# *A Real Option Model for Investment Strategy on Underground Gas Storage Facilities Considering Market Reform in China*

[Siyuan Chen, Academy of Chinese Energy Strategy, China University of Petroleum (Beijing)]
[Qi Zhang*, Academy of Chinese Energy Strategy, China University of Petroleum (Beijing), Email: zhangqi@cup.edu.cn]
[Ge Wang, Academy of Chinese Energy Strategy, China University of Petroleum (Beijing)]
[Yan Li, Academy of Chinese Energy Strategy, China University of Petroleum (Beijing)]

## Overview

Natural gas, as a clean fossil fuel in the process of low-carbon transformation, has regained focus of policy makers in China. In 2015, China in its submitted INDC (Intended Nationally Determined Contribution) has promised that the percentage of natural gas would be over 10% by 2020 and increase to 15% by 2030. The gap between gas production and demand is predicted to reach 210.4 billion cubic meters by 2020 (Wang et al., 2013) [1]. However, there aren't enough underground gas storage facilities available for adjusting natural gas peak of China, which is a huge barrier of China's natural gas development. By the end of 2015, China had only 18 underground gas storage facilities with a working volume of 5.5 billion cubic meters, accounted for 2.2% of China's gas consumption, far lower than America whose gas storage capacity accounted for 12.38% of its gas consumption. Why Chinese underground gas storage facilities develop so slowly though they are decisive that has always been a hot topic. There are three main reasons causing this phenomenon, one is that Chinese gas market has been strictly regulated by the government; the second is the underground gas storage facilities have the features of long construction period, great capital input amount and long pay-off period; and the third is the common appraisal method of projects--discounted cash flow, which excludes uncertain factors and ignores flexible management of project leaders. As a result, the investment value of underground gas storage facilities is underestimated, and enthusiasm of investors is dampened. There exists enormous significance to propose a new method to evaluate gas storage facilities correctly.

The objective of this study is to propose a real option model to evaluate gas storage investment in China and find out the optimal investment timing, taken gas market reform and flexible management into account. In addition, four uncertain factors consisting of gas demand, gas production, investment cost, as well operation and maintenance cost of gas storage facilities project, are considered when gauging gas storage investment value. Then a sensitivity analysis is carried out to measure the effects of the subsidy, volatility of investment cost and gas service price on the optimal investment timing and investment value. Lastly, this study is to provide advices for government to promote gas storage facilities development based on numerical results.

The rest of the paper is organized as follows: Section 2 is a brief literature review made up for two parts: one is about the real option theory and its application in the energy system, especially in natural gas industry [2]; the other is concerning characteristics of underground gas storage facilities projects [3]. Section 3 addresses the methodology adopted in this paper, including Least Square Monte Carol (LSMC) method used in uncertainties simulation, and backward dynamic programming adopted to find out the optimal investment timing. In Section 4, a sensitive analysis is executed to explore the effects of uncertain factors on underground gas storage facilities investment value and optimal investment timing. Finally, there are a few conclusions of this study showed in Section 5.

## Methods

The real option method is used to evaluate gas storage facilities investment in this paper. According to characteristics of underground gas storage facilities, three kinds of option are developed and combined: a) in the time horizon, investors have the right to defer this investment; b) in the long construction period, there are significant risks for these investors. Once they discover other alternative projects more profitable, they will give up this project, thus, they have the right to abandon investment in the construction period; c) in the operation period, operators of the storage facilities have the right to adjust their strategy based on the external environment, which means that they can make a choice between providing storage service for gas sellers or buyers and selling gas at the high-price period by storing gas of the low-price period.

In addition, uncertain factors that we consider in the model contain gas demand, gas production, investment cost and operation and maintenance cost, which all are described by the Geometric Brown Motion and simulated based on LSMC method. Related parameters including historical gas demand and production data are from Wind database, and other parameters such as investment cost parameters are from existing literatures.

Besides, the model also takes into account the influence of related policies, including gas market reform in China and subsidy policies in gas storage. Two scenarios are designed to measure impacts of gas market reform on underground gas storage facilities investment. In Scenario 1, the government doesn't open the gas market, implementing regulated gas price. However, in Scenario 2, the state decides to deregulate gas market and adopt a market-based gas price. Although the Chinese government has announced to open the domestic gas market, it still needs a long time to achieve a free market. This is because the gas market reform will be hindered by big state-owned companies. Therefore, a hypothesis is proposed that the probability of the gas market reform succeeding is subjected to a kind of probability distribution function related to time T. If the time of implementing gas market reform is longer, the greater the probability of successful gas market reform.  A sensitivity analysis is performed to analyse effects of subsidy policies.

At last, expected investment value at each decision node is calculated, then we will find out the optimal investment timing by adopting backward dynamic programming.

## Results

Firstly, in Scenario 1, the optimal decision is to invest in the year 2027, whose value is 4.84 RMB/Cubic meter when using the real option method, while under the discounted cash flow method the best choice is to abandon this investment because investment value is negative. In Scenario 2, the optimal decision is to invest the project in the year 2023, and the investment value is 8.82RMB/Cubic meters under the real option method. In addition, the optimal investment timing is the year 2030, and the investment value is 2.72 RMB/Cubic meters when the discounted cash flow method is adopted. Therefore, the price reform does raise the investment value and advance optimal investment timing no matter which method is used to estimate the project.

Then, through conducting a sensitivity analysis, we can find that the subsidy has a positive impact on optimal investment timing and investment value whether or not considering the price reform. If subsidies increase to 0.45 RMB/Cubic meters under the market reform scenario, the optimal investment timing will be advanced to 2017.

Moreover, the advancement of technology is supposed to have a great impact on gas storage facilities investment, because it will contribute to decreasing the investment cost. When the government implements the storage service price reform, a higher sensitivity coefficient of storage price will lead to a higher investment value of the project however, will put off the optimal investment timing.

## Conclusions

First, the current investment environment is not positive enough to attract immediate investment in China, even if the implementation of market-oriented store prices in China, which maybe explain why the development of Chinese underground gas storage capacity is not as rapid as expected.

Second, the investment value tends to increase substantially as gas storage price reform took into consideration, and we can get an earlier optimal investment timing. Thus, the government is supposed to further promote gas market reform in China and formulate supporting laws.

Third, the more the subsidy, the greater the investment value is and the earlier the optimal investment timing will be. Instead, increasing the drift rate of investment costs will defer the investment and decrease investment value. And effects of sensitivity coefficient of storage price on underground gas storage facilities development are complicated, which will lead to a higher investment value of the project, however, will put off the optimal investment timing. Therefore it can advance the optimal investment timing of the gas storage facilities by increasing subsidy and taking a variety of actions to promote technological progress.

Future works are still needed to promote this study, which mainly focus on following directions: a) to further investigate the effects of gas storage price; b) to construct different option portfolio to assess different kinds of underground gas storage facilities; c) to consider the game between investors.

## Reference

[1] Wang JL, Feng LY, Zhao L, et al. China's natural gas: resources, production and its impacts [J]. Energy policy, 2013, 55(1), 690-698.
[2] Daniel Hach and Stefan Spinler. Capacity Payment Impact on Gas-fired Generation Investments under Rising Renewable Feed-in — A Real Options Analysis. Energy Econ, 2016, 53, 270-280.
[3] M. Breton, M. Kharbach. The Welfare Effects of Unbundling Gas Storage and Distribution [J]. Energy Economics, 2008, 30: 732-747.