Analysis and forecasting of energy consumption in Hebei Province, China

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Abstract. Energy plays a crucial role in the economic growth of a country or region. Therefore, scientifically predicting energy consumption and formulating a reasonable energy development strategy are important steps in promoting economic development. Based on the analysis of the economic development situation and energy consumption in Hebei Province, China, this paper uses unit GDP (Gross Domestic Product) energy consumption forecasting method, trend fitting method, and regression analysis method to predict the energy consumption in Hebei Province from 2018 to 2022, and analyses the advantages and disadvantages of the three methods of prediction to provide theoretical support for the development of Hebei’s energy development policy.

1. Introduction

Energy is an important material basis for the development of the national economy and social progress. Scientific analysis and prediction of total energy consumption also play a crucial role in formulating energy development strategies [1-2]. The main objectives of the “13th Five-Year Plan” energy development plan in Hebei Province are to control the total amount, optimize supply, improve efficiency, and reduce emissions. Therefore, it is imperative to scientifically forecast energy consumption in the process of economic and social development, and formulate practical and feasible energy development strategies and measures to promote sustainable economic and social development and ecosystem stability [3].

At present, there are many documents that use different forecasting methods for energy consumption. The author analyzed the future energy demand of Sichuan Province using three methods: grey system forecast, consumption elasticity forecast and unit GDP energy consumption forecasting[4]. The author built the ARMA (1,2,1) model to make short-term predictions of energy consumption in Beijing, and proposed relevant policy recommendations based on the prediction results[5]. The author used ARMA model, trend fitting model and regression analysis model to forecast China's energy consumption and compared the advantages and disadvantages of the three methods[6]. The author used a stepwise regression analysis to predict the energy demand of Shenyang City, and proposed ways and measures to improve energy development and its environmental benefits[7].

Based on the analysis of the economic development situation and energy consumption in Hebei Province, this paper put forward three methods of unit GDP energy consumption forecasting, trend fitting method, and multiple linear regression are applied to predict energy consumption in Hebei Province from 2018 to 2022. The comparative analysis of the prediction results by using the three
methods provides a strong theoretical support for the formulation of practical energy development strategies and measures.

2. Analysis of economic development situation in Hebei Province

As shown in Table 1, the gross product of Hebei Province in 2017 was 3.5964 trillion yuan, and increased by 6.7% from the previous year which was calculated at the constant price. In the whole year, the total investment in fixed assets of the whole society was 3.3407 trillion yuan, an increase of 5.2% over the previous year. The per capita disposable income of urban residents was 30548 yuan, an increase of 8.9% over the previous year. At the end of the year, the total permanent population was 75.2 million, an increase of 0.4947 million over the end of the previous year. And the province's total fiscal revenue was 508.7 billion yuan, an increase of 16.4% over the previous year.

Table 1. Total and speed indicators of national economy and social development in Hebei Province.

| Year | Total population at the end of the year (million people) | Per capita disposable income of urban residents (yuan/person) | Gross Regional Product (100 million yuan) | Total social fixed assets investment (100 million yuan) | Local fiscal revenue (100 million yuan) |
|------|--------------------------------------------------------|------------------------------------------------------------|------------------------------------------|--------------------------------------------------------|----------------------------------------|
| 1990 | 61.59                                                  | 1397                                                       | 896                                      | 177                                                    | -                                      |
| 2000 | 66.74                                                  | 5661                                                       | 5044                                     | 1847                                                   | 249                                    |
| 2010 | 71.94                                                  | 16263                                                      | 20394                                    | 15083                                                  | 1332                                   |
| 2014 | 73.84                                                  | 24141                                                      | 29421                                    | 26672                                                   | 2447                                   |
| 2016 | 74.71                                                  | 32051                                                      | 33706                                    | 31756                                                   | 4370                                   |
| 2017 | 75.20                                                  | 30548                                                      | 35964                                    | 33407                                                   | 5087                                   |

3. Current situation of energy consumption in Hebei Province

As shown in Figure 1, the energy consumption in Hebei Province has continued to grow from 91.5112 million tons of standard coal in 1998 to 297.841 million tons of standard coal in 2016. From 1998 to 2016, Hebei's average annual energy consumption growth rate was 6.63%, which remained at a
relatively high level. Among this, the energy consumption growth rate maintained at more than 10% in 2002-2006. And the growth rate of energy consumption in 2000 was the fastest, reaching 19.37%.

4. Energy consumption forecasting
Based on the economic development situation and energy consumption in Hebei Province in recent years, this paper uses data from the years of 1998-2016 and the three models: unit GDP energy consumption forecasting, trend-fitting model and multiple linear regression method to forecast the annual energy consumption of Hebei province in 2018-2022, respectively.

4.1. Unit GDP energy consumption forecasting
According to the development situation of Hebei Province and the average value of GDP of Hebei province from 2007~2016, 6.83%, this paper has divided the annual growth rate of GDP in Hebei Province from 2018 to 2022 into three types: high, medium and Low. The predicted GDP for 2018-2022 in Hebei Province is shown in Table 2.

| GDP growth rate | Predictive value | Predictive value of GDP(100 million yuan) |
|-----------------|------------------|------------------------------------------|
|                 | Predictive value | 2018 | 2019 | 2020 | 2021 | 2022 |
| High            | 8.0%             | 28540.07 | 30823.28 | 33289.14 | 35952.27 | 38828.45 |
| Medium          | 7.0%             | 27497.62 | 29422.46 | 31482.03 | 33685.77 | 36043.78 |
| Low             | 6.0%             | 26484   | 28073.04 | 29757.42 | 31542.86 | 33435.44 |

The development trend of energy consumption per unit of GDP in Hebei Province in 2007-2016 based on EXCEL is shown in Figure 2.

![Figure 2](image-url)

**Figure 2.** Development trend of energy consumption per unit of GDP in Hebei Province, 2007-2016.

As shown in Figure 2, the black curve is the fitted curve of energy consumption per unit of GDP, x is the year, and y is the fitted unit GDP energy consumption.

Based on this, the energy consumption per unit of GDP in Hebei Province from 2018 to 2022 can be predicted which is shown in Table 3.
Table 3. Forecast results of Energy Consumption Per Unit of GDP from 2018 to 2022.

| Year | Energy consumption per unit of GDP (10000 tons of standard coal/100 million yuan) |
|------|--------------------------------------------------------------------------------|
| 2018 | 1.13                                                                          |
| 2019 | 1.07                                                                          |
| 2020 | 1.01                                                                          |
| 2021 | 0.95                                                                          |
| 2022 | 0.90                                                                          |

According to the prediction of Hebei Province's GDP from 2018 to 2022 and the prediction of energy consumption per unit of GDP, the energy consumption of Hebei Province from 2018 to 2022 can be calculated, as shown in Table 4.

Table 4. Energy consumption forecast for 2018-2022.

| GDP growth rate | Predictive value of Energy consumption (100 million tons of standard coal) |
|-----------------|--------------------------------------------------------------------------------|
|                 | 2018                        | 2019                        | 2020                        | 2021                        | 2022                        |
| High            | 32209.98                    | 32859.38                    | 33521.88                    | 34197.73                    | 34887.21                    |
| Medium          | 31033.48                    | 31366.03                    | 31702.14                    | 32041.84                    | 32385.2                     |
| Low             | 29889.52                    | 29927.47                    | 29965.47                    | 30003.51                    | 30041.61                    |

4.2. Trend fitting method

In this paper, linear fitting, exponential fitting and polynomial fitting are used to fit the energy consumption curve of Hebei Province. $R^2$ of the linear fitting method, exponential fitting method, and polynomial fitting method are 0.9565, 0.9093 and 0.985, respectively. $R^2$ is the determination coefficient ranging from 0 to 1, which represents the degree of fitting between the estimated value of the trend curve and the corresponding actual data. When the $R^2$ of the trend curve is equal to 1 or close to 1, the reliability of this curve is the highest. Therefore, this paper decides to use the polynomial fitting method which had the biggest $R^2$. The fitting results has shown in Figure 3.

![Figure 3. Polynomial Trend Fitting of Energy Consumption in Hebei Province, 1998-2016.](image-url)
The final fitting formula is:
\[ y = -46.374x^2 + 2236.7x + 4928.2, \quad R^2 = 0.985 \]

Based on this formula, the energy consumption in Hebei Province from 2018 to 2022 can be predicted, as shown in Table 5.

**Table 5. Energy consumption in Hebei Province from 2018 to 2022.**

| Year | Energy consumption (10,000 tons of standard coal) |
|------|--------------------------------------------------|
| 2018 | 31447.97                                         |
| 2019 | 31690.58                                         |
| 2020 | 31840.45                                         |
| 2021 | 31897.58                                         |
| 2022 | 31861.95                                         |

### 4.3. Multiple linear regression analysis

Industrialization is often defined as the process by which industry (especially the manufacturing industry) or the secondary industry's output value is rising in proportion to the gross national product. In the process of industrialization, the main manifestation is the rapid growth of industrial production, the emergence of a large number of emerging sectors, the wide application of high and new technology, the substantial increase in labor productivity, and the overall improvement of urbanization level and national consumption level. Thus, besides the Hebei Province's GDP \( (x_1) \), this paper selects the industrialization rate \( (x_2) \) from 1998 to 2016 as the explanatory variable for multiple linear regression analysis on energy consumption \( (y) \). The regression equation obtained is:

\[ y = -41993.1 + 0.9769x_1 + 113347.5x_2 \]

Before forecasting energy consumption, it is necessary to predict the GDP and industrialization rate of Hebei province from 2018 to 2022. The prediction results is shown in Table 2 and Table 6. The average value of industrialization rate in Hebei province from 2007-2016 is 45.6%, this paper has divided industrialization rate in Hebei Province from 2018 to 2022 into three types: high, medium and low to predict the energy consumption of Hebei province.

**Table 6. Prediction result of Industrialization Rate of Hebei Province from 2018 to 2022.**

| Industrialization rate | Predictive value |
|------------------------|------------------|
| High                   | 47.0%            |
| Medium                 | 46.0%            |
| Low                    | 45.0%            |

**Table 7. Energy Consumption in Hebei Province from 2018 to 2022**

| Industrialization rate | Energy Consumption (10,000 tons of standard coal) |
|------------------------|--------------------------------------------------|
|                        | 2018     | 2019     | 2020     | 2021     | 2022     |
| High                   | 39161.19 | 41391.67 | 43800.59 | 46402.21 | 49211.97 |
| Medium                 | 37009.34 | 38889.73 | 40901.73 | 43054.58 | 45358.13 |
| Low                    | 34885.65 | 36438.00 | 38083.48 | 39827.68 | 41676.56 |
Based on the forecast results of GDP and industrialization rates in Table 2 and Table 6 and the regression equations obtained, the energy consumption in Hebei Province from 2018 to 2022 can be predicted, as shown in Table 7.

5. Conclusions

By comparison, it can be seen that the energy consumption forecasted by unit GDP energy consumption forecast and trend-fitting method is small, and the results based on multiple linear regression method are the largest.

The energy consumption per unit of GDP forecast is mainly calculated by forecasting the GDP growth rate and energy consumption per unit of GDP. The principle is simple and easy to grasp, but the accuracy of GDP growth and energy consumption per unit of GDP calculated from raw data cannot be guaranteed. The trend-fitting method is to find out the most suitable type of function by observing the distribution of the original data. Using the EXCEL tool can quickly get the result, but whether the fitting function can fully show the actual situation of energy consumption needs further verification. And the trend-fitting method only considers the impact of time on energy consumption, and does not consider the role of regional economic development, population and social factors in energy consumption. The multiple linear regression analysis method considers a variety of factors that affect energy consumption, and forms a regression equation to explain the relationship between the respective variables and the dependent variable, which has a certain degree of reliability. But the sequence correlation and collinearity need further verification.

This paper studies three methods for predicting energy consumption in Hebei Province. Although some achievements have been made, there are still many shortcomings in this paper due to various factors. The above three models are quantitative prediction models, but qualitative prediction models can well overcome the situation of large changes in the policy environment. Therefore, in future research, we can consider how to add qualitative prediction models and combine qualitative and quantitative models to predict future energy consumption.

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