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Low carbon technology assessment and planning—Case analysis of building sector in Chongming, Shanghai

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ABSTRACT

This paper aims to comparatively analyze the carbon reduction potential of several low carbon technologies by means of different assessment and planning methods for regional development. Seven commonly used building energy saving technologies are evaluated and the priority-setting among them is identified on the example of the building sector in Chongming Island, Shanghai. By applying Decoupling Theory, the CO_2 emission reduction extent under a low carbon scenario and an ideal scenario are estimated for 2030. The required application areas for different technology schemes are calculated using the Technology Combination Planning Method. In order to further find out required application areas for each technology under the least costs, the Goal Programming Method is then applied. Findings of the Technology Combination Planning Method reveal that the combination of energy saving technologies with high GHG emission reduction such as building insulation and geothermal heat pump have obvious effect in helping reducing the required technology application area. Goal Programming provides results for the required application area of each technology, and the minimum emission reduction cost is found as 2.54×10^8 US dollar under low carbon scenario and 3.50×10^8 US dollar under ideal scenario.

1. Introduction

In the process of low carbon transition, strategies are needed that not only reduce GHG emissions but implement this task also in a sustainable manner, which means they are not compromising other environmental priorities and legal obligations while being low carbon [12].[1] Some low carbon strategies are considered to be unsustainable because they do not sufficiently factor in economic, environmental, and social impacts [4,17]. In previous research, we established an assessment framework for low carbon technology concerning both the GHG emission reduction and sustainable development criteria. Indicators of sustainability encompassing economic, environmental and social aspects were also designed to meet technologically sustainable requirements in the building sector [13].

The process of low carbon planning is usually designed according to planning objects' developing requirements. Based on different objects and scopes of research, the existing studies can be divided into macro and micro level: macro level focuses on the general low carbon strategy setting; micro level usually focus on low carbon technology planning in special industry sector. For instance: (1) on the macro level [1]; present an analysis of public preferences for a low carbon future in the UK and compare them with three future scenarios proposed by the UK government [3]. analyze feasibility and a roadmap of a low-carbon society in Japan by 2050, while satisfying required demands. Thus, future technology roadmaps, CO_2 emission pathways and energy mix transitions leading Japan are calculated using the Asia–Pacific Integrated Model (AIM) [10]. developed a local (city-scale) low carbon scenario creation method and identify countermeasures to achieve the low-carbon target. (2) on the micro level [24]; gives a general view of prior technologies in different industrial sectors for China to achieve low carbon future [8]. find 10% savings on CO_2 emissions using renewable energy technologies will be required in London in order to gain planning permission [7]. identified and evaluated key low-carbon technology solutions in the power sector in China, and low-carbon technology roadmaps under specific scenarios are elaborated, which implies corresponding optimal evolution of power

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[1] HM government: Her Majesty's Government commonly referred to as the British Government, is the central government of the United Kingdom of Great Britain and Northern Ireland.

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generation.

Based on these examples it can be seen that methodologies such as models and scenario analysis are most commonly applied in the macro level planning. As for the micro level planning, scenario analysis is also widely used. The processes of low carbon technology planning in specific industry sector are usually identifying the key low-carbon technology solutions-evaluating the energy saving potential and cost of the technology solutions-low carbon scenario setting and optimal technology roadmaps finding. However, this "common planning procedure" can only give a general developing scene for regional industry development. In addition to meet specific energy saving target, technologies with the least cost are always preferred. Thus, a more elaborated planning method is necessary.

In the case of China, as for the GHG reduction pressure, low carbon industrial transition is one essential part that needs policy action [25]. With its rapid development, the building sector is estimated to experience an explosion in the ongoing decade [15]. This paper is a follow up to our previous sustainability evaluation analysis of low carbon technology [13], taking the building sector as a case analysis. In order to further indentify the minimum cost technologies, this study uses a traditional industrial planning methodology—Goal Programming—in addition to the "common planning procedure" to do low carbon planning of selected technologies. In the following, we firstly show the geographic scope and the different theories applied and then we describe the methods used in our assessment. Afterwards we show how the methods are applied in the assessment and planning of building energy saving technologies in Chongming, Shanghai, and present our results regarding the priority-setting among the seven technologies under the two scenarios. Finally we end with conclusions.

2. Methodology

In this section the geographical scope, one evaluation method and three planning methods are described.

2.1. Geographical scope of the study: Chongming Island, Shanghai

Chongming Island lies on the northern shore of the Yangtze River and is an alluvial island formed by silt carried along the river. Expanding over 1041.21 km^2, it is the third largest island in greater China [30] (Fig. 1). The island has joined Shanghai by 25.5 km Shanghai Yangtze River Tunnel and Bridge in 2009, and has been connected to Jiangsu Province via Chonghai Bridge in 2011.

According to the government development plan, Chongming is aim to be built into a center for tourism, ecology, scientific and technological research, serving as a bridge linking the Yangtze River Delta and the north [30]. In view of the high speed development trend, Chongming is accounted as a suitable case study for a low carbon industry transition plan. Construction industry is selected as the study object, as it is one of the most potential industries for CO_2 emission reduction.

The total building area including floors in multilevel constructions in Chongming Island is 3.5×10^8 m^2 in 2010, in which around 3.0×10^7 m^2 is the public building, and 3.2×10^8 m^2 is residential building [30]. The building energy saving condition is out of optimum in Chongming Island as the percentage of buildings that meet the energy saving standards is very low. For public buildings, this rate is around 15.34%, and in residential buildings, the rate is only around 9.3%.

2.2. Evaluation method

The evaluation method is established based on the three sustainability criteria suggested in the Multi-Attributive Assessment for the Clean Development Mechanism (MATA-CDM),[2] which is already discussed in our previous analysis [13]. A utility value of 0 indicates no change to the baseline. Values 1 and -1 represent the most positive and negative scenarios, respectively, and 0.5 and −0.5 indicate intermediate scenario. Quantitative indicators, including microeconomic efficiency and GHG emission reduction, are measured using the interpolation algorithm method. The indicator of the contribution to industrial development is graded using a possible energy saving potential of 50%. The qualitative indicator measurements are classified into 5 categories. Technologies with basic information and data are judged according to this indicator measurement, and referring to opinions from experts of building energy saving area. For these three criteria, seven sustainability assessment indicators were designed for low carbon technologies of building sector, and utility functions were set based on general conditions in China (Table 1). The value distribution of the assessed technologies is then analyzed using radar chart,[3] with the aim of gaining a better understanding of how technologies affect the evaluated indicators.

2.3. Planning methods

The prospective CO_2 emission reduction for 2030 is set by using Scenario Setting through applying the Decoupling Theory. The required application areas for different technology schemes are calculate by using Technology Combination Planning method. Application area under least cost is further identified by application of Goal Programming method. Following we provide an explanation of this planning methods and processes.

(1) Method of Scenario Setting by using Decoupling Theory

In public utility regulation, decoupling refers to the disassociation of a utility's profits from its sales of the energy commodity [27]. When referring to low carbon development, decoupling means the disassociation between emissions and economic growth [9]. indicate that CO_2 emission can be estimated as increasing 50% in the relative decoupling scenario and 0% in the absolute decoupling scenario when GDP is deemed to have increasing rate with 100%. Consequently in our research, a low carbon scenario is set at 50% and ideal scenario at 0% increasing rate respectively. The time horizon set is midterm till 2030 while an absolute decoupling appears to be impossible in the long run [23].

(2) Technology Combination Planning Method

Technology Combination Planning is done based on the priority order of the technology assessment results. This method is grounded in the assumption that technologies in each scheme have the same application area.

Different technology application schemes are set by adding technology one after another according to their priority order. The required building area of different technology combination schemes will be calculated under the low carbon scenario and the ideal scenario. CO_2 emission of Chongming Island is calculated according to the KAYA formula, which can investigate the drivers of GHG emissions such as following: Total emissions = population × affluence

[2] MATA-CDM is developed by Swiss Federal Institute of Technology, the World Business Council for SD and International Emission Trading Association. Some CDM projects were assessed with this method in countries such as Uruguay, India, South Africa and China.

[3] Radar chart is a circular chart that is used primarily as a data comparison tool. It is sometimes called a spider chart or a star chart. It uses the circumference of the chart as the X axis.