareto front, and Q is the set of Pareto-optimal solutions obtained by the algorithm. The term d(v, Q) represents the minimum Euclidean distance from an individual v in P to the population Q. Therefore, IGD evaluates the algorithm's overall performance by calculating the average minimum distance from the set of points on the actual Pareto front to the obtained population.

Based on the above theory, three categories with a total of seven objective functions are given as follows:

$$minEnergy = A_1X + B_1Y \tag{2}$$

$$minGWP = A_2X + B_2Y \tag{3}$$

$$minAP = A_3X + B_3Y \tag{4}$$

$$minEP = A_4X + B_4Y \tag{5}$$

$$minPOCP = A_5X + B_5Y \tag{6}$$

$$minHTP = A_6X + B_6Y \tag{7}$$

$$minCOST = A_7X + B_7Y \tag{8}$$

Equation (2) represents the minimization of energy consumption. Equation (3) represents the minimization of Global Warming Potential (GWP). Equation (4) represents the minimization of the Acidification Potential (AP). Equation (5) represents the minimization of Eutrophication Potential (EP). Equation (6) represents the minimization of Photochemical Ozone Creation Potential (POCP). Equation (7) represents Human Toxicity Potential (HTP) minimisation. Equation (8) represents the minimization of cost. The specific constraints for the optimization system are given by Equation (9).

$$\begin{gathered} X + Y \geq P_{Installed} \\ 0 < X < X_{\max} \\ 0 < Y < Y_{\max} \end{gathered} \tag{9}$$

Where X and Y are divided into the installed capacity(unit: MW) of the wind power generation equipment and the installed capacity (unit: MW) of the solar power generation equipment put into service in a certain year.

A and B of different subscripts represent a specific value in the life cycle of wind and solar power plants. The subscript 1 represents the energy consumed per MWh of electricity produced. The subscript 2 represents GWP per MWh of electricity produced. The subscript 3 represents the AP produced per MWh of electricity produced. Subscript 4 represents EP produced per MWh of electricity produced. The subscript 5 represents the POCP produced per MWh of electricity produced. Subscript 6 represents the HTP produced per MWh of electricity produced. Where subscript 7 represents the cost per MWh of electricity produced.

B. Ethical Discussion of Landscape Design for Renewable Energy Projects

Compliance with relevant standards and regulations is critical to successfully applying renewable energy systems in landscape design. This paper discusses the impact of zoning laws, building codes, and environmental regulations on installing and operating renewable energy facilities. Zoning laws have different requirements for the type and size of renewable energy facilities in other areas (e.g. residential, commercial, industrial). For example, residential areas may limit the installation of large wind turbines, while commercial areas may allow larger-scale solar panel systems. Therefore, a detailed study of local zoning laws to ensure the design meets the regulations is a prerequisite for the project's success.

The Building Code specifies requirements for the safety, structural design and installation of renewable energy systems. For example, solar panels must be installed according to fire, water resistance, and structural strength specifications. These specifications guarantee the system's safe operation and ensure its durability and reliability in extreme weather conditions. Environmental regulations ensure that renewable energy systems have minimal impact on the environment. An environmental impact assessment (EIA) is carried out during the project planning phase to identify potential environmental risks and develop appropriate mitigation measures. In addition, sustainability certifications, such as LEED certification, ensure that projects are designed, built, and operated by sustainable principles. By adhering to these standards and regulations, the application of renewable energy systems in landscape design is legally compliant and minimizes negative environmental impacts.

In sustainable landscape design, a holistic approach to sustainability is crucial. This paper discusses the application of multidisciplinary cooperation, community participation and ecological design principles in landscape design. Interdisciplinary collaboration is the foundation of sustainable design. More integrated and innovative design solutions can be developed by combining knowledge from multiple disciplines, such as landscape architecture, engineering technology, environmental science and sociology. For example, landscape architects can work with engineers to optimize the layout and installation of solar panels to maximize energy production efficiency, Work with environmental scientists to select local, adaptable plants to reduce irrigation needs and maintenance costs, Work with sociologists to ensure that design solutions are tailored to the needs and cultural context of the local community, enhancing the social acceptance and long-term sustainability of the project. Community engagement is also an essential part of a holistic approach to sustainability. By involving community members in the design process, a more comprehensive range of opinions and suggestions can be obtained, ensuring that the design is closer to the actual needs. For example, community meetings and workshops can be organized when designing parks and public spaces to gather residents' opinions and suggestions on space functions and facilities. At the same time, community education and publicity are used to improve residents' awareness and acceptance of renewable energy and sustainable design and promote the implementation and maintenance of the project. Ecodesign principles emphasize harmonious coexistence with the natural environment. Utilizing natural resources and ecosystem services can achieve more efficient and sustainable design. For example, they are using natural terrain and vegetation for stormwater management, reducing the need for hard paving and drainage facilities, Maintaining biodiversity and ecological balance through the selection of native plants and natural habitats, Improving urban microclimate and air quality by designing green infrastructure such as green roofs and vertical gardens. A holistic approach to sustainability not only focuses on energy efficiency and environmental protection but also emphasizes social and economic sustainability. Through multidisciplinary collaboration, community engagement and eco-design principles, more integrated and long-term sustainable landscape design can be achieved.

C. Optimization of Landscape Design Strategy for Renewable Energy Projects

Using big data for strategic optimization, the author will verify the aforesaid model's validity and applicability. Outdoor ecological design, which includes landscaping and trees, is frequently included into the landscape design of renewable energy installations. These elements will be the main focus of this study, which will optimize landscape design techniques while upholding the low-carbon idea and looking at them from a sustainable angle.

As mentioned earlier, carbon emissions at each stage will respond to carbon footprints in landscape design. Therefore, to achieve the goal of low carbon, we must conduct a comprehensive carbon emission assessment for different landscapes in the design process to meet the requirements of sustainable development.

Since different sites have different capacities for fixing carbon, local tree species should be widely used in garden designs in line with the principle of planting suitable trees in suitable locations. This is on top of keeping the vegetation intact. This should highlight the vegetation landscape characteristics of the garden in different regions. Strengthening the construction of vegetation diversity can create more scientifically reasonable plant landscapes. Each greenhouse gas has a different impact on the greenhouse effect. International agreements state that carbon dioxide has a global warming potential of 1, and that the value of other gases' GWPs, which are typically far more important than 1, signify their multiple of the greenhouse effect in relation to CO_2. CO_2 is chosen as the reference gas because of its most significant contribution to global warming and is considered the primary cause of the greenhouse effect. Converting the GWP values of other gases to equivalent CO_2 emissions, it is only necessary to multiply their emissions by the corresponding GWP values.

Low-carbon landscape designs should be actually executed by choosing distinctive low-carbon landscape elements. To preserve the natural ecosystem of garden landscapes, the site plan should be rationally designed in compliance with low-carbon objectives. Prioritization should be given to site selection and shape, careful use of local materials, reflection of local cultural characteristics, and achieving harmony and coherence between plants, space, and landscape. Renewable low-carbon materials with minimal environmental impact should be selected for the design of landscape features, and local natural resources should be fully utilized in production and use. In addition to taking into account the use of renewable energy sources, such as solar energy, to lower the garden's carbon emissions, the design should have a cohesive aesthetic and distinctive local cultural features [25], [26].

The energy sources used by various forms of mobility vary, which will impact the carbon emissions of guests who use them inside the garden. This experiment calculates the best form of transportation for gardens without compromising journey time by comparing the carbon dioxide emissions of several modes of transportation and considering variables like road layout and garden layout. Table 1 displays popular energy sources' carbon dioxide emission coefficients based on pertinent data. Table 2 demonstrates that private vehicles have much greater per capita carbon dioxide emissions per kilometre than buses and public transit.

Table 1. Common Energy Sources' Coefficient of Carbon Dioxide Emissions

Name	Coefficient
Electric power	0.962
Gas	0.231
Gasoline	2.700
Natural gas	2.166
Coal	1.973
Fuel	3.185

Table 2. Emissions of Carbon Dioxide from Frequently Used Vehicles

Means of transportation	Fuel density	Real energy use	Emissions of carbon dioxide	Unit emissions of carbon dioxide
Bus	0.876	0.248	0.2179	0.0052
Public transit	0.876	0.310	0.2700	0.0040
Car	0.731	0.083	0.6012	0.0125

Garden plant arrangements should follow the rule of planting appropriate trees in appropriate places according to their functional needs. Native tree species should be the primary choice, emphasizing localization, naturalization, and rationalization. To enhance sustainability, minimize tree transplantation, and preferentially select plant communities with ecological diversity. In applying plant specifications, a rational arrangement should be pursued to reduce the use of large tree species. Due to the extended maintenance intervals, difficulty in excavation, and high transportation costs associated with these large tree species, they require significant energy and result in higher carbon dioxide emissions. Research data (Figure 6) indicates that plants such as Lechanghanxiao, coral papyrus, weeping willow, bulrush, camphor tree, and elm have relatively high annual net carbon sequestration amounts. Therefore, they should be prioritized and used as primary tree species and ornamental functions to enhance carbon sequestration and landscape benefits in garden design.

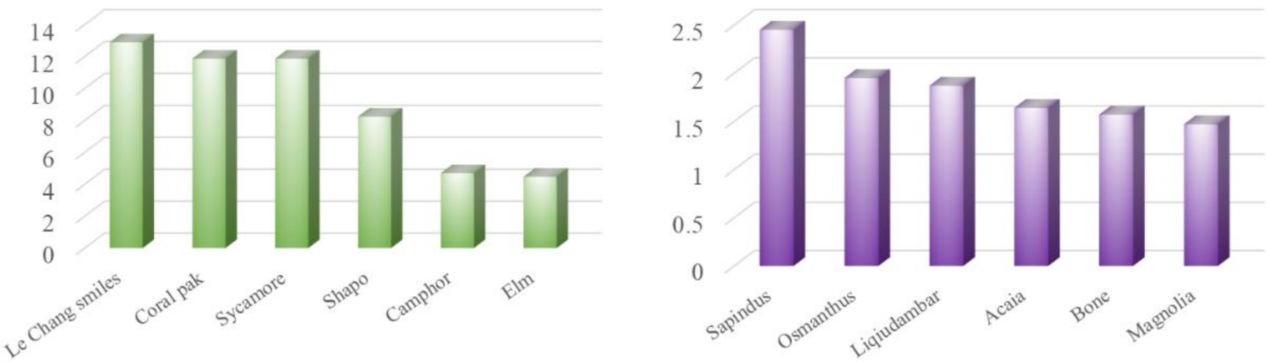

Figure 6. The Average Yearly Sequestration of Carbon by Various Tree Species

Native plants can adjust to the growing circumstances in the area, lower nursery upkeep and replacement costs, and highlight the landscape's economic advantages. As a result, many native tree species are widely employed as garden plants to enhance the quality of rural surroundings and lower carbon emissions. The park intentionally blends evergreen and deciduous plants to create a multi-layered plant landscape, with the primary goal being to increase the carbon sequestration impact of plant landscapes. Ancient trees are essential for reducing carbon emissions and promoting species variety in the environment because of their thick foliage and potent carbon absorption capacity. It is also crucial to preserve and use the village's huge plants and old trees, such as by establishing outdoor areas under the garden trees. When designing green areas, plant species with the most significant potential for solid carbon sequestration should be given preference (Figure 7).

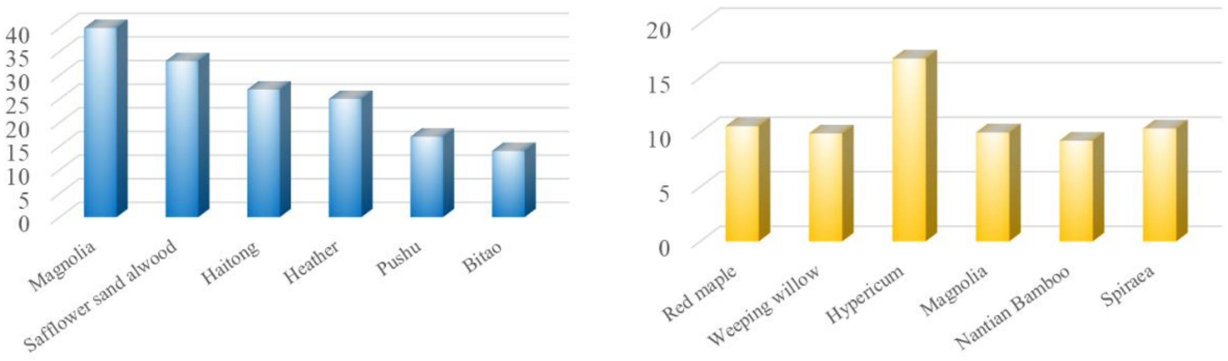

Figure 7. Comparing the Same Tree Species' Capacities for Sequestering Carbon

Choosing trees with solid carbon sequestration capabilities is essential when choosing garden plants. Such as Lagerstroemia indica, Red Flower, Pittosporum tobira, Rhododendron, Magnolia grandiflora, Illicium verum, Lagerstroemia speciosa, Acer buergerianum, Diospyros kaki, Cinnamomum camphora, Populus alba, Ulmus parvifolia, and Osmanthus fragrans. Based on site conditions and landscape effects, a reasonable combination should achieve year-round beauty and enhance carbon sequestration effectiveness. After comparing the capabilities of different plant species for carbon sequestration, the design should be categorized according to different types of green spaces, preserving the original forested areas and conducting organic ecological restoration. Bamboo groves and other evergreen plants dominate the park, with the introduction of some mountainous vegetation such as Cyclobalanopsis and others. In the green spaces of courtyards and around houses, ornamental fruit trees such as loquat, pomegranate, Michelia alba, bayberry, pear, and persimmon are selected to beautify the landscape, achieve economic benefits and showcase the unique features of the garden. Plant arrangement at rest nodes should minimize carbon emissions during shipping and planting while accurately reflecting the area's natural features. Thus, native tree species, including persimmon, pomegranate, osmanthus, and camphor, are selected. As public nodes to express seasonal landscapes, species such as Malus domestica, Crabapple, Acer rubrum, Rhododendron, and flowering shrubs like Azalea are selected to highlight the ornamental effects of plants within the site. For some disorderly water environments in the village, remediation and restoration measures are first taken, including organizing overgrown plants, repairing damaged river channels, and enhancing riverbank greening.

The characteristics of different plants were studied according to the soil conditions and climate characteristics of other regions. At the same time, some characteristic plants with ornamental value and ecological function were introduced, such as flowers and aromatic plants. Design multi-level vegetation structures, including tree canopy, shrub layer, and herbaceous layer, to provide a rich ecological environment to meet the survival needs of different plants and animals. Bioremediation technology is introduced for water system design, and plants purify water quality to keep water clean and ecological balance. Applying these technologies not only improves the environmental function of the green belt but also provides a demonstration and reference for the protection and management of urban water resources. The leisure facilities are also set with ecological considerations, such as planting flowers and plants around the rest points, attracting butterflies and bees, increasing biodiversity, and providing citizens with an opportunity to get closer to nature. After a period of operation and development, the ecological benefits of the city's green belt have gradually emerged. Environmental monitoring data show that the air quality around the green belt has improved significantly, and the concentration of PM2.5 and PM10 has decreased, indicating that the vegetation in the green belt can effectively purify the air. Water quality monitoring data showed that the water quality after reintervention was good, pH value and ammonia nitrogen content were in the safe range, and the aquatic organism population was restored or even increased.

Table 3. Comparison of Ecological Indexes Before and After Design

Index	**Before ecological landscape design**	**After ecological landscape design**
PM2.5 concentration	69 $\mu g/m^3$	63 $\mu g/m^3$
PM10 concentration	79 $\mu g/m^3$	72 $\mu g/m^3$
pH value	7.5	7.8
Nitrogen oxygen content	1.1 mg/L	0.9 mg/L

Carbon footprint calculations are performed by collecting the above data and input into the model. After low-carbon planning and landscape design, the net and total carbon footprint have significantly decreased. The carbon sequestration of Greenfield increased from 301,023.21 to the current 347,856.02 per kilogram, showing an increase of 46,832.81.

This design adopts a distributed photovoltaic power generation design; the installation capacity of this project is 276 kWp, and according to the comprehensive cost of 3 yuan/W, the initial total investment is 828,000 yuan. The design life of the photovoltaic power generation system is 25 years. Polycrystalline silicon, monocrystalline silicon and thin film battery components from the date of operation of the project, the attenuation rate within a year should not be higher than 2.5%, 3% and 5%, respectively, after which the annual attenuation should not be higher than 0.7%. In this project, the monocrystalline silicon module is selected, the attenuation rate is 3% in one year, and then the annual attenuation is 0.7%, so the installation capacity of the 25th year is calculated as P25A=276×(1-3%)×(1-0.7%)23=227 kWp, The attenuation does not exceed 20% of the initial installation capacity. The total power generation in 25 years is 6 396.063 MWh. The average annual power generation is 255.842 MWh.

It is divided into two forms to calculate its economic benefits, mode one is the self-use rate of power generation online is 80%, and mode two is all self-use. The calculation results according to the electricity price are shown in Table 4.

Table 4. Two Ways of Investment Payback Period Measurement

Item	**Self-use surplus electricity online (80%+20%)**	**Spontaneous self-use**
Capacity /kWp	276	276
Investment amount (unit: Yuan)	828 000	828 000
First year power generation /kWh	285 936	285 936
20-year average annual return (unit: Yuan)	0.5669	0.62
Electricity price (unit: Yuan)	154 908	169 417
Average annual income for the first 7 years (unit: Yuan)	93.35	85.48
Total revenue for the first 7 years (unit: Yuan) Investment recovery (unit: Year)	6	5

From the above analysis, it can be seen that the cost recovery period of the two ways is 5 to 6 years, and the service life of the photovoltaic power generation system is 25 years. It's a net gain for another 20 years or so. There is no pollution to the environment, which is a huge advantage of photovoltaic power generation. In the process of coal combustion, thermal power generation in power supply will accumulate a lot of harmful gases, such as SO_2, CO_2, etc., causing pollution to the environment. After the operation of the photovoltaic power generation system, "zero" emissions can be achieved. The statistical table of carbon emission savings is shown in Table 5.

Table 5. Distributed Photovoltaic Panel Saving Carbon Emission Statistics Table

Argument	**Numerical value**
Annual electricity generation /kWh	255 842
Saving standard coal /t	122.8
Carbon dioxide emission reduction /t	246.631
Sulfur dioxide emission reduction /t	10.233
Dust reduction /t	69.588

4. Conclusion

In this article, we focus on a sustainable perspective and systematically summarize the principles of landscape design within this framework, primarily revolving around the three critical points of ecology, humanity, and technology. In particular, we elaborate on three critical design concepts: emphasizing ecological sustainability, advocating for cultural integration, and utilizing advanced technology. We thoroughly explore and discuss these design focal points to provide a comprehensive and in-depth analysis of sustainable landscape design.

Subsequently, the author applies these three design concepts to the landscape design of sustainable energy projects and expounds on the outcomes and conclusions as follows:

● Addressing the balance of economy, energy, and environment in landscape design, we determine, from a methodological perspective, that it is fundamentally a high-dimensional multi-objective optimization problem and propose an energy-economic-environment coupling model.

● Utilizing the energy-economic-environment coupling model in conjunction with big data, we provide a detailed discussion on the carbon footprint issues in the landscape design of renewable energy projects. We are maintaining native forests and increasing plant carbon sequestration to help keep natural landscapes intact and improve gardens' ability to act as carbon sinks.

● Applying the energy-economic-environment coupling model for carbon footprint calculations, we observe a significant reduction in net and total carbon footprint after implementing low-carbon planning in the landscape design. The carbon sink of Greenfield increases from 301,023.21 to the current 347,856.02 per kilogram, showing an increase of 46,832.81. In addition, water resources, air quality and biological diversity are also improved. At the same time, the economy before and after the design is compared, the result is good.

Future research directions could further enhance the sustainability of landscape design while exploring the application of new and innovative technologies in renewable energy sources. The application of new materials and technologies in renewable energy systems, such as more efficient photovoltaic materials and advanced energy storage technologies, can be investigated. Advances in these technologies will further improve the efficiency and sustainability of renewable energy systems. In addition, multidisciplinary cooperation is an important direction for future research. More integrated and innovative design solutions can be developed by combining knowledge from multiple disciplines, such as landscape architecture, engineering technology, environmental science and sociology. For example, landscape architects can work with engineers to optimize the layout and installation of solar panels to maximize energy production efficiency, Work with environmental scientists to select local, adaptable plants to reduce irrigation needs and maintenance costs, Work with sociologists to ensure that design solutions are tailored to the needs and cultural context of the local community, enhancing the social acceptance and long-term sustainability of the project. Another important research direction is intelligent technology and data-driven management strategies. By leveraging the Internet of Things (IoT) technology and big data analytics, real-time monitoring and optimization of renewable energy systems can be achieved. For example, they monitor the performance of solar panels and wind turbines through a network of sensors to detect and resolve problems promptly and optimize energy production and usage strategies through data analysis to improve the overall efficiency and reliability of the system. Policy and economic studies are also important areas for future research. By studying the effects of different policies and incentives, we can provide a scientific basis for governments and policymakers to support the promotion and application of renewable energy and sustainable design. Economic feasibility studies assess the costs and benefits of different design options to help project developers and investors make more informed decisions.

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