

The Evolution of Landscape Aesthetics Under Energy Transition

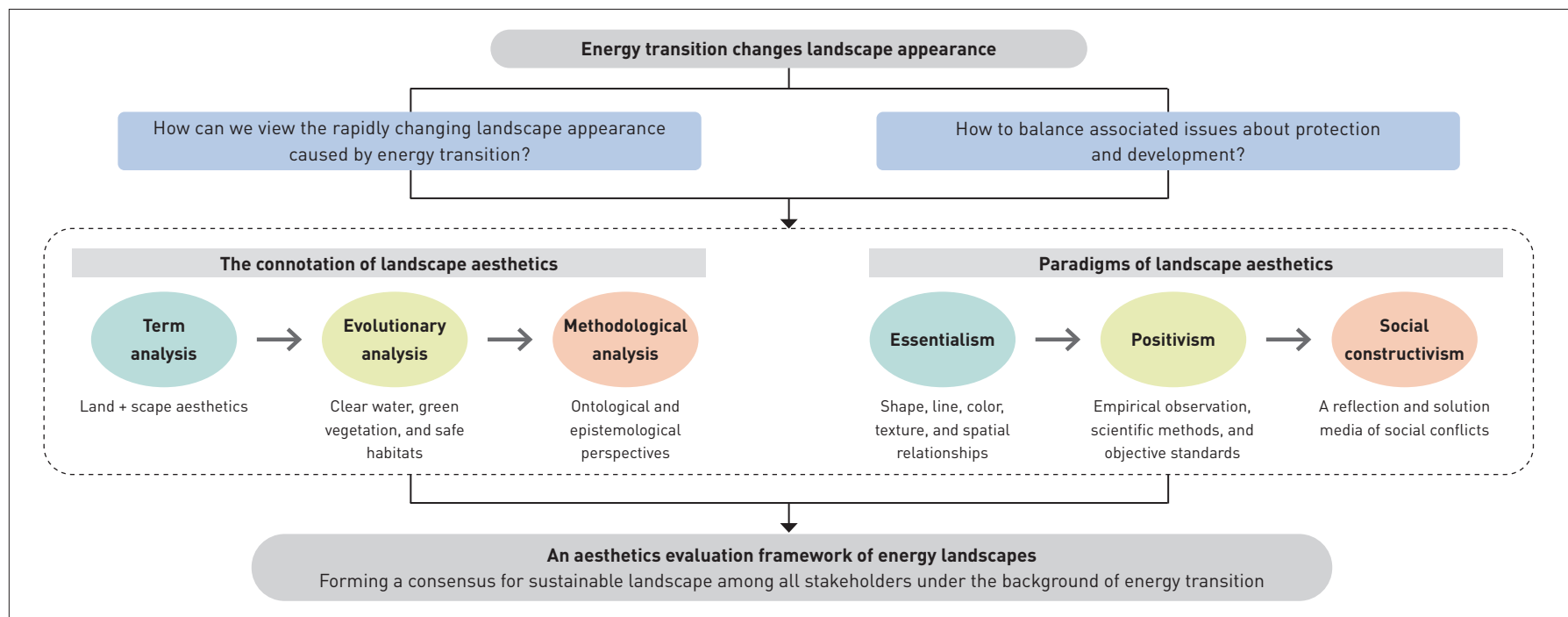
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GRAPHICAL ABSTRACT



ABSTRACT

The energy transition and the resulting changes in landscape appearance have brought great social repercussions. Nowadays we have to answer the questions that how can we view the rapidly changing landscape appearance caused by energy transition, and how to balance associated issues about protection and development. Since the energy landscape aesthetic theory in the low-carbon era has not yet been constructed, this paper explores landscape aesthetics from terminological, evolutionary, and methodological perspectives, and discusses the connotation, core values, and research scopes of postmodern aesthetics, post-

industrial aesthetics, and ecological aesthetics. Based on theoretical review, assessment paradigms of landscape aesthetics are sorted out from essentialism, positivism, to social constructivism. A framework is introduced to assess energy landscapes under energy transition background to generate a consensus for sustainable landscape among all stakeholders.

KEYWORDS

Energy Transition; Landscape Aesthetics; Evolutionary Aesthetics; Renewable Energy; Landscape Protection; Social Constructivism

HIGHLIGHTS

- Landscape appearance is changing with energy infrastructure forms
- Landscape aesthetics theories coincide with the development of evolutionary aesthetics
- The methodology of energy landscape aesthetics expands from essentialism, positivism to social constructivism

RESEARCH FUND

Project of “Research on Spatial Low-Carbon Collaborative Governance Mechanism From a Nature–Society Perspective—Taking Shanghai as an Example,” Shanghai Social Science Planning Youth Project (No. 2024ECK005)

EDITED BY Tina TIAN

1 Energy Transition and Changes in Landscape Appearance

As a major contributor to climate change, carbon emissions by fossil fuels are keeping at a high level. Achieving a balance between carbon sources and sinks of greenhouse gases (GHGs) has become the common target of major countries globally. Among all the solutions, energy transition has been proved as the optimal pathway to achieve the emission cuts needed. The energy transition is a systemic overhaul of energy infrastructure, transforming from dependence on fossil fuels towards prioritizing sustainable alternatives such as solar, wind, hydroelectric, and geothermal power^[1]. This shift reimagines energy production, distribution, and consumption to establish cleaner, more resilient systems^[2]. Historically dominant fossil fuels are progressively ceding their primacy to diversified emerging energies. Among all the electricity generation resources, renewable energies are the major contributor,

accounting for nearly half of the growth in the last decade^[3].

The rapid advancement of renewable energy technologies and their widespread global deployment have spurred the development of various prediction models across different scenarios, underscoring a profound transformation in societal, environmental, and economic domains^[4]. While most attention is paid on the technologies, cost, and policies of clean energies^{[5][6]}, the landscape changes caused by the space occupied by large-scale energy infrastructure have not yet attracted enough public attention. Unlike fossil fuels, renewable energies, represented by wind and solar energies, are characterized by low-capacity density and power density^[7]. Therefore, the energy transition can cause changes in regional landscape identity and visual impacts on existing landscapes. Sören Schöbel introduced the concept of “Morpheme” in wind energy planning, highlighting the substantial spatial disparity between wind farms and natural landscape elements in rural Germany^[8]. He pointed out that wind turbines were several times taller than other vertical reference objects (such as trees and chimneys), leading to disorders in visual perception and the spoil of original landscape images. Their cumulative visual impacts cause substantial changes in local landscapes, accompanied by negative effects on land use patterns, economic productivity, and spatial accessibility^[9]. In areas with sensitive landscape resources, huge wind turbines would depreciate local real estate and tourism projects^[10]. Except the extraordinary scales of renewable energy infrastructure, their impacts on sense of belonging and ecology have also been discussed^{[11]~[13]}.

Regional landscape identity is always changing, and energy revolutions in human history have driven significant changes in landscape appearance. From firewood energy, fossil energy to diversified renewable energy currently, the form and efficiency of energy utilization determine human productivity and civilization. Simultaneously, these irreversible changes will also impact the public’s landscape aesthetic preferences and the evolution of landscape aesthetic in the long term. The theory explaining landscape aesthetic evolution under the energy transition background needs to be discussed and refined to adapt to landscape changes caused by climate change.

Currently, energy infrastructure is becoming part of daily-life landscapes. The aesthetic paradigm of energy landscapes should be valued and widely discussed. What attitude should we take towards energy landscapes? Should energy landscapes all be regarded as negative impacts, or be gradually tolerated and accepted? In this paper, a new aesthetic framework is constructed to explore reasonable aesthetic connotation and assessment standards for energy landscapes.

2 The Connotation of Landscape Aesthetics

2.1 Sources of Landscape and Aesthetics

Along with architecture, music, sculpture, and painting, landscape has long been considered a classic subject of aesthetics. The question of how to define and recognize beauty remains a highly related issue in landscape research. Due to the broadness of landscape aesthetics concepts, the diversity of individuals' perception, and the variety of disciplinary fields, scholars have different understandings and expressions of research scope, connotation, typical paradigms, and existing problems of landscape aesthetics^[14], for which they are unable to grasp the aesthetic evaluation standards and planning guidance of energy landscapes. This paper, instead of giving a definite concept of landscape aesthetics, provides a context for thinking and constructs an evaluation framework for energy landscape aesthetics from an evolutionary perspective.

When the term "landscape" is initially associated with "scene," the connection between land and beautiful scenery is also established. Since the emergence of the term "landscape," aesthetics has constituted an important part of landscape's connotation. The term "aesthetics" originates from Greek with the connotation of sensory perception, indicating that the beauty of a landscape can be experienced through all the senses, not only by vision. Aesthetics explains the way how people perceive beauty, experience beauty, and entertain themselves with beauty.

2.2 Evolutionary Aesthetics

The theory of evolutionary aesthetics originates from Darwin's Evolution Theory^[15]. When it comes to aesthetics—and landscape aesthetics in particular—Evolution Theory implies that landscapes preferred by humans enhance their survivability and reproducibility. "Survival of the fittest"^[15], which refers to the adaptability of an organism's survival and reproduction to the current environment, determines the group's aesthetic preferences. By contrast, the population of groups will reduce due to their less suited landscape aesthetic preferences.

The term "evolutionary aesthetics" refers to theories in evolutionary psychology^[16], and explains the spontaneous distinction between "beauty" and "ugliness" as a biologically adapted ability of human beings. As a manifestation of the human evolutionary process, human aesthetic preferences for landscapes typically favor features such as clear water, green vegetation, and safe habitats, which historically promoted human survivability and reproductive success.

An interesting phenomenon is that the classic landscape

aesthetics theories also coincide with the development of evolutionary aesthetics from survival needs to cultural construction and then to personal needs. A landscape with high aesthetic quality satisfies human biological needs to survive and thrive as species, and provides abundant information about the cultural-social experience^[17].

2.3 Landscape Aesthetics Under Ontological and Epistemological Perspectives

As a term with abundant connotation, "landscape aesthetics" is usually discussed within specific logical and conceptual frameworks, as well as cultural backgrounds^[18]. On the one hand, from the perspective of ontology, landscape elements and spaces are based on physical and materialistic objects. Landscape aesthetics is tied to the physical environment of human settlements, yet existing independently of human influence. On the other hand, with the connotation of landscape enriched by ethics, morality, political constitutions, customs, gardens, and paintings, human value systems turn more reliance on epistemological levels instead of merely ontology. Human perceptions of landscapes are shaped by above factors, which change over time^[19].

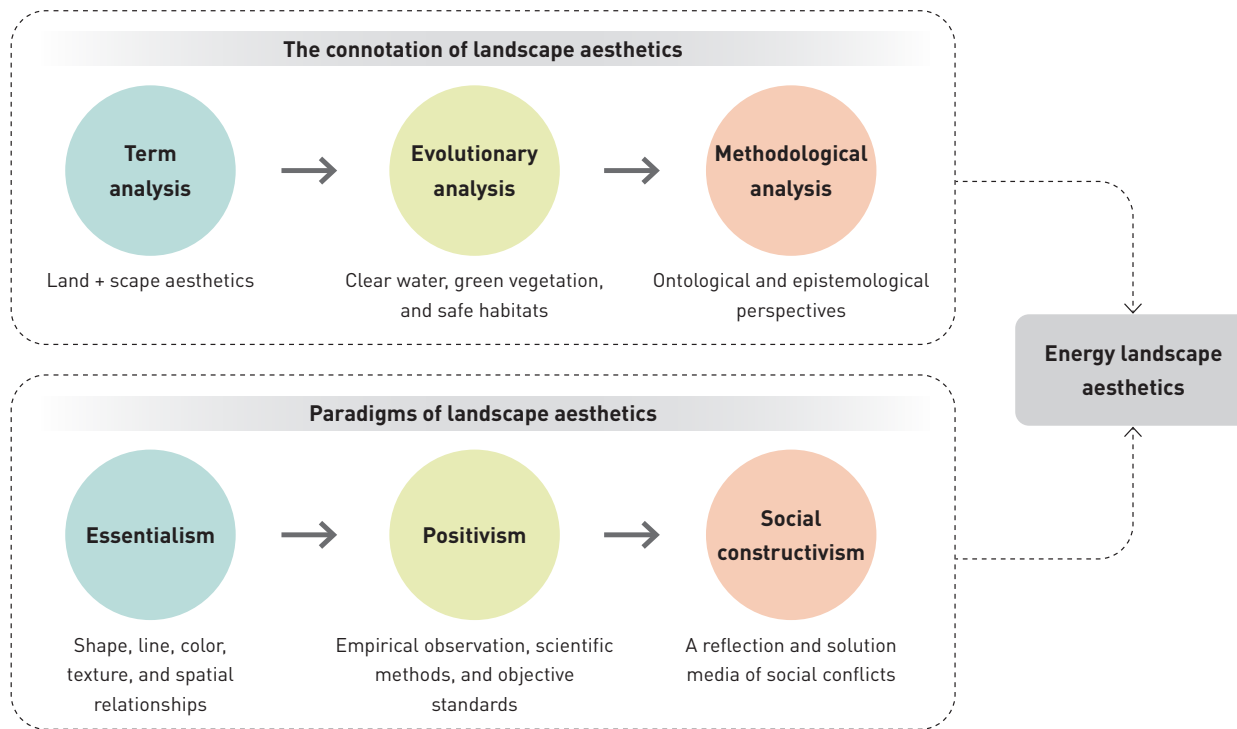
The interplay between ontology and epistemology is crucial: ontology focuses on the essence of physical landscapes, while epistemology explores how we socially construct and assign meaning to them. As explained by Simone Linke, landscape changes with social development and is supported by the social constructivism theory^[20]. Figure 1 outlines the methodological evolution of landscape aesthetics and related factors and metrics, thereby inferring the development of aesthetics under the influence of energy transition.

3 Evolution of Landscape Aesthetics

In the late 20th century, under the influence of various ideological trends, the theory of landscape aesthetics derived various theoretical branches. They combined various social needs and technical methods, not only enriching the connotation of landscape aesthetics theory but also promoting the formation of the aesthetic theory framework.

3.1 Landscape Aesthetic in Postmodern Era

Postmodernism has refined the connotation of landscape aesthetics by emphasizing the indivisible relationship between art and life. The landscape methodology has shifted from essentialism, positivism to social constructivism, according to which landscape is understood not as a physical object, but as a social construction



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1. Energy landscape aesthetics based on the methodological evolution of landscape aesthetics.

process^[21]. Social and political issues, popular arts, fashion styles, and lifestyles are involved in the field of aesthetics^[22]. Simultaneously, pluralism, eclecticism, and individual difference are also recognized as aesthetic values. Anna Eplényi et al. have summarized six characteristics of postmodern landscape as: narratives, indeterminacy, self-realization, pluralism, rhizome principle, and playful^[23].

Under the processes of the socialization of landscape interpretation, the core issue of landscape aesthetics lies on the following questions: What is the basis of the social judgment of landscape aesthetic quality? How can these social attributes be collected and analyzed, and how can these attributes change over time^[21]? In Linke's contribution, the criteria describing the landscape quality are not from physical characters, but from socially-constructed experience^[20]. Landscape is recognized more as a reflection and solution media of social conflicts. Along with the characteristics of dynamics and sustainability^[24], landscape aesthetics has a multi-valued orientation tendency. In addition to beauty, sublimity and ugliness have developed into important categories of landscape aesthetics^{[25][26]}. The changes of values in the postmodern era thus represents an opportunity for the acceptance of changing landscapes in the future.

3.2 Landscape Aesthetics in Post-industrial Era

Since industrialization, the world has become more automated,

chaotic, and highly linked. Daniel Bell, the founder of Information Sociology, divided social development into three stages: pre-industrial society, industrial society, and post-industrial society. They correspond to three models: 1) the struggle between human and nature; 2) the struggle between human and machine; and 3) the struggle between human and information^[27].

In the post-industrial era based on information and services, design is no longer a tool to transform materials for extending human functions, but solutions to problems. Aesthetics in this era is not only the appearance of what we have seen, but also about how it is constructed and how it can influence the external environment^[28]. Post-industrial aesthetics try to explain the nature of human interactions with the built and natural environment^[29]. The key issues that landscape design has to solve shifted from materials, concrete aesthetic signs, and design languages, which represent from the appearance to the economic, socio-cultural, and ecological demands. Forced by "Arts and Crafts" movement and Architectural Modernism^[28], the western society has set off a wave of discussions on architecture, products, and process design. Their preferences reflected the new attitudes towards arts, economy, society, culture, and politics. Propelled by emerging technologies (e.g., in transportation) and electronic information, the global commerce has expanded the influence of individual aesthetics. Globalization and commoditization have led to the solidification and loss of the locality of design aesthetics. Even for landscape design, an industry

with local characteristics, standardization of design language, design process, and design specifications has become the key to quickly generating works. For example, the famous landscape architect John Dixon Hont commented that the reason why the High Line in New York has become a milestone of post-industrial landscape is that it honors place^[30]. Even though many landscape works contain elements such as industrial heritage, linear landscapes, and abandoned railway reconstruction, the respect and interpretation of history and nature have shaped the unique High Line.

3.3 Landscape Aesthetics and Ecology

Since Joseph W. Meeker published *Notes Toward an Ecological Aesthetic* in 1972, the term “ecological aesthetics” (eco-aesthetics hereafter) has been widely known and become an important sub-field of aesthetic research^[31]. There is a consensus among ecologists and landscape planners on the close relationship between ecology and natural aesthetics. The keystone of the theory put forward by Meeker is ecological aesthetic appreciation based on ecological ethics, which is the fundamental reason that differs from traditional aesthetic theories. Aldo Leopold proposed the concept of “scientific cognitivism,” which links the beauty of nature with ecological integrity and stability^[32].

With the development of Landscape Ecology, ecologists and environmental ethicists have emphasized the importance of ecological principles in landscape aesthetic preferences and advocated management goals based on eco-aesthetics. Paul H. Gobster et al. present a sharply polarized and still ongoing debate between the “scenic aesthetics” and eco-aesthetics^{[33][34]}.

Catherine Howett asserts that landscape aesthetics cannot be independent of ecology^[35]. What makes a landscape beautiful is often intimately linked to other intrinsic landscape ecological criteria, such as biodiversity and sustainability^[36]. The core research question of eco-aesthetics lies in the aesthetic manner, which represents how to perceive and participate in aesthetic activities by an ecological consciousness.

4 Landscape Aesthetics Under Energy Transition

As mentioned above, various trends of thoughts under societal development have had an influence on landscape aesthetics, thus promoting the diversified development of aesthetic theories. In the era of energy transition, landscape aesthetics is superficially a judgment on the value of technology innovations under energy transition (visually represented by the influence of natural landscapes by huge energy infrastructure). However, the key issue

is the reinvention of production and lifestyle brought by renewable energy.

Initially, the construction of renewable energy receives fierce opposition at the local level, which is represented by the attitude of “not in my backyard”^[37]. Residents’ rejection rises with the distance to energy infrastructure. As people’s awareness of renewable energy increases, their aesthetic appreciation of energy landscapes shows a shift of “opposition–acceptance–utilization”^[38]. At the beginning, due to the unknowns about renewable energy technology and the fear of giant structures, residents living near power points were extremely resistant. Over time, surrounding residents can gradually accept such infrastructure and see it as part of their daily landscapes. Under the paradigm of social construction, landscape aesthetics is a cultural image set up by the public, which is changeable with the value of renewable energy within a specific time span or a given region.

Landscape aesthetics is not a static or immutable concept, but a continually evolving field that is shaped by various disciplines, including Philosophy, Ecology, Environmental Sciences, and Social Sciences. These disciplines have contributed to a multifaceted understanding of how landscapes are perceived, evaluated, and interacted with. As our technological, social, and environmental contexts evolve, so too does the way we approach and assess landscape aesthetics.

4.1 Early Theories: Essentialism and Positivism in Landscape Aesthetics

In the initial stages of renewable energy development, the dominant approach to assessing landscape aesthetics is rooted in essentialism—the idea that beauty or aesthetic value resides inherently within the object itself, independent of human perception or social context. Key physical attributes that influenced aesthetic evaluations are as below.

1) Site occupation: the extent of land or space occupied by renewable energy installations, and their integration within the broader landscape.

2) Color: the color of renewable energy installations, which could either blend with or contrast against the surrounding environment; the aesthetic appeal of color harmony was the central consideration.

3) Height and scale: the vertical and horizontal scale of renewable energy installations, particularly wind turbines, could dominate vast stretches of land and alter the visual perception of the landscape.

4) Noise and shadow flicker: wind turbines, for example, could

produce noise or cause shadow flicker, both of which impact the sensory experience of the landscape^[39].

5) Warning lights: the flashing lights on energy installations (e.g., wind power stations) could disrupt the visual tranquility of the environment, particularly in light sensitive areas^{[40][41]}.

6) Spatial relationships and arrangement: the configuration of energy installations, including how turbines or solar panels are spaced out, how they align with natural features, and how they interact with the surrounding natural or built environment^[42].

The physical attributes of renewable energy infrastructure—including geometric forms, linear structures, chromatic properties, material textures, and spatial configurations—are analyzed through empirically observable and quantitatively measurable frameworks^[20]. These attributes lend themselves to systematic evaluation due to their objectively verifiable impacts on landscapes. The assessment methodology is grounded in classical aesthetic theories, particularly the premise that aesthetic value resides intrinsically within the formal properties of objects. This analytical approach aligned with positivist epistemology, which prioritizes quantifiable evidence and structural decomposition of phenomena. During renewable energy's formative development phases (1970s to 2000s), above aesthetic evaluation approaches dominated technical discourse, as the field emphasized physical characteristics over analyses of socio-cultural embeddedness^[9]. The visual qualities of energy installations were consequently assessed through standardized visual indicators rather than interpretive or contextual lenses, reflecting the period's technocentric priorities.

4.2 The Development of Aesthetics Assessment Frameworks: Positivism in Practice

As renewable energy technologies scale up and become more integrated into various countries and regions, the approaches to evaluating energy landscapes have also evolved. The positivist approach of landscape aesthetics is increasingly sophisticated, incorporating standardized evaluation guidelines and technological innovations to improve the accuracy and applicability of aesthetic assessments. In countries like Germany, these guidelines became a vital part of environmental planning and policy-making^[43]. Such evaluation systems include quantitative metrics (such as viewshed analysis to assess visual impact) and qualitative evaluations (such as expert opinion surveys and public consultations)^[44]. A general guideline consists of the following parts.

1) A brief introduction of the assessment object, including its essential landscape elements and spatial scope (for instance,

onshore wind farms near sensitive landscape and nature reserve);

2) Targets and goals of (for instance, protecting the landscape environment of the evaluation area and evaluating the impact level);

3) Basic principles, methods, and implementation procedures of the assessment;

4) Detailed assessment steps;

5) Application of specific methods and conclusions;

6) Discussion, evaluation, and optimization of the guideline itself.

Technological advancements, particularly the introduction of 3D modeling, animation software, and geospatial data analysis, allow for a more comprehensive and dynamic evaluation of renewable energy landscapes. By integrating real-world data about energy generation, environmental conditions, and public perception into the design and planning process, it becomes possible to simulate energy infrastructure's aesthetic impact on the landscape through scenarios with various viewpoints, lighting conditions, and seasonal scenes. The application of Internet of Things technologies has also enhanced these evaluations, enabling real-time monitoring and dynamic analyses of energy installations. This would support decision-making processes in adaptive and responsive landscape planning^[45].

Despite these methodological advancements, the positivist paradigm maintain its emphasis on quantitative and measurable outcomes. The empiricist framework retains methodological primacy in aesthetic impact assessment, with systematic measurement protocols consistently prioritizing expert-derived metrics over community-based perceptions. This epistemological orientation proves increasingly inadequate as renewable energy infrastructure becomes deeply integrated into settlement landscapes, revealing inherent limitations in capturing the socio-cultural complexities of aesthetic reception.

The disjunction between technical quantification and lived experience becomes particularly apparent during project implementation phases, where standardized visual metrics fail to account for place-specific meaning-making processes. Along the transition of renewable energy systems from experimental prototypes to community-scale installations, the reductionist conflation of aesthetic value with formal properties proved insufficient for addressing contested landscape imaginaries and culturally-situated evaluation frameworks. For instance, the height of wind turbines was usually used as a critical indicator for assessing energy landscapes, while this approach cannot reflect the relative height difference between wind turbines and

the surrounding terrain and lacks relevance to regional industry, economy, and culture.

4.3 Social Constructivism: The Role of Culture, Community, and Social Acceptance

Social acceptance and public participation are widely recognized solutions in social constructivism. From the social constructivism viewpoint, landscape aesthetics is seen as a dynamic and contingent process shaped by the collective experiences and the shared values of the people who engage with the landscape. The social constructivism approach recognizes that different communities, based on their specific socioeconomic backgrounds, cultural beliefs, and historical experiences, may have vastly different views on what constitutes a pleasing or acceptable energy landscape. Key components of this evolving aesthetic theory in the context of renewable energy are as below.

1) Public participation. Involving local communities, stakeholders, and experts in the planning process ensures that their aesthetic preferences directly affected by energy installations are considered. This democratic approach can help prevent conflicts and foster greater social acceptance of renewable energy projects.

2) Cultural contexts and local values. People from varied cultural backgrounds or geographical regions may perceive the aesthetic impact of energy installations differently. For example, in rural areas where landscapes are traditionally valued for their natural beauty and tranquility, wind turbines may be viewed as intrusive, while in more industrialized areas they may be seen as a symbol of development and sustainability, resulting in higher acceptance.

3) Socioeconomic influences. Economic factors play a crucial role in shaping aesthetic preferences. Communities that directly benefit from the economic opportunities provided by renewable energy projects, such as jobs and local investment, may have a more positive view of these installations.

4) Power dynamics and stakeholder perspectives. The decision-making process regarding the site selection and design of renewable energy installations is often manipulated by power gaming. Different stakeholders—policymakers, energy providers, urban planners, local residents, etc.—may have conflicting views on what constitutes an acceptable energy landscape. By involving diverse stakeholders in the process and accounting for competing values and interests, social constructivism seeks to create a more inclusive and context-sensitive approach to landscape planning of energy landscapes.

It acknowledges that no single, universal aesthetic standards

can be applied to all energy landscapes, and that aesthetic values are subject to negotiation, dialogue, and compromise.

4.4 The Framework for Energy Landscape Aesthetics Evaluation

Emerging from critiques of objectivist aesthetic paradigms, contemporary landscape theory increasingly incorporates social constructivism principles to address the co-constitutive relationship between energy infrastructure and sociocultural evaluation process. This epistemological shift positions landscape aesthetics as a dynamic system contingent upon collective meaning-making, where landscape aesthetics emerges through negotiated interactions among stakeholders rather than inherent formal properties.

The framework consists of three analytical dimensions: 1) participatory co-production of aesthetic standards through deliberative engagement with localized communities, countering technocratic decision-making hierarchies; 2) cultural embeddedness recognizes how historical land-use narratives and place identities mediate the public's perceptions on renewable technologies; and 3) power-gaming shapes aesthetic conflicts, particularly between the efficiency of metrics and the considerations of community well-beings. This paradigm challenges traditional aesthetic assumptions, proposing an understanding where energy landscapes become sites of contested cultural reproduction, demanding methodological approaches that reconcile measurable design parameters with hermeneutic analyses of situated lived experiences.

5 Conclusions

Under the global climate change and energy transition background, the theories of landscape aesthetics and their evolution processes are discussed in this paper. The cognition and evaluation criteria of landscape aesthetics have evolved with the development of human society and formed various branches. This paper explores how landscape aesthetics have transformed from essentialism to positivism and then to social constructivism. It also addresses how landscape aesthetics respond to modern issues by comprehending the progression of aesthetic evolution, especially when it comes to energy transitions. Under the proposed evaluation framework with holistic approaches to guiding landscape protection, stakeholders can collaboratively create a sustainable energy landscape for improving societal values and enhancing well-beings against the challenges of climate changes.

Competing interests | The author declares that she has no competing interests.

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能源转型背景下的景观美学演变

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摘要

能源转型及其引发的景观风貌变化带来了巨大的社会反响。当前我们不得不回应以下问题: 如何看待能源转型下快速变化的景观风貌? 以及如何平衡保护与发展之间的关系? 鉴于低碳时代下能源景观美学理论尚未建构, 本文从术语学、演化论和方法论视角剖析景观美学, 并探讨后现代美学、后工业美学和生态美学的内涵、核心价值与研究范围。在理论回顾的基础上, 本文对能源景观美学的评价范式进行梳理, 归纳从本质主义、实证主义到社会建构主义的发展规律。最后, 文章提出了一个能源景观美学的评价框架, 以期在能源转型背景下促使各类利益相关者达成可持续景观的共识。

关键词

能源转型; 景观美学; 进化美学; 可再生能源; 景观保护; 社会建构主义

文章亮点

- 景观风貌随着能源设施的形式产生变化
- 景观美学理论与进化美学的发展相契合
- 能源景观美学的方法论从本质主义、实证主义扩展到社会建构主义

基金项目

上海哲学社会科学规划课题“基于自然-社会视角的低碳空间协同治理机制研究——以上海市为例”(No. 2024ECK005)

编辑 田乐