Journal of Cleaner Production 81 (2014) 89–102

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Greenhouse gas emissions estimation and ways to mitigate emissions in the Yellow River Delta High-efficient Eco-economic Zone, China

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ARTICLE INFO

Article history:
Received 18 April 2014
Received in revised form
27 May 2014
Accepted 10 June 2014
Available online 17 June 2014

Keywords:
GHG emissions
Regional scale
Government plan
Yellow River Delta

ABSTRACT

Rapid economic development and urbanization has led to a tremendous carbon emissions increase. The development of the Yellow River Delta High-efficient Eco-economic Zone (YRDHEZ), according to its plan, would be accompanied by a sharp economic increase and new pattern of urbanization. This paper, based on IPCC guidelines, explored the carbon emissions trajectory in YRDHEZ from 2005 to 2011 from 6 sectors (industrial energy consumption, fugitive emissions, transportation, industrial processes, livestock emissions, and waste), and predicted its carbon emissions in 2015 and 2020 based on the development plan. The results showed that total carbon emissions substantially increased from 2005 to 2011 and it would still increase in 2015 and 2020, with the largest emissions sector coming from industrial energy consumption. The carbon emissions intensity decreased from 2005 to 2011, and would decrease in 2015 and 2020. The carbon emissions intensity reduction rate would fail to meet the national target of 40–45% reduction in 2020 compared to the level in 2005 if no further mitigation methods were adopted. To increase the mitigation of carbon emissions, universal and unique methods were proposed in YRDHEZ: industrial structure adjustment, energy efficiency improvement, and adoption of renewable energy; transformation of reserve land into eco-land; and the employment of carbon capture and storage technology in the future. These results and implications would provide valuable suggestions for development of YRDHEZ.

1. Introduction

In recent years, GHG emissions have attracted more and more attention because of global warming and consequent significant damages (Dhakal, 2008; Kennedy et al., 2009). Cities, which occupy less than 1% of the earth surface and concentrate over 50% of the population, emit about 80% of the world's GHG emissions (Feng et al., 2014). Therefore, more studies are concentrated on GHG emissions at the city level (Dhakal, 2009; Li et al., 2010). At the city level, most of the studies focused on geographical and administrative boundaries due to data availability and comparisons among cities. The literature addressed GHG emission sources differently, some only covered CO_2 emissions (Tian et al., 2013), others focused on CH_4, N_2O, and other greenhouse gases (Bi et al., 2011). The sectors the literature focused on also differed (Shao et al., 2014; Liu et al., 2012). Mega cities, such as capitals, had priority in carbon emission calculations at the city level. The studies mainly explored carbon emission trajectories and drivers and inhibiting factors of certain cities (Liu et al., 2012; Wang et al., 2012; Xi et al., 2011). Some inquired into the carbon emissions in the coming years under different development scenarios (Lin et al., 2010; Liu et al., 2009). Generally, across cities, great variations are witnessed in the scale of total emissions, carbon emission density, and the per capital emissions. The variations mainly came from the nature of emission sources, industrial structures, and energy mixes (Dhakal, 2008).

Two sources of standards and protocols were mainly used in the calculation of carbon emissions at the city level: the technical reports and methodology guidelines of the International Panel on Climate Change (IPCC) and the Greenhouse Gas Protocol (GHG protocol) (IPCC, 2006) of the World Resource Institute (WRI) and the World Business Council on Sustainable Development (WBCSD) (WBCSD, 2004). The IPCC method, which focuses on local emissions and has an important impact on the local situation and arguably

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http://dx.doi.org/10.1016/j.jclepro.2014.06.032
0959-6526/

should be thought of as the most important object for accounting, is controversial because it excludes any indirect emissions and does not give a comprehensive picture of carbon emissions of a city (Hoornweg et al., 2011; Jacobson, 2010). The GHG protocol is also disputed because it regards GHG emissions outside of the geographical boundaries as indirect emissions. Because of the above reasons, the concept "scope " was used to delineate direct and indirect emissions and avoid double accounting (ICLEI, 2009). Scope 1 includes all direct GHG emissions within the geographical boundary which contains fossil fuel consumption, waste emission, industrial processes and product use, agriculture, forestry, and other land uses (AFOLU). Scope 2 includes the indirect GHG emissions of purchased electricity, steam, and heating. Scope 3 includes other life-cycle emissions excluded from scope 1 and 2, such as embodied emission from food and materials consumed (Kennedy et al., 2010). The ideal scope of GHG emissions should include Scope 1–3 (Xi et al., 2011). Due to data availability and multiple counting problems, most of the studies only included Scope 1 and 2. A new standard, which aims at carbon emissions at city or municipal levels, was developed by the Local Governments for Sustainability (ICLEI) and has been popular since over 1000 local governments worldwide have taken part in its initiatives. However, the ICLEI approach cannot be applied to Chinese circumstances since the statistics in China cannot meet the ICLEI statistical requirements (Feng et al., 2014). By far, most of the studies are based on the standards and protocols of IPCC guidelines and GHG protocols.

Carbon emissions studies were also conducted at the national level to reveal national level emissions and find mitigating solutions from a holistic perspective. Carbon trade is another reason for calculation at the national level. IPCC guidelines, input–output models, and the stochastic frontier model have been employed to estimate the carbon emissions at the national level (Chen and Chen, 2010; Dong et al., 2013; Zhang et al., 2011). Previous literature mainly focused on the following aspects: total carbon emissions in the whole economy or in specific sectors, carbon emissions in different regions in the country and influencing factors, the convergence analyses of different regions, and the spillover of different regions (Huang and Meng, 2013; Meng et al., 2013; Zhang et al., 2011). The results of those studies provided a database for carbon emissions in the nation and put forward feasible carbon mitigation methods at the national level.

Compared to studies at city and national levels, research at the regional level was much less. This might be because regions consist of multiple counties from different cities and the inconsistence of development policies and strategies complicate the analysis. Also, the lack of carbon trade among different regions within the country might slow down the process of carbon emission calculation at the regional level. As one of three deltas (Yangze River Delta, Pearl River Delta and Yellow River Delta) in China, the Yellow River Delta is facing great development opportunities and challenges. Unlike the Yangze River Delta and Pearl River Delta which are characterized by great economic volume, all-scale export-oriented economy, and a large population, the Yellow River Delta is still in the early stage of economic development. With the endorsement of Yellow River Delta High-efficient Eco-economic Zone (YRDHEZ) by the central government, the development plan in this region will be more consistent. A high speed booming economy, a new pattern of urbanization, and highly-efficient eco-industrial system are expected to happen, which might bring about large quantities of carbon emissions. Therefore, it is essential to explore the carbon emission trajectory in the past years and predict the carbon emissions in the future in YRDHEZ and put forward effective and efficient methods to mitigate carbon emissions. The research can not only provide information and insights for the development of YRDHEZ, but be of great reference value for integrative development zones in China and of the world.

In this study, following the IPCC guidelines, carbon emissions in YRDHEZ were investigated and calculated from retrospective and prospective aspects. In this paper, we want to answer the following 2 questions: (1) what is the trajectory of carbon emissions in YRDHEZ and (2) will carbon emission intensity in 2020 meet the national target of 40–45% reduction compared to the level in 2005? In addition, we also tried to provide ways to reduce carbon emissions in YRDHEZ.

2. Methodology

2.1. Study area and data collection

YRDHEZ was endorsed by China's government in 2009 and is located along the Yellow River estuary in Shandong Province. It consists of 196 counties in 6 cities(Dongying City; Binzhou City; Hanting County, Shouguang County and Changyi County in Weifang City; Qingyun County and Laoling County in Dezhou City; Laizhou County in Yantai City; and Gaoqing County in Zibo City) with an area of 26.5 thousand square kilometers (Fig. 1). The total population was 9.88 million and the GDP was 456.4 billion RMB in 2008 (NDRC, 2009). YRDHEZ is characterized with a large amount of reserve land and this reserve land is increasing because of the Yellow River alluvia. The oil and natural gas storage is 5 billion tons and 230 billion cubic meters respectively which make it an energy base for the whole country. It is also the largest salt chemical engineering base in China and a big reservoir for wind energy, geothermal energy, and marine resources. YRDHEZ has been a heavy industrial zone since 1960s after oil was discovered. Secondary industry accounted for 69.3% in 2006, of which 87% of the industrial added value came from textile, building materials, energy, machinery, and chemical engineering industries (Gu and Yang, 2011). The development of industries has resulted in a large amount of GHG emissions and energy consumption. According to the plan, the GDP of YRDHEZ will double that of 2008 in 2015 and be over 3 times in 2020, which will be mainly achieved by the secondary industry development. The energy demand and carbon emission will be tremendous.

Data used in this paper come from city statistical documents and published reports and literature. Data on industrial energy consumption, industrial processes and products use, fugitive emission, ground transportation, and annual breading stock of livestock were obtained from the Statistical Yearbook of Dongying (DMSB, 2006–2012b), Statistical Yearbook of Binzhou(BMSB, 2006–2012), Statistical Yearbook of Weifang (WMSB, 2006–2012), Statistical Yearbook of Yantai (YMSB, 2006–2012), Statistical Yearbook of Dezhou(DMSB, 2006–2012a), and Statistical Yearbook of Zibo (ZMSB, 2006–2012). Data on waste and transportation prediction were obtained from the literature (He et al., 2005; Mou et al., 2009; Qu and Yang, 2011).

2.2. Scope of research

Determining the boundary of the study area's carbon emission is of great importance since the study area as an open system often involving intensive energy and materials exchanges with the surroundings. The World Resource Institute/World Business Council for Sustainable Development defined GHG emissions related to the spatial boundary at a city scale. To reflect the real emissions in the geographical boundary, we only considered Scope 1 for the emissions because Scope 2 reflects the real emissions in power plants