Energy Strategy Reviews 10 (2016) 18–28

Contents lists available at ScienceDirect

Energy Strategy Reviews

journal homepage: www.ees.elsevier.com/esr

ANALYSIS

Study and analysis of energy consumption and energy-related carbon emission of industrial in Tianjin, China

Yang Wang, Xiao-ling Ge, Jun-liang Liu, Zequn Ding*

State Nuclear Electric Power Planning Design & Research Institute, Beijing 100095, PR China

ARTICLE INFO

Article history:
Received 10 June 2015
Received in revised form
27 March 2016
Accepted 28 April 2016
Available online 14 May 2016

Keywords:
Energy consumption
Carbon emission
Industrial structure
Intensity
Performance

ABSTRACT

This paper analyzed the total industrial energy consumption and energy-related carbon emission of Tianjin from 2003 to 2012. During 2008–2012, Tianjin's energy consumption of industrial added value decreased by 11.46%. The carbon dioxide emissions caused by industrial energy consumption of Tianjin increased year by year, with an average annual growth rate of 9.11% from 2005 to 2012, but the carbon emission intensity decreased by 53.17% during the same period. Using these energy consumption data, a model was able to predict the future with a high degree of accuracy to check if the target can be achieved that reduce its energy consumption per unit of GDP by 18% and carbon emission per unit GDP by 17% during the "12th Five-Year" period. Additionally, an energy decomposition analysis indicated that while the scale of production played a major role in the growth of industrial energy consumption, the intensity of energy played a major role in slowing the growth. These results show that energy-saving efforts and the optimization of the industrial structure have increased the energy efficiency of Tianjin. To achieve energy conservation and emissions reduction, the development of green and low-carbon industries and energy structure adjustments are needed.

1. Introduction

In the past century, the global climate has changed perceptibly, and global warming has become the most significant concern during the last three decades. Substantial carbon dioxide emissions have resulted in a series of environment issues [1]. Since a policy of reform and openness were adopted china's economy has made significant progress, and China is now the world's second largest economy [2]. However, as the world's largest energy consumer [3], China's consumption of coal increased from 5.86 × 10^8 tce in 1980 to 36.2 × 10^8 tce in 2012 [4]. During this time, China has also become the world's largest CO_2 emitter [5], with CO_2 emissions increasing from 14.24 × 10^8 tons in 1978 to 79.55 × 10^8 tons in 2011 [6]. To respond to requests to reduce greenhouse gas emissions and to solve the international energy crisis, it is extremely urgent for China to practice energy conservation and to reduce emissions and consumption.

Currently, the energy strategies of different countries reflect two different policy orientations: one encouraging the development and utilization of new energy instead of fossil fuels and one encouraging energy-saving technologies and products. To achieve its energy-saving goals, the Chinese government has taken tangible steps. It has set up a differential responsibility system with provinces supported by administrative consultations [7,8]. To achieve its energy-saving goals, the Chinese government has taken tangible steps. It has set up a differential responsibility system with provinces supported by administrative consultations [9]. It has also passed laws and regulations to promote technological innovation in the form of new enterprises, reduce energy consumption and attain an optimum energy mix. For example, the "National Energy Development 11th Five-Year Plan"[10] was released in 2007, and the "National Energy Development of 12th Five-Year Plan"[11] was released in 2013. These documents analyzed the current energy situation and defined the main energy development goals of China in 2010 and 2015, respectively. The "National Energy Technology 12th Five-Year Plan" [12], issued in 2011, highlighted the key technology areas for development during 2011–2015; this report declared that "Improve Efficiency First" was the main principle to be applied in the planning and implementation of these plans in key

* Corresponding author.
E-mail address: dingzequn@tju.edu.cn (Z. Ding).

http://dx.doi.org/10.1016/j.esr.2016.04.002
2211-467X/

technical spheres. All the five-year plans mentioned above serve as an action plan and blueprint for China's energy sector activities during the "11th Five-Year" and "12th Five-Year" periods.

Industry holds a key position in not only China's economy but also China's total energy consumption. Approximately 70% [13]of China's total energy consumption can be attributed to industrial activities. In the past, growth in industrial energy consumption has exceeded growth in national energy consumption, and this increase in industrial energy consumption has resulted in a rapid increase in the total energy consumption in recent years. Therefore, industrial energy conservation and the reduction of industrial emissions continue to be the focus of China's energy strategy [14].

Tianjin is the birthplace of China's modern industries and an important industrial city. It is also a manufacturing-centered city with a wide range of well-developed industries. These industrial enterprises are the main force behind Tianjin's economy, and these businesses also play a key role in total energy consumption. The ratio of industrial energy consumption to total energy consumption is listed here for reference. In 2012, the total industrial energy consumption of Tianjin accounted for more than 70% of its total energy consumption. The total energy consumption in Tianjin was equal to approximately 8208.01×10^4 tce, with an industrial energy consumption of 5816.17×10^4 tce that accounted for 70.86% of the city's total energy consumption. Coal consumption in Tianjin was approximately 5298.12×10^4 tce, which accounted for 64.55% of the city's total energy consumption [15]. However, Tianjin has been directed to reduce its energy consumption per unit of GDP by 18% and carbon emission per unit GDP by 17% during the "12th Five-Year" period via a "comprehensive energy reduction program". In terms of the existing energy and economic structures, it is challenging but necessary for Tianjin to achieve its goals of energy-saving and emissions reductions and to achieve sustainable development without diminished growth.

With the high-speed development of the economy and the overall progress of society, energy demand has increased rapidly. However, local resources are limited, which has led to an increasing gap between energy supply and demand in Tianjin.

2. Literature review

Many methods are available to model and forecast energy indicators, but each method has limitations. Because the primary trend of energy consumption takes the form of an S-shaped curve, it is impossible to obtain an accurate result using a linear model. Considering the difference in the energy consumption structure of most countries and regions, a logistic regression model can more accurately forecast energy consumption. Logistic regression models, also called block growth models, have been used by scholars at home and abroad for theoretical analysis and for research specifically focused on predicting energy consumption. Based on some studies concerning the energy resources of China as an example, Lin and Liu [16] used a logistic model to analyze and predict China's coal consumption. Along similar lines, Yang and Tan [17] conducted some prediction and research work on China's total energy consumption using an optimized logistic model. Meng and Niu [18] used the Logistic Model to analyze and predict China's carbon dioxide emissions, while Wang and Gu [19] investigated the growth trend of carbon dioxide emissions resulted from energy consumption. Du et al. [20] used the Logistic Model to predict the carbon dioxide emissions in various provinces in China. Xie and Wang [21] predicted the carbon dioxide emissions in Beijing by using the Logistic Model.

The gray system theory has also been widely used to analyze, model and predict the gray system. Many scholars have successfully predicted carbon emissions by using grey prediction model (GM). Pao and Tsai [22] used the GM model to forecast carbon emissions for Brazil's energy consumption and its economy. GM was also used to analyze and predict the development trends of the number of motor vehicles, vehicular energy consumption and CO_2 emissions in Taiwan during 2007–2025 by Lu et al. [23]. Pao et al. [24]forecasted China carbon emissions, energy consumption and economy by using GM model.

Numerous decomposition techniques are now available in the energy and environmental literature. The two most common ways to decompose energy consumption are index decomposition analysis and structural decomposition analysis. Index decomposition analyses include the Divisia, Fisher, Laspeyres, and Paasche methods, among others. According to studies by Liu and Ang [25] and B.W. Ang [26,27], it is better to use the average value of the index (the logarithmic mean Divisia index, LMDI) and avoid residual decomposition on any of the other factors. The LMDI method is applied in two main forms: LMDI-I and LMDI-II. Ang and Liu [28] noted a consistency problem for the two methods: in the process of decomposition, as the decomposition level gradually improves, the decomposition method should be able to ensure consistency in the results at all levels of decomposition. The results of the LMDI-I and LMDI-II methods were compared by inspection, revealing that only the LMDI-I method could ensure consistency. In conclusion, based on the existing research on the index decomposition analysis method, the LMDI-I method was selected and used for the study conducted in this paper. In recent years, the LMDI decomposition model had been successfully applied in the field of energy decomposition by many domestic and foreign scholars. For example, P. Fernández González et al. [29] analyzed the decomposition of energy consumption for the EU's 27 member states using a LMDI decomposition model. Additionally, Zhao et al. [30]used this model to conduct a decomposition analysis for China's urban residential energy consumption, and the UK's transportation energy consumption was analyzed by Sorrell et al. [31] using an LMDI model.

The current literature mainly focuses on energy consumption in construction, including works on energy-savings in commercial buildings in Tianjin by Jing Zhao et al. [32] and an analysis of a community's residential building energy awareness and behavior in Tianjin by Bai and Liu [33].

However, few reports are available concerning industrial energy. Using Tianjin's industries as an example, this work will analyze the development trends and the major factors affecting energy consumption. It will also predict the industrial energy-related carbon emission and energy consumption in Tianjin using a fitting formula. And then estimate industrial energy intensity and carbon emission performance in Tianjin. Through analyze and forecast above mentioned, some suggestions will be provided to resolve existing problems.

3. Methodology

3.1. Energy consumption decomposition model

The difference value of energy consumption between the target year (year t) and the base year (year 0) is called the total effect according to the LMDI model and is represented as ΔE_{tot}. The total effect is divided into three parts: the effect caused by the scale of production (ΔE_{pdn}), the effect caused by the economic structural adjustment (ΔE_{str}) and the effect caused by the changes in the intensity of energy consumption (ΔE_{int}). As a result, the model can be expressed as

$$\Delta E_{tot} = \Delta E_t - \Delta E_0 \tag{1}$$

$$\Delta E_{\text{tot}} = \Delta E_{\text{pdn}} + \Delta E_{\text{str}} + \Delta E_{\text{int}} \tag{2}$$

$$\Delta E_{\text{pdn}} = \sum_i \mathrm{L}(E_{i,\text{t}}, E_{i,0}) \quad \ln \quad (Y_\text{t}/Y_0) \tag{3}$$