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A new approach to estimating surface facility costs for shale gas development

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ABSTRACT

Surface facility costs are a significant component of the development costs that account for most of the shale gas development input. In conducting feasibility studies for shale gas development projects, particularly during the preliminary feasibility study stages, better estimation techniques for surface facility costs can help quickly and accurately estimate the input required to unlock shale gas investment opportunities. After investigating the salient characteristics of shale gas surface facilities, this study develops a new estimation approach for shale gas surface facility costs that combines the advantages of considering terrain variance and the law of declining costs. The results of an example in China indicate that this new technique can significantly improve the accuracy of estimating surface facility costs associated with shale gas development. Furthermore, this study can significantly improve the evaluations of the economic viability of shale gas development projects, thereby reducing investment risks and enhancing investment opportunities.

1. Introduction

As it implements an active strategy of economic transformation, China is increasing its efforts to develop a low-carbon green economy, which has led to an increasingly urgent need for an energy source that is cleaner than coal and oil (illustrated in Fig. 1) (National Bureau of Statistics (NBS) of China, 2015). A higher use of natural gas is likely to help the energy mix used in China to replace its intensive use of coal and hence reduce its carbon emissions. Natural gas is a cleaner and more efficient energy source than coal, and shale gas in particular seems to be more widely distributed and in much larger quantities than conventional gas reserves, which makes it a very promising energy option to help China improve its energy mix (Lozano Maya, 2013; Nülle, 2015; Wang and Lin, 2014). Shale gas resources in China are fairly abundant and thus have significant future development potential. However, given the nature of the endowment of this unconventional natural gas resource, developing shale gas resources requires fairly sophisticated technologies and substantial investment. Moreover, the uncertainties and risks accompanying shale gas development are substantially higher than those in conventional natural gas development (Aguilera, 2014; Vedachalam et al., 2015). In this respect, a more accurate economic evaluation of shale gas development is particularly important for investment decisions (Nülle, 2015; Yuan et al., 2015a,b).

The accuracy of the input estimates is generally accepted to have a significant effect on the economic evaluations and subsequent investment decisions for shale gas development. In addition to drilling and completion (fracturing) costs, surface facility costs are a vital component of shale gas development costs, accounting for most of the input (Agbaji et al., 2009; Xia and Luo, 2014). Thus, estimating surface facility costs is critical to accurately assessing inputs and has significant impacts on cost reduction, investment control and project economics (Guarnone et al., 2012; Haskett and Brown, 2010; Liao and Luo, 2012). As little detailed data and information exist on shale gas development projects, finding a good method for more precisely estimating surface facility costs is important for assessing the inputs and the subsequent economics of shale gas production, particularly in the early stages of a feasibility study (i.e., the preliminary feasibility study stages). However, no detailed methods exist for forecasting shale gas surface facility costs in the published literature (Yuan et al., 2015b). Instead, relatively simple estimation methods, such as unit well cost, predominate for

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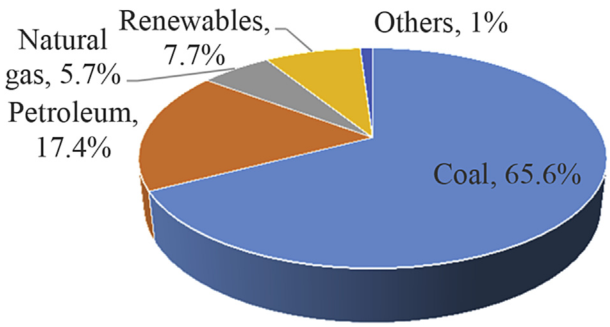

Fig. 1. The primary energy consumption mix in China in 2014.

estimating shale gas surface facility costs (Kong et al., 2015; Li et al., 2013; Wehunt et al., 2012). Moreover, many studies incorporate the shale gas surface facility costs into the well costs, which is typically simply assigned (Baihly et al., 2010; Lake et al., 2013; Williams-Kovacs and Clarkson, 2014). Some studies have not even considered this cost item in their work (Marongiu-Porcu et al., 2013; Plaksina and Gildin, 2015; Song et al., 2011). If there is no appropriate method for accurately estimating these costs, distortions will be generated in the real economic opportunities underlying these projects.

Given the limitations of current estimation techniques for shale gas surface facility costs, this paper aims to establish a more effective and accurate approach to estimate surface facility costs in the early stages of feasibility studies based on the characteristics of shale gas surface facilities. With the analysis of the significant characteristics of surface facilities for shale gas development, terrain conditions are identified as a major impact factor for surface facility costs. Based on an investigation of the relationship between terrain conditions and surface facility costs and the law of declining costs for surface facility costs, a new estimation approach for shale gas surface facility costs is proposed for quick and accurate estimations of surface facility costs.

The remainder of this paper is organized as follows. Section 2 investigates the key characteristics of shale gas surface facilities and how these attributes affect surface facility costs. Section 3 briefly introduces the relevant methods and the data used for validation. Section 4 describes the empirical results of a shale gas example in China and offers a discussion. The closing section summarizes the main conclusions and highlights the key aspects of this work.

2. The characteristics of shale gas surface facilities

Due to the nature of shale gas resources, extracting shale gas from ultra-low permeability shale formations is characterized by certain particularities. As an introduction to a sound understanding of the differences between shale gas development and conventional natural gas development, the overall process of shale gas development is showed in Fig. 2 (US Department of Energy (DOE), 2009; Hefley et al., 2011; Wang et al., 2014). Significant features are associated with shale gas exploitation in terms of drilling and completion, hydraulic fracturing stimulation and production operation, all of which have important impacts on the surface facilities of shale gas development. The characteristics of the surface facilities associated with shale gas development differ from those related to conventional natural gas development in several ways that require idiosyncratic ideas and methods for estimating and minimizing surface facility costs (Guarnone et al., 2012; Lake et al., 2013; Yuan et al., 2015b).

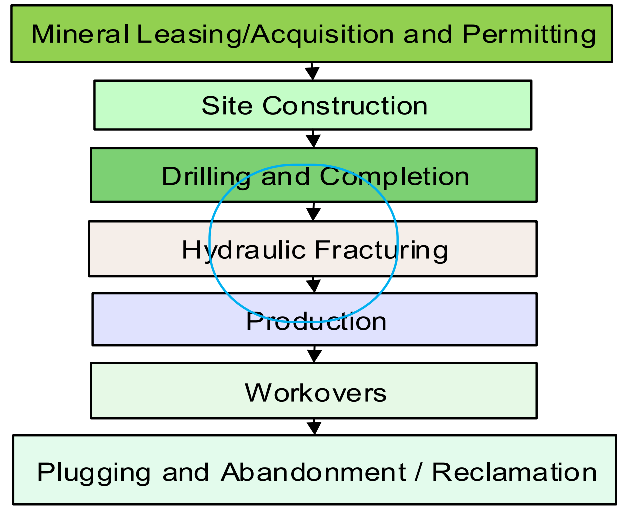

Fig. 2. Overall process of shale gas development.

2.1. *The impact of development technology features on facilities*

Conventional natural gas is located in stratigraphic traps as free gas that is extracted by natural flow. To increase production and recovery factors, water or gas flooding is frequently adopted, and large injection facilities must be constructed. In contrast, shale gas is mainly found as both absorbed and free gas in ultra-low permeability shale formations that have no traps. To produce economically feasible quantities of gas from shale formations with low porosity and low permeability, horizontal drilling and hydraulic fracturing stimulation are utilized in shale gas development (Alexander et al., 2011; Eshkalak et al., 2014; Pei et al., 2015), as depicted in Fig. 3.

Large quantities of fresh water must be supplied when employing these two key technologies, resulting in substantial quantities of wastewater that must be handled (Simpson, 2010; Xia

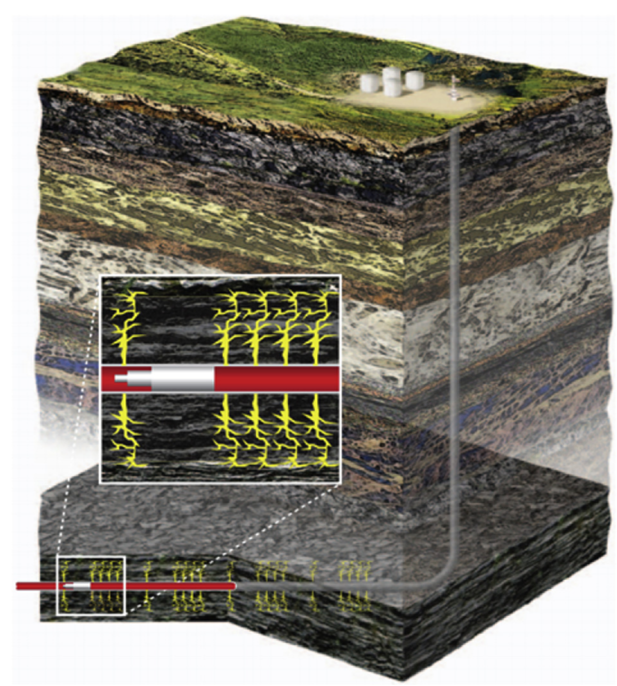

Fig. 3. Horizontal drilling and hydraulic fracturing as used in shale gas development.