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China's natural gas production and consumption analysis based on the multicycle Hubbert model and rolling Grey model

Jianzhou Wang [a], Haiyan Jiang [b,*], Qingping Zhou [b], Jie Wu [b,c], Shanshan Qin [b]

[a] School of Statistics, Dongbei University of Finance and Economics, Dalian 116025, China
[b] School of Mathematics and Statistics, Lanzhou University, Lanzhou 730000, China
[c] School of Software Engineering, Faculty of Engineering and Information Technology, University of Technology, Sydney (UTS), PO Box 123, Broadway, NSW 2007, Australia

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ABSTRACT

As fossil fuels reserves deplete rapidly and the low-carbon economy develops expeditiously, especially in China, natural gas as a clean and alternative energy is underway to help meet increased energy needs and climate needs. Therefore, accurate forecasts of natural gas production and consumption have been a necessary task for policy making in the coming years. This paper presents a review of natural gas forecasting models. The multicycle Hubbert model is employed to forecast China's annual nature gas production and to determine the peak production, the peak year and the future production trends based on several different URR scenarios. Moreover, a small-sample effective rolling GM(1,1) model is proposed for the first time to forecast exponential natural gas consumption with different lengths of data sets. Then, the grey relationship analysis is used to select the best consumption curve in correspond with different URR scenarios. The empirical result shows that the supply–demand gap will be larger and larger in the future, with a minimum gap of 22 bcm in 2011 and 225 bcm in 2050, with a maximum gap of 31 bcm in 2011 and 807 bcm in 2050, which indicates that the natural gas production in China cannot meet the rising consumption. Therefore, policy measures must be taken to ameliorate the situation, including expanding natural gas imports, increasing unconventional natural gas production, complementing the gap with other energy resources and combining energy saving with emission reduction. Accurate forecasting of natural gas production and consumption can provide the basis for decision making and help the government generate new significant policies.

Contents

Abbreviations: GW, gigawatt; BP, British Petroleum; Mtoe, million tons oil equivalent; tcm, trillion cubic meters; bcm, billion cubic meters; URR, ultimate recoverable reserves; PCMACP, polynomial curve and moving average combination projection; FTW estimation, Fermat–Torricelli–Weber estimation; ARIMA, autoregressive integrated moving average; ANNs, artificial neural networks; FIS, fuzzy inference system; RBF, radial basis function; OLS, ordinary least square; ANFIS-SFA, adaptive network-based fuzzy inference system-stochastic frontier analysis; TS-FIS, Takagi–Sugeno adaptive FIS; ANFIS, adaptive network-based FIS; LS-SVM, least squares support vector machine; SOFM-MLP, self-organizing feature map and multilayer perceptron; ARDL, autoregressive distributed lag; GM, grey model; RGM, rolling GM; MAPE, mean absolute percentage error; RMSE, root mean square error; NRMSE, normalized root mean square error; R, correlation coefficient; LNG, liquefied natural gas; CBM, coal bed methane; PV, photovoltaic

* Corresponding author. Tel.: +86 13659462863; fax: +86 931 8912481.
E-mail address: jianghy2012@lzu.edu.cn (H. Jiang).

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1. Introduction

With the unceasing progress of human civilization, the world is demanding increasing quantities of energy from natural sources now, including coal, oil, natural gas and other primary energy sources. Worldwide, production and consumption of energy resources is becoming more and more essential to the prosperous global economy.

Since the start of the 21st century, the continuous development of the world economy has resulted in a huge increase in the demand for primary energy. According to statistics from the British Petroleum (BP) statistical review of world energy [1], from 2003 to 2013, the world's total annual primary energy consumption increased sharply from 9943.8 million tons oil equivalent (Mtoe) to 12,730.4 Mtoe with an average annual growth rate of 2.8%.

And currently, oil, natural gas and coal are still three main energy resources in the world energy consumption structure, representing 32.9%, 23.7% and 30.0% of the total annual energy consumption in 2013, respectively. Other fuels such as nuclear energy, hydroelectricity and other renewable energy are supplementary energy resources. With flourishing economic growth, the world will see a tremendous increasing energy demand in the near future. According to BP energy outlook 2035 the world total energy consumption is expected to increase to 17,454.7 Mtoe in the year of 2035 [2].

With increasing world population and the developing world economy, the demand for energy in the world has increased dramatically. At the same time, large-scale use of fossil energy all over the world has also led to a series of environmental problems such as acid rain, air pollution and global warming [3]. Fossil fuel use is the primary source of carbon dioxide (CO_2). Therefore, to address the energy crisis and global climate warming, it is highly important to develop clean and renewable energy resources. Many countries are making an effort to balance the growing energy demand while trying to reduce the dependence on fossil fuel and to address environmental safety and sustainability [4].

Natural gas is a type of low-carbon energy, which touches our lives in countless ways every day, such as heating homes, cooking foods and fueling cars, and even helping to generate electricity. Especially in recent years, it is of high significance in many nations' energy structure and has received a substantial amount of attention as an automotive fuel [5]. In particular, it has been reported that the amount of natural gas reserves is much larger than that of oil globally, so the exploring and exploiting has adequate resources foundation. The preliminary statistics from China's Ministry of Land and Resources in 2012 indicated that the remaining technologically recoverable reserves of conventional natural gas reach 4.02 trillion cubic meters (tcm), marking the country is relatively rich in total natural gas reserves. Therefore, Substitution of natural gas for coal in China could significantly reduce emissions of carbon dioxide.

China, as the largest developing country as well as the fastest-growing major economy in the world, has risen to the second place after the United States in terms of economic aggregate, with an economy growth rate of approximately 11% over the past 30 years. Energy consumption has been growing very rapidly since 1953, especially after 1978 when the Chinese economic reform was initiated, which can be seen from Fig. 1(a). In 2010, China overtook America for the first time as the world's largest energy consumer, with total energy consumption of 2339.6 Mtoe, accounting for 19.6% of the world's total, and in 2013, the figure changed to 2852.4 Mtoe, representing 22.4% of the world's total. The global shares of oil, natural gas, coal and others in 2013 were approximately 32.9%, 23.7%, 30.0% and 13.4%; however, the corresponding shares in China were respectively 17.8%, 5.1%, 67.5% and 9.6%, which demonstrated that China's energy structure was not well aligned with the global energy mix [3] and that the long-term energy consumption structure was dominated by coal in China, whose usage proportion was nearly 70%.

Coal, as an important strategic material, is still dominated in China's energy structure. However, China's coal-dominated energy structure cannot achieve the harmonious development of social economy. In comparison, natural gas supplies only a small part of the primary energy consumption. Natural gas supplied only 5.1% of the domestic energy consumption in China, however, the proportion in the United States was 29.6%, and naturel gas supplied 23.7% of the total world consumption in 2013. As the case stands, the proportion of natural gas in the energy consumption structure is currently still quite low compared with the international standards. Furthermore, China has recently imported more natural gas from other countries, which implies the natural gas dependency is getting higher as demonstrated in Fig. 1(b). Based on an analysis of CO_2 emissions, China has surpassed the United States as the world's current largest emitter of CO_2, putting out 9524.3 million tons carbon dioxide in comparison with America's 5931.4 million tonnes. As displayed in Fig. 1(c), the greenhouse gas emissions in China can also be broken down by burning different fossil fuels that lead to their