Collaborative Development Model and Strategies of Multi-Energy Industry Clusters

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Abstract

The development of energy clusters plays a vital role in regional and national economic growth, contributing to sustainable development and industrial optimization. Previous studies, especially the energy-based industrial clusters (EBICs) model proposed by Lis and Xiu (Xiu & Lis, 2024), have attempted to quantify energy cluster development within the framework of economic growth. The model promotes to infer the prospects of cluster energy development and identify the primary and secondary factors affecting energy cluster development. The model highlighted key parameters such as capital, labor, industrial concentration, and enterprise size, which have a significant impact on cluster productivity (Ada et al., 2021; Biggeri, 2020). These findings provide scientific guidance for investment decisions and policy making in the energy sector. However, the EBICs model also has certain limitations. Notably, it does not consider external interference factors in cluster development but relies on simulation-based methods to quantify the development cycle. These limitations restrict the model's ability to fully capture the dynamics of real-world energy clusters, where external influences such as market resistance, government intervention, and macroeconomic factors play an important role (Bechara & Alnouri, 2022; Colgan & Baker, 2003).

To address these shortcomings, this study introduces an improved cluster development cycle quantification method that integrates real-world data from existing literature to improve the accuracy of model predictions. In addition, the role of macro-control in the development of energy clusters is considered by incorporating government intervention into the model. This is achieved by enhancing the Logistic growth model, which better reflects the development trajectory of energy clusters by incorporating external regulatory forces. The original EBICs model focuses primarily on internal

cluster dynamics, but the improved model recognizes that the external environment, including policy changes, economic fluctuations, and technological advances, has a significant impact on energy clusters. The improved approach considers both coordination and competition within the cluster as well as external environmental factors that may accelerate or hinder cluster development. In addition, by improving the method of quantifying the time cycle of cluster development, this study can more accurately assess how long it takes energy clusters to reach different development stages under various external conditions. The integration of these elements enhances the practical applicability of the model, making it more suitable for policymakers and industry stakeholders seeking to optimize cluster development strategies.

The improved model produces several important findings. First, the inclusion of external factors, especially government intervention, provides a more realistic description of the energy cluster development process. As a key component of the revised model, the logistic function effectively captures the saturation effects and constraints encountered by clusters over time. Second, by incorporating an improved period quantification method, this study provides a more systematic approach to assessing the time required for clusters to grow from the nascent stage to full maturity. This advance is particularly important for stakeholders involved in long-term energy planning as it enables more accurate forecasting and decision-making. Third, the model shows that market resistance, which was previously overlooked in the EBICs model, plays a key role in shaping the growth trajectory of energy clusters. Factors such as competition, regulatory barriers, and resource constraints can seriously hinder cluster expansion, so targeted interventions are needed to mitigate these challenges. Overall, the results of this study help enrich the theory of energy cluster development and fill key gaps in existing models. By integrating macroeconomic control mechanisms, external environmental influences, and improved time quantification methods, this study provides a more comprehensive framework for understanding and optimizing the growth of energy clusters. The results have practical implications for policymakers, industry leaders, and investors as they provide a scientific basis for formulating policies and investment strategies to promote the development of sustainable and efficient energy clusters.

Keywords: Energy clusters, energy management, economic growth, cluster development, sustainable development

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