Energy Policy 122 (2018) 17–26

Contents lists available at ScienceDirect

Energy Policy

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

Natural gas consumption of urban households in China and corresponding influencing factors

Guixian Liu[a], Xiucheng Dong[a,b,*], Qingzhe Jiang[b], Cong Dong[a], Jiaman Li[a]

[a] School of Business Administration, China University of Petroleum-Beijing, Beijing 102249, China
[b] School of International Trade and Economics, University of International Business and Economics, Beijing 100029, China

ARTICLE INFO

Acronyms used:
TNGCTotal Natural Gas Consumption
NGPNatural gas population
NGCPer Capita Natural Gas Consumption of Urban Households in China
LPLength of pipe
LPGPLPG population
UPUrban population
PNGNatural gas price
FPFamily size
PEElectricity price
HDDHeating Degree Days
HSCentralized heat supply

Keywords:
Chinese urban households
NGP
Natural gas consumption per capita
Feasible generalized least squares
Natural gas consumption amount

ABSTRACT

Driven by the impact of economic growth, urbanization, and national strategies for low-carbon development, the TNGC of urban households in China is growing rapidly. In this paper, the feasible generalized least square method is used to investigate the consumption of natural gas and the per capita natural gas consumption of urban residents in 30 provinces in China (not including central heating and the natural gas consumption of natural gas vehicles). We study the factors influencing natural gas consumption by urban residents in China and conduct scenario forecasting. The empirical results show that the impact coefficients of PNGs and household income on average natural gas consumption are − 0.895 and 0.222, respectively, while the impact coefficients of the NGP are − 0.603 and 0.346, respectively. The scenario forecast results show that the consumption of natural gas in Chinese households reached 75.469 billion cubic meters in 2025. China's natural gas season peak pressure will continue to increase. In response to this, the following three suggestions are proposed. (1) According to the price elasticity of natural gas, the Chinese government should adjust and improve the mechanism for the formation of PNGs for residents and promote the marketization of natural gas. (2) Accelerate the construction of natural gas reserves and allocate the natural gas supply according to regional differences in natural gas consumption to enhance China's natural gas peak shaving capacity. (3) Improve and optimize natural gas development plans to achieve coordinated development of natural gas supply and demand.

1. Introduction

The impacts of anthropogenic greenhouse gas emissions on Earth's climate are of growing concern (Wu et al., 2016). Increasing emissions of sulfur and nitrogen oxides and other pollutants from fossil fuel burning are causing damage to both health and the environment at local to regional scales. These problems are particularly serious in developing countries such as China and India. Consumption of energy consumption in China is currently dominated by coal, a major source of air pollution and carbon emissions (Tang et al., 2015b). Clean energy consumption in China is still at low levels, while the coal consumption share of total energy consumption has been decreasing in recent years (Han et al., 2017). If China wants to protect the environment and ameliorate man-made climate change, it must change the decades-long state of coal-dominated energy consumption (Sun et al., 2016).

It is generally believed that renewable energy sources (including solar energy, wind energy, geothermal energy, ocean energy, hydroelectric power, and bioenergy resources) can help us achieve the goal of protecting the environment (Mac Kinnon et al., 2018). And natural gas has become the bridge fuel for the transition from flammable fossil energy to zero-emission renewable energy (Han et al., 2017). In addition, natural gas is unique amongst fossil fuels with regards to the benefits of complementing renewable resource integration (Mac Kinnon et al., 2018). As an energy source, natural gas will not only reduce the emission of standard pollutants and greenhouse gases, it has potential for transition to 100% renewable fuel (e.g., biogas, renewable hydrogen) injection, storage, and delivery in the future (Mac Kinnon et al., 2018).

Natural gas is rapidly developing as a clean energy source, and China's natural gas consumption has rapidly increased (Tang et al., 2015a; Wang and Lin, 2017). According to the "13th Five-Year Plan for Natural Gas Development", natural gas consumption will reach 3.6 trillion cubic meters in 2020, with primary energy accounting for 8.3–10%. However, there are many problems in the rapid

* Corresponding author at: School of Business Administration, China University of Petroleum-Beijing, Beijing 102249, China.
E-mail address: xiuchengdong@163.com (X. Dong).

https://doi.org/10.1016/j.enpol.2018.07.016
Received 17 November 2017; Received in revised form 1 July 2018; Accepted 10 July 2018
0301-4215/

development of China's natural gas industry. For example, in the winter of 2009 and 2017, seasonal demand for natural gas surged due to increased heating demand. China has a large-scale shortage of natural gas supply. To protect civilian natural gas, measures to limit gas have already been implemented in Henan, Shandong, and Shanxi. Studies indicate that China's domestic gas resources cannot be regularly rapidly enough to match this surge in demand (Tang et al., 2015a). This will lead to China having greater reliance on natural gas imports in the future and increased instability in its natural gas supply (Tang et al., 2015a). Perfecting natural gas reserves and pipeline facilities can increase the stability of natural gas supply (Chen et al., 2018). Accurately grasping the changes in China's natural gas consumption, especially the seasonal changes in natural gas consumption, is prerequisite for the scientific establishment of reserves.

The seasonal fluctuations in China's natural gas consumption come from seasonal fluctuations in the consumption of urban gas. With the advancement of urbanization and the implementation of national policies such as coal-to-gas reform, urban gas is the main factor driving the growth of natural gas consumption (Liu and Jiang, 2017). From 2000 to 2016, the share of urban gas consumption increased rapidly. As shown in Fig. 1, city gas accounted for 18.79% in 2000 and 40.95% in 2016. Natural gas consumption by residents is an important part of urban gas. Therefore, we study the effect of natural gas consumption in households and analyze the total and seasonal changes in natural gas consumption in China.

This paper uses unbalanced panel data from 31 provincial-level units (excluding Taiwan) from 2006 to 2015 to study the factors affecting NGP and per capita natural gas consumption. It also makes scenario projections for total household gas consumption, NGP, and per capita natural gas consumption. Feasible Generalized Least Squares (FGLS) regression analysis was used to control the autocorrelation and heteroskedasticity of the model. We find that PNGs and residents' income will affect both the average natural gas consumption and the NGP. The impact of PNGs and residents' income on the average natural gas consumption and the NGP in the eastern, central, and western regions is significantly different. In addition, the TNGC will increase rapidly in the next ten years, and seasonal consumption differences will increase, making it difficult for China's natural gas season to peak.

The main research contributions of this article are as follows. First, there is little research on the consumption of natural gas in Chinese households, and most of these articles are for per capita consumption or total consumption. In these studies, when considering demographic factors, this is done mainly from the perspective of either the labor force or the total population of the region. There is no literature studying the relationship of NGP changes. The relationship between the NGP and household gas consumption is different from the relationship between the NGP and the total gas consumption in the region. The work of this paper is to expand upon and supplement the above research by studying

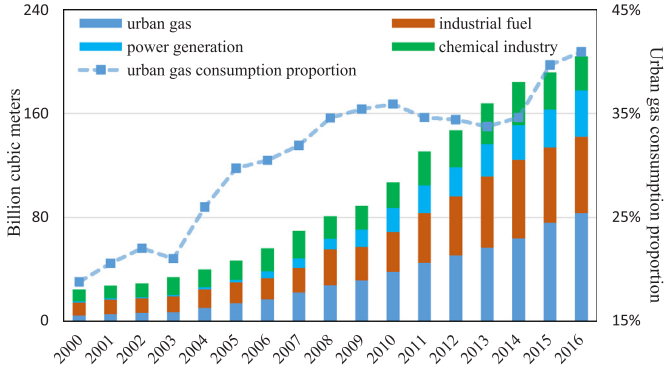

Fig. 1. Natural gas consumption structure of China.
Source: China National Bureau of Statistics and China Petroleum Institute of Economics and Technology.

the impact of PNGs and residents' income from the two perspectives of NGP and per capita consumption and explore the seasonal changes and long-term development trends of the TNGC of households. Secondly, by studying the changes in the natural gas consumption of residents throughout the country, we have sought to explore regional and seasonal differences in natural gas consumption and to provide foundations for research on the natural gas supply and reserves.

The remainder of this article is organized as follows. Section 2 provides a brief literature review. Section 3 gives the total household gas consumption model, the NGP model, and the per capita gas consumption model. The sources of variables and data are explained and the choice of measurement methods is explained. Section 4 discusses the results of the natural gas consumption model and makes scenario predictions for urban natural gas in China in 2020 and 2025. Section 5 introduces the findings and provides some policy recommendations.

2. Literature review

In the existing literature, there is a large amount of research on regional natural gas consumption. Based on the differences in time limits, we classify these documents into two categories: the study of regional short-term changes in natural gas consumption and the study of regional long-term changes in natural gas consumption.

The short-term change rule refers to the regularity of the monthly frequency, daily frequency, and hourly frequency of natural gas consumption. Such research results are mainly used for gas companies and provide gas companies with information and technical support for natural gas scheduling in both the short- and the medium-term. As shown in Table 1, most of the short-term natural gas forecasting models use statistical models and artificial intelligence models, and the factors considered are mainly calendar information and environmental information (Baldacci et al., 2016; Franco, 2016; Oliver et al., 2017; Taşpinar et al., 2013). Izadyar et al. (2015a) used support vector machines to study the relationship between Iranian monthly ambient temperature and natural gas consumption. Izadyar et al. (2015b) studied the monthly natural gas consumption in Iran using methods such as Extreme Learning Machine, Artificial Neural Network, and Genetic Programming, taking into consideration the ambient temperature and calendar information. Soldo et al. (2014), Szoplik (2015), and Yu and Xu (2014) used artificial intelligence models to study the relationship between daily natural gas consumption, environmental information, and calendar information and tried to predict short-term natural gas consumption based on environmental information and calendar information. In studying the hourly natural gas consumption in Greece, Panapakidis and Dagoumas (2017) used artificial intelligence models to consider only the changes in natural gas consumption and predict these changes.

We have found that most of the areas targeted by this kind of research are areas in which the natural gas industry is relatively stable. In the short-term, the NGP stability, the PNG level, energy substitution, the economic level, and the natural gas infrastructure will not greatly affect these areas. For those areas where the natural gas industry is rapidly developing, such as China, the results of such studies may not be appropriate. This is because the NGP, residents' income, alternative energy, and PNGs in these areas are all in a stage of rapid change. Therefore, it is impossible to provide the relationship between the TNGC in these areas and the local population, prices, and residents' income.

The long-term change rule refers to the change of annual natural gas consumption patterns. The results of such studies have a certain reference role in the formulation of long-term energy planning and policy deductions by countries and regions. As shown in Table 2, they mostly study the relationship between the TNGC in the region and regional economic development, taking into account the combined effects of GDP, population/labor force, environmental information, price factors, and energy substitution (Apergis et al., 2010; Balitskiy et al., 2016;