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Case study of an industrial park toward zero carbon emission

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HIGHLIGHTS

- Schemes to realize zero carbon emission at an industrial park level were studied.
- Practical case study of a Traditional Chinese Medicine industrial park was performed.
- Carbon reduction potential was evaluated based on scenario analyses.
- Purchasing carbon offsets gets the min. cost effectiveness under current situation.
- Challenges and solution schemes for zero-carbon development are discussed.

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ABSTRACT

Industrial park shoulders heavy responsibilities for economic development, and in the meantime, acts the role as energy consumer and carbon emitter. Under the background of holding the average global temperature increase limited in 2 °C compared to the pre-industrial level, which was proposed in the Paris Agreement, the development of zero carbon emission at the industrial park level is of great importance. This study investigated how to realize zero carbon emission at an industrial park level. In addition, a practical case study of the Southern China Traditional Chinese Medicine Industrial Park located in the Zhongshan City, Guangdong Province of China was conducted. Scenario analyses were projected to realize zero carbon emission in this industrial park and the results show that zero carbon emission can be realized under all the three scenarios. Economic assessments found that purchasing carbon offsets get the minimum cost effectiveness under current market situation. However, purchasing carbon offset may not be the best choice from the aspect of absolute reduction. Sensitivity analyses illustrate that the cost effectiveness of carbon reduction is remarkably influenced by the carbon price and solar energy cost reduction ratio. Meanwhile, applying large-scale renewable energy and producing more carbon offset can harvest more economic and carbon reduction benefits when the current solar energy cost has been reduced by 90%. Moreover, challenges of building zero-carbon industrial park as well as the corresponding solution schemes were discussed.

1. Introduction

During the 21st century, climate change is one of the most unprecedented changes faced by the human society [1]. According to the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report, human activity is closely related to climate change [2]. Governments and scientists have committed to slowing down and adapting to climate change under the urgency of sustainable development. The Paris Agreement calls for net zero anthropogenic greenhouse gas emissions to be reached during the second half of the 21st century, which opened a new era in low-carbon development. Participants in the Climate Conference in Paris promised that the level of carbon emission caused by anthropogenic activity will decrease to the amount that the forest and ocean can absorb after 2050 [3]. In the adopted version of the Paris Agreement, it is proposed that the global temperature increase should be limited in 2 °C compared to the pre-industrial level. According to researchers, in order to realize this stringent target of temperature increase, the whole world will require to realize net zero carbon emission sometime by 2050 [4].

As the global largest carbon emitter, China attaches great

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importance to addressing climate change, and makes it a significant national strategy for its social and economic development. China committed in the Intended Nationally Determined Contributions 2015 and the Paris Agreement that the domestic carbon emission peak will be reached around 2030 and make efforts to achieve peak value as early as possible. In addition, the carbon intensity (carbon emission per unit of gross domestic production) of the whole nation will be reduced by 60–65% compared to the 2005 level [5]. Later on, the State Council of China launched the Work Plan for Controlling Greenhouse Emissions during the13rd Five-Year Plan Period (2015–2020) in which the net zero-carbon emission projects are encouraged. Moreover, this work plan emphasized that 50 demonstrating projects of net zero-carbon emission would be established by 2020.

To reach the zero-carbon emission level, scientists and governments around the world are making great efforts. As a result, the corresponding technologies, business models, and management policies are becoming research hotspots. Tokimatsu et al. [6] investigated the roles of the innovative technologies and the biomass energy with carbon capture and storage under the global zero emissions scenarios. Not only the research at the global level, the performance and prospect of zero carbon emission at a smaller scale (such as the zero carbon cities) are investigated as well [7]. In addition, Pan et al. [8] summarized the clusters and exemplars of zero carbon buildings, and they concluded that the zero carbon community and zero energy community are becoming a growing trend worldwide. Zero carbon has been set as a middle and long-term target in many countries. For example, it is specified by the Energy Performance of Buildings Directive of the European Parliament and European Council that all new buildings and communities in the European are required to be zero Carbon by 2020 [9]. The California Government made an appeal that all new buildings should achieve the zero carbon level from 2020 as well [10]. Zero carbon technology and strategy have also been encouraged in China. For example, zero carbon buildings were designed and exhibited in Shanghai World Exposition. Solar energy and geothermal energy act as energy supplier to guarantee energy self-sufficiency in the building. In addition, water source heat pump was installed as natural air conditioner and food waste was utilized for biomass power generation [11]. Furthermore, even the 2016 G20 Hangzhou Summit adopted the concept of Zero Carbon Summit for the first time. During this G20 summit, afforestation project was applied for neutralizing the carbon emitted from transportation, catering, and hotel in the summit [12]. In general, the previous studies associated with zero carbon emission mainly focus on the global emission, zero carbon city, zero carbon community, and zero carbon building. However, global zero carbon emission can't be realized without tremendous efforts from all countries, multiple regions, different sectors, and various entities. Industrial parks are not an exception. This is because industrial parks are not only economic engines for many regions [13], but also make great contribution to the local target of carbon reduction and energy conservation [14–16]. The innovative technologies and model of carbon reduction in industrial park can effectively reduce the carbon emission in the urban areas [17], and constructing zero carbon emission industrial park plays an important role for the whole urban areas to achieve zero carbon emission.

In order to reduce carbon emission in an industrial park, many countries have launched a range of practices in low carbon industrial park (LCIP). For instance, the industrial park in Kalundborg [18], Denmark shows an outstanding example of industrial symbiosis in the development of industrial ecology and cleaner production. Recycling of water, steam, solid waste and energy are implemented in the industrial park in Kalundborg to realize industrial symbiosis. According to estimation, a total of 154,788 tons of carbon emission had been avoided during 1997–2002 in this industrial park. Other international investigations in Japan [19], Finland [20–22], Switzerland [23], Sweden [24], Liuzhou [25], Suzhou [26,27], Tianjin [28], and Beijing [29,30], et al. have also demonstrated the effectiveness of climate mitigation through energy innovation in the industrial parks.

To date, the literature about LCIPs around the world mainly focused on carbon auditing and the corresponding low carbon approaches investigation for industrial park. Case studies in the above mentioned industrial parks mainly concentrated on analyzing the rules of industrial symbiosis and energy conservation to decrease carbon emission. However, to achieve deeper carbon reduction effect in a targeted industrial park and realizing zero carbon emission, systematic analyses cover the emission boundary and internal structure, scheme of energy supply, energy consumption level, carbon auditing, program of negative carbon emission, and the corresponding management pattern are required. Block et al. [31] discussed the neutrality of the industrial park of Herdersbrug (Brugge, Flanders, Belgium) in a broader sense. Nonetheless, the comprehensive framework of building a new zero carbon industrial park (ZEIP) or how to transforming a LCIP to ZEIP should be investigated, and the emission boundary as well as the definition of a ZEIP are required to be elaborated. For a targeted ZEIP, the potential of carbon balance and the corresponding economic evaluation are also important.

In this study, we investigated how to realize zero carbon emission at an industrial park level, in which the specific definition and calculation boundary of the ZEIP are determined. A comprehensive framework and steps to achieve the ZEIP are also proposed. This proposed framework and strategy was applied in a Traditional Chinese Medicine industrial park which is named as the Southern China Traditional Chinese Medicine Industrial Park (the SCTCM Industrial Park) in Zhongshan, Guangdong province of China. Three different scenarios of realizing zero carbon emission in this industrial park are performed. Inventories of energy demand and supply, carbon emission, as well as negative emission approaches in each scenario are analyzed in detail. In addition, carbon reduction effect and economic assessment for these scenarios are discussed as well. Based on these studies, challenges and the corresponding schemes to carry forward the ZEIP are discussed.

The structure of this article is arranged as follows: Section 2 is the methodological section, which describes the comprehensive framework, implementation steps, and economic evaluation method to construct zero carbon emission industrial parks; Section 3 presents the situation of the case study and scenario analysis; Section 4 discusses the challenges to carry forward zero carbon emission industrial park and the corresponding solution schemes; Section 5 shows the conclusion.

2. Methodology

This section introduces the methods of constructing a zero carbon emission industrial park or transforming a low carbon industrial park to a zero carbon industrial park. Here the industrial park mainly refers to the kinds of high-technology industrial parks which have the advantages of much less environmental pollution and energy consumption. The detailed definition of zero carbon emission for an industrial park level was shown. The carbon accounting boundary and calculation method was introduced as well.

2.1. Concept and boundary

Published research since the IPCC 2007 assessment has verified the fact that zero carbon emission plays an important role for controlling the continuing global warming. The restricted definition of zero carbon implies the following meanings [32]: zero fossil fuel combustion for energy, zero biomass combustion for energy, zero biofuels combustion for energy, zero CO_2 emitting manufacturing, and zero deforestation. For industrial park, energy consumption plays an important role on its economic development. However, the rigorous zero carbon emission has limitation on the economic development of an industrial park, because of the increase of energy cost. Therefore, unlike this restricted definition of zero carbon emission, in this study, zero carbon emission in the industrial park level is aimed for net zero carbon emissions which can be described by Eq. (1):