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Achieving energy transition through spatial planning - A case of onshore wind energy planning procedures optimization in China

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Abstract. Wind energy is expected to be an effective solution to mitigate climate change and environmental pollution with broad resource distribution, decarbonization characteristics, and mature technologies. However, the rapid expansion of wind energy may also bring about new issues in space allocation and land use conflicts. Integration research of wind energy into spatial planning framework is imperative. Based on the dynamic change theories and conventional energy planning process, this paper proposed a planning framework with four main phases: 1) preparation, analysis, and orientation; 2) model design; 3) optimization and systematization; 4) implementation and supervision. Under the new framework, the connotation of wind energy planning and existing issues have been re-examined, and the planning procedures have been reorganized to correspond to the Chinese spatial planning system and energy development targets. Principles, priority, and systematization measures were discussed to optimize the planning system from the organizational perspective. The newly constructed framework connected the wind energy development plan and spatial planning into well-organized procedures with definite principles, targets, implementation guidelines, and supervision mechanisms at each planning level. The outcome of the research can be utilized as a guideline strategically positioning of planning goals and content.

1 Introduction

With the progressive energy transition globally, wind energy is recognized as a reliable solution to reduce carbon emissions, mitigate climate change, and increase regional energy security [1][2]. After decades of development, onshore wind energy has developed mature technologies, manufacturing chains, and market mechanisms. Promoted by the Paris Agreement that promised the decarbonization targets, various countries set roadmaps for energy transition.

The Chinese government has also set corresponding targets to improve the proportion of non-fossil energy to 42% by 2035 and 65% by 2050. It also committed a total reduction of CO2 intensity of 66% relative to 2005 [3]. By 2022, the national wind capacity exceeded 329 GW, accounting for 40 % of the global share.

In the energy transition process, the spatial planning regimes have direct influences on energy efficiency and environmental issues of wind energy. With the initial high-quality wind resource sites being occupied, searching available areas for wind farms is getting harder. Especially in intensive land use regions, land use compliance, environmental impact, and local resistance constitute the main obstacles to wind energy expansion [4]. Additionally, the wind turbines and infrastructure are recognized as the visual impairment of the landscape, which causes aesthetic value decline and the loss of local identity [5]. With the increasingly prominent contradiction between spatial planning and energy development, integration research of wind energy into spatial planning framework is imperative.

This paper aims to construct a proper framework to integrate wind energy into the spatial planning regimes of China. The wind energy planning system is optimized from connotation re-examination, existing issues analysis, planning targets assignment, standardization of planning procedures, and sustainability in space utilization to cope with the evolution of spatial planning system and decarbonization demand of China.

2 Methods

This section discusses which phases are needed in the theoretical framework to integrate wind energy and spatial planning, the critical problems in each phase of the framework, and which content needs to be integrated. Drawing on Hill's theory of dynamic change, policy implementation is the externalization performance of the development of public projects, which provides the perspective of dynamic change to abstract the framework from the policy implementation process [6]. Based on the theoretical model for energy planning proposed by Mirakyan and Guio [7], this paper constructed a framework to gradually deconstruct the integration of wind energy and spatial planning with the following four

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phases: 1) Preparation, analysis, and orientations; 2) Model design; 3) Prioritization and systematization; 4) Implementation and supervision (Fig. 1).

This paper discusses the detailed planning regimes and procedures of wind energy planning under the planning framework. Phase Ⅰ laid the foundation for the framework construction by re-examining the connotation of planning system, analyzing the existing issues and evolution targets of the spatial planning system. Phase Ⅱ designed the theoretical model for wind energy planning by identifying planning targets, principles, implementation paths, and detailed procedures of wind energy at each planning level. In phase Ⅲ, recommendations for optimization planning regimes were proposed, including the principles, priority, and systematization for the wind energy planning procedures. Phase Ⅳ focuses on planning implementation and supervision, which tries to learn foreign planning experience and explores a suitable roadmap for Chinese wind energy planning.

3 Results

3.1 Chinese spatial planning regimes evolution

This stage is primarily backgrounded interpretation and policy analysis to clarify the connotation of spatial planning, existing issues, and developing orientation during wind energy and spatial planning integration in China.

Wind energy planning consists of development plan and spatial planning, with comprehensive targets from strategic, industrial, economic, and spatial dimensions. The development plan emphasizes coordinating social, industrial, economic, and administrative systems by technical and policy instruments, while spatial planning focuses more on spatial distribution, resource allocation, and their coupling relationships. However, there is a significant gap between these two plans: the planning principles, planning objectives, data processing methods, and standards are not well connected.

Even though the central government issued the experimental pilot Multiple Planning Integration, there is no precise regulation to coordinate comprehensive planning and sectoral planning. The vast number of departments dealing with sectoral planning cannot coexist in an overlapping spatial range and similar planning contents, causing difficulties in planning implementation at the local level. Repeated planning contents waste social resources and prevent each type of sectoral planning development.

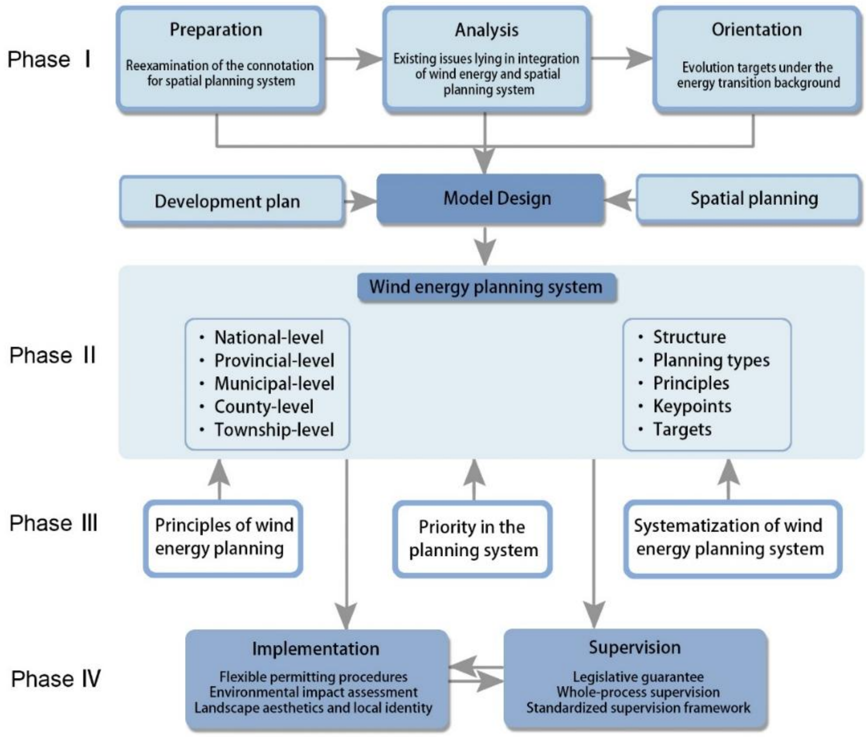

Figure 1. Framework of wind energy planning system

In the last few decades, wind farms have been planned in an extensive model for rapid development. There is no appreciable differentiation of planning methods, objectives, and technological standards among different planning levels, representing a hidden danger to newly planned wind farms under a more complicated social background [8].

The synchronization of sectoral planning in China faces a number of challenges: 1) There are overlapping and misplaced issues among several sectoral planning; 2) Planning durations are not correspondent; 3) Planning principles and tools are not standardized; 4) There is a lack of communication and coordination channel. Learning from Germany, through cross-regional cooperation between different authorities, renewable energy can obtain more efficient and precise development positioning and inter-regional coordination. The Spatial Planning Act (ROG) and wind energy decree in each state set clear laws, procedures, and leading authorities for wind power planning [9].

China's Multiple Planning Integration policy is based on the coupling and convergence of various types of sectoral planning in the national space. It is a seamless fit in the area and an integration of planning objectives, durations, scales, and methods. The new planning system is expected to eliminate the losses caused by internal systems such as cross-regional and cross-departmental repetitive work and resource competition.

Referenced European countries' experiences, a semi-open planning framework provides the interface between national development goals and the implementation of wind farms at regional and local levels [10]. The flexible land use ratio considers local governments' development goals and industrial structure. Furthermore, setting flexible land ratios and buffer distances for wind farms also considers the industrial structure and development priorities of local governments [11].

3.2 Model design

From the macro-perspective, wind energy planning can be classified into two sections: development plan and spatial planning [12]. The Wind Energy Development Plan encompasses detecting, evaluating, and utilizing wind resources and then setting development targets for wind facilities. It should also coordinate the policies, technologies, and open market to design a reasonable roadmap over a midterm or long-term period. The Medium and Long-term Development Plan for Renewable Energy (2050) and the Renewable Energy Five-year Plan (short-term) constitute the Wind Energy Development Plan by setting the national strategic target of installing 1 TW of wind energy by 2050, meeting 17% of domestic electricity consumption [13]. The development plan aims to coordinate general social-economic development with the specific industry development of political, economic, and spatial control policies. However, the achievement of the targets is finally conducted through the spatial planning system. The Wind Energy Development Plan must be combined with spatial-related implementation to locate the strategic objectives at the spatial level.

Among the spatial planning system, wind energy belongs to sectoral planning, developed by the Energy Ministry and other related authorities. The wind energy spatial planning system aims to disintegrate strategic targets of development plans into a vertically structured spatial planning system. It is released by planning authorities at the provincial, municipal, county and township levels, aiming to transfer the abstract targets of the Wind Energy Development Plan to spatial distribution. Other sectoral planning can be divided into assistant and constraint planning according to their relationships with the wind energy industry chain. For instance, the transportation plan, infrastructure facility plan, and electricity grid plan are associated with wind energy. Constraint plans, such as landscape planning, ecological protection planning, and cultural heritage planning, usually compete with wind energy in land use.

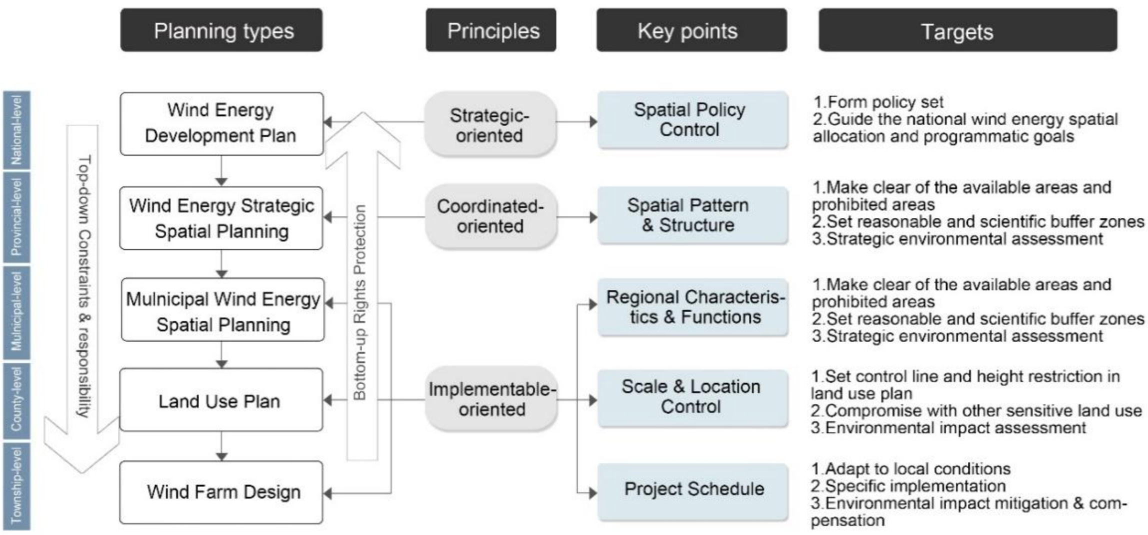

Figure 2. Structure, principle, and targets of wind energy planning system (edited by the author)

There is a great necessity to integrate the development plan and spatial planning of wind energy in the same planning system with a hierarchical structure, as illustrated in Figure 2. The system includes multiple planning levels corresponding to comprehensive planning. Specific principles, key points, and targets are issued at each level. The hierarchical structure features the mechanism of top-down constraints and bottom-up rights protection.

3.3 Optimization and systematization

3.3.1 Principles of wind energy planning

The prosperity of renewable energy development is not independent but is influenced by a complex context of global energy markets, technologies, geopolitics, etc. The dynamic evolution of spatial planning is closely connected to the energy transition. As a basic plan, spatial planning cannot set permanent standards, but it can set principles for wind energy development: environmental protection and sustainability.

- Environmental protection principle

Due to the various environmental impacts (noise, visual impact, flicker shadow, soil erosion, etc.) emitted by wind turbines [14][15], the social opposition to wind energy has become a critical obstacle to wind farm planning and construction. There is a growing consensus among the public that environmental protection should be considered as the priority in wind energy expansion.

- Sustainability principle

It is unrealistic to expect purely quantitative growth in wind energy capacity. Instead, we call for a sustainable roadmap following the principle of fair resource utilization. With a considerable energy consumption market in China, the total primary energy consumption of 4.64 billion tones of standard coal equivalent (tce) in 2018 [16], the energy transition should move from a coal resource-based economy to a sustainable economy based on affordable, stable, and green energy. In another aspect, wind energy development should also be gradual and proceed in parallel with other energy-supporting facilities to reduce the inner waste due to improper planning.

- Intensive land use principle

With the expected population growth and built-up land, the land reserved for renewable energy is limited and unavoidably mixed with ecological space, agricultural land, countryside, forest, etc. An intensive energy transition model combines land for various functions such as photovoltaic, wind power, agriculture, and fishery to maximize economic efficiency. Additionally, energy-efficient spatial structures can improve the density and output of hybrid energy facilities, and promote the spatial allocation between the energy production- and consumption side [17].

3.3.2 Priority in the planning system

Renewable energy can reduce carbon emissions and mitigate environmental pollution. On the other hand, renewable energy has side effects that impact the environment, although far less than conventional energy [18]. The priority of spatial planning is the sustainable use of natural resources, which means irreversible damage is not allowed in the natural environment. Even if many benefits can be obtained in the short term, the necessary conditions for long-term development, namely an excellent ecological environment, cannot be ignored. Wind energy planning should make concessions when it conflicts with ecological resources such as basic farmland, ecological reserves, and national parks.

The priority of environmental protection depends on a comprehensive legislation and regulation system. Guaranteed by the Renewable Energy Law (amended in 2010) and Environmental Impact Assessment Law (amended in 2016), environmental and ecological conservation awareness has been raised. This is reflected in the promulgation of more related regulations, such as " Interim Procedures for the Administration of Examination and Approval of Construction Facilities in National Nature Reserves" (March 2018) and "Notice on Further Strengthening the Management of National Forest Parks" (December 2017).

3.3.3 Systematization of wind energy planning system

Based on the initial framework proposed in phase II (Fig.2), it is necessary to optimize the wind energy planning system with differentiated targets corresponding to comprehensive planning at each level. Under the consensus principles of environmental protection, sustainability, and intensive land use (see 3.3.1), detailed planning procedures are further discussed in Figure 3. It optimizes the framework of wind farm planning from the organizational perspective in China and emphasizes the primary tasks at each step. Wind energy planning has spatial and temporal scopes, targets, planning instruments, and technical indicators corresponding to respective planning stages. For different participants, their responsible and assisting roles are also assigned clearly.

3.4 Implementation and supervision

The wind energy planning implementation contains extensive prework involving the investigation of geological conditions, microclimate, soil, ecological environment, and local acceptance of wind energy. During the planning process, permitting is challenging, which decides whether the project can be implemented. In China, the permitting process contains not only an Environmental Impact Assessment Permit but also Land Use Permit, Planning Permit, and Construction Permit [19]. It is recommended to refer to the case in Germany, where wind turbines with different heights and numbers correspond to different permitting procedures. Wind turbines below 50 meters are subject to the Building Law. In view of the construction of a large number of GW-level wind farms in northern China, the disturbance of wind farms to microclimate, soil erosion, and ecological environment also requires continuous observation and research [18]. Additionally, the change in landscape aesthetics and local identity should be included in the Environmental Impact Assessment from a cultural perspective.

Supervision is a critical part of the spatial planning regime, ensuring the quality of the implementation and bottom-up feedback channel. The complex legislative framework challenges the enforcement of supervision. For high-polluting projects, supervision plays a significant role in permitting process, which decides whether the project can be approved and constructed [20]. The optimization of the supervision system reflects in two aspects. Firstly, the supervision should shift from a single, conclusion-oriented target to whole-process supervision. It enhances supervision from source and process and ensures the legality and rationality of the entire Plan. Secondly, the supervision should shift from single-department supervision to a strict, standardized supervision framework to not facilitate any problems that may exploit loopholes.

4 Conclusions

This paper proposed a four-phase framework based on the dynamic theory and conventional energy planning system, which aimed to integrate wind energy into spatial planning system under the evolution of Chinese urbanization and Multiple Planning Integration background. The study sequentially reorganized the wind energy planning system with literature research on spatial planning regimes, existing issues, and evolution orientation. Based on the model dealing with multi-level principles, key points, and targets, the proposed framework was optimized by discussing the principles, priority, and standardization of the regimes. And finally, the planning implementation and supervision recommendations were put forward for further research.

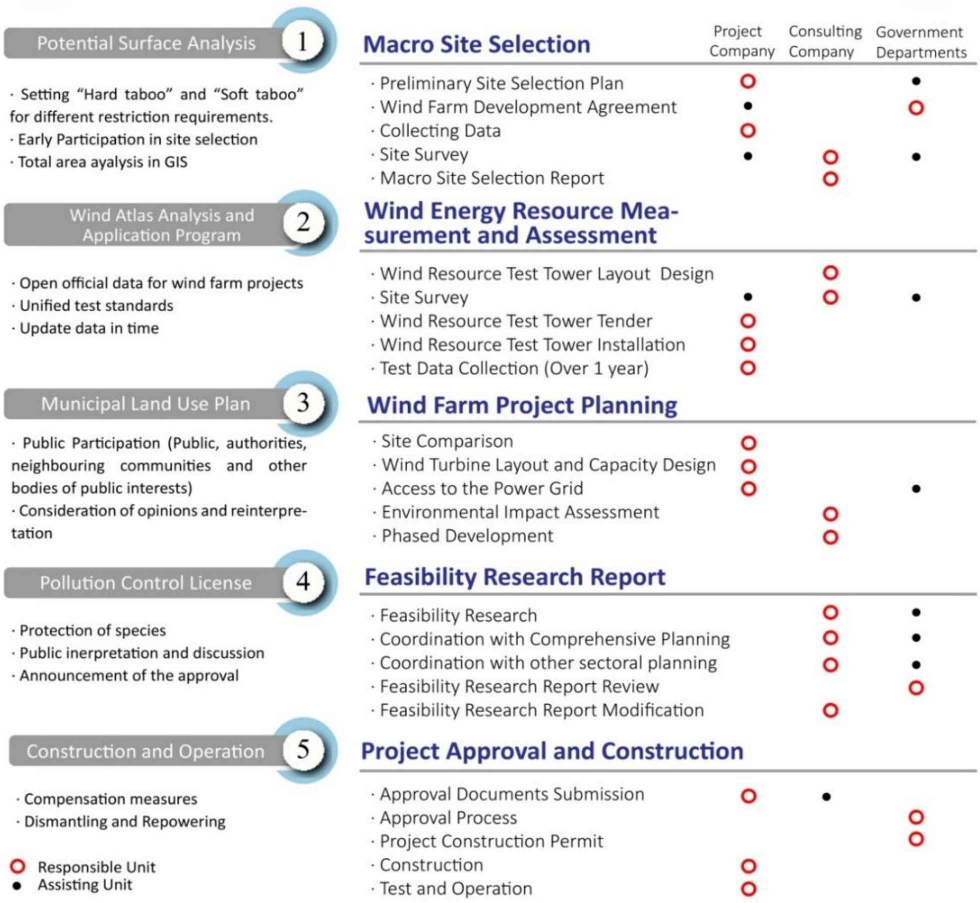

Figure 3. Wind energy planning procedures and optimization recommendations (edited by the author)

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