Energy xxx (2016) 1–13

Contents lists available at ScienceDirect

Energy

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

A new approach for the comprehensive grading of petroleum reserves in China: Two natural gas examples

Wandi Li [a], Dongkun Luo [a, *], Jiehui Yuan [b]

[a] School of Business Administration, China University of Petroleum, No. 18, Fuxue Road, Changping District, Beijing 102249, China
[b] Institute of Energy, Environment and Economy, Tsinghua University, No. 1, Tsinghua Garden, Haidian District, Beijing 100084, China

ARTICLE INFO

Article history:
Received 1 February 2016
Received in revised form
20 May 2016
Accepted 27 October 2016
Available online xxx

Keywords:
Petroleum reserves
Comprehensive grading
Discount cash flow method
Natural gas
Unconventional natural gas

ABSTRACT

For orderly and sustainable development, petroleum resources should be planned scientifically. Based on the discount cash flow (DCF) method, we propose a new approach for the comprehensive grading of petroleum reserves in China because existing reserve classification methods are unable to support the formulation of exploitation planning. This approach combines five factors: economic value, technological progress, subsidy policy, reserve scale and resource risk. Examples show that this approach can be used to grade natural gas resources rapidly and effectively, which is helpful for providing effective guidance for the scientific development of gas resources.

1. Introduction

The petroleum industry is dependent on available resources. Different classes of resources will influence the development planning, yield prediction and evasion of investment risks. Based on the grade and rank of oil and gas reserves, companies can formulate exploitation plans, manage oil and gas resources in a scientific manner, maximize the benefits of resource assets, optimize investment orientation and improve investment benefits. From the perspective of governments at all levels, development plans must be made according to the comprehensive ordering of oil and gas reserves under the guidance of national strategic goals for oil and gas development, as they are the basis for the overall deployment of resource exploitation, reasonable allocation of oil and gas resources within the administrative area, sustainable development of the industrial chain and rapid and coordinated socioeconomic development of a given region. Therefore, it is of great practical significance to formulate a comprehensive grading proposal for oil and gas reserves.

There are two main types of existing classifications. The first type, which is the most important form of classification, is the official standard established by governments and influential institutions [1–5]. The main aims of these existing reserve classification systems are different from one another, and there is no comprehensive classification method for guiding development planning. This will be discussed in detail in the following section. The second type of existing classifications was introduced by scholars. Hu [6–9] established physical and mathematical models of oil and gas reserve value classification based on the principle of differential rent. The differential factor is divided into price differential factors [10], investment cost differential factors [11], recovery cost differential factors [12], transportation cost differential factors [13] and external cost differential factors [14]. The research is focused on the proven reserves without regard to whether reserves are technologically and economically recoverable. The purpose is to determine the level of oil and gas resource tax. The core is value evaluation to eliminate human, socioeconomic and technological factors. Application of the analytic hierarchy process (AHP) and the Delphi method to calculate the weight of each factor is not objective. Thus, the results of such research cannot be the basis of development planning. Li [15] analyzed the developed blocks to evaluate the potential of the undeveloped blocks and then calculated and classified them. However, this approach is not precise; there may be no similar developed blocks, or the data of a given developed block could be unavailable. Therefore, in some cases, this method has no operability.

* Corresponding author.
E-mail address: ldkun_edu@hotmail.com (D. Luo).

http://dx.doi.org/10.1016/j.energy.2016.10.125
0360-5442/© 2016 Published by Elsevier Ltd.

To establish a more suitable grading scheme for the development planning of petroleum reserves, we review and analyze the representative and influential classification systems for reserves around the world and China's common classification schedules in section 2. We explain why they cannot be used to guide the planning formulation. Because the core of enterprises' economic activities is to obtain benefits, the economic value of the reserves is regarded as the key index in the comprehensive grading approach in section 3. The net present value (NPV) for different discount rates, the reserves scale and the uncertainty are selected as the indexes. The technological advances and subsidy policy are also considered to be important factors. In section 4, two natural gas examples are employed to demonstrate the function and method of the application.

2. Current status of reserve classification methods

In this chapter, we divided the review of the existing classification methods into two parts: the existing representative reserve classification systems around the world and China's common classification scheme. At the end of each part, we summarize their characteristics to establish a useful method for planning.

2.1. Existing representative reserve classification systems around the world

In 2005, the Reserve Committee of the Society of Petroleum Engineers (SPE) identified the representative reserve classification standards as follows: ①SPE/WPC/AAPG/SPEE, ② UNFC of UN-ECE, ③ SEC, ④ SORP, ⑤ CSA, ⑥Russia RF, ⑦ China PRO, ⑧ Norway NPD, and ⑨ USGS [16]. Although these systems cannot completely cover or replace the classification systems formulated by all countries or companies, they are highly representative in terms of inclusivity and recognition. The most representative five classification systems are selected in the paper for comparison. Two primary international standards for oil and gas reserve classification and the representative standards of Norway, Russia, and China are selected.

(1) Thus far, the most influential reserve classification system in the oil and gas industry around the globe is the *Petroleum Resources Management System*, which is jointly formulated by the SPE, World Petroleum Council (WPC), Society of Petroleum Evaluation Engineers (SPEE) and American Association of Petroleum Geologists (AAPG). As shown in Figs. 1 and 2, reserves are classified according to the range of uncertainty of the recoverable and/or potentially recoverable volumes associated with a project and its likelihood of commerciality [17].
(2) In accordance with the United Nations Framework Classification for Fossil Energy and Mineral Resources (UNFC) enacted by the United Nations Economic Commission for Europe (UN-ECE), reserves are classified by three key properties: economic value (E), feasibility (F) of oil and gas projects, and geological knowledge (G), as shown in Fig. 3. The system is sub-divided into 36 possible combinations in the 3D coordinate system, among which 19 combinations are applicable to petroleum. To facilitate the system's use by users worldwide, the E/F/G axis is further divided by digital codes, as shown in Fig. 4 [2]; the meanings of the codes are provided in Table 1.
(3) The Norwegian Petroleum Directorate (NPD) classification system (Table 2) classifies oil and gas resources in strict accordance with the project progress from the undiscovered resources to the contingent resources and finally to the reserves [18]. The classification also distinguishes two mining methods: primary recovery (first oil/gas, extracted by natural energy, in terms of F) and production relying on well stimulation (additional oil/gas, in terms of A) [19].
(4) The Russian Federation's classification system for oil and gas resources is shown in Fig. 5. It classifies oil and gas reserve/resource quantity according to the exploitation degree, geological knowledge, project progress, and commercial development maturity [20,21].
(5) China's classification system for oil and gas resource quantity/reserves shown in Fig. 6. This system classifies reserves according to their exploitation status and technical and economic feasibility.

The main aims of the existing classification systems are to disclose information of reserves to the listed companies (SEC, CSA, SORP), report information of reserves to the host country of the resources (Norway, Russia, China, USGS), and contribute to the reference standards (UNFC, SPE) for oil and gas asset transactions between international petroleum companies. These systems are primarily concerned with the state of the reserves rather than the total quality of the oil and gas reservoirs. Thus, they focus on classifying reserves of a single resource instead of comparing resources from different zones. Therefore, they do not apply to another important purpose of reserve classification, i.e., providing decision-making support for exploitation and development deployment.

2.2. Classification in China's Regulation of Petroleum Reserves Estimation

The classification of reserves has been proposed in the *Regulation of Petroleum Reserves Estimation* [22] based on the classification of oil and gas reserves since the implementation of the *Regulation of Oil Reserves* [23] and *Regulation of Gas Reserves* [24], as summarized in Table A1 of the Appendix. This classification scheme is the most common in China's petroleum industry; however, it has numerous limitations.

Reserves are mainly classified from the technical perspective in the existing classification schemes, which plays a crucial role in the management of reserves and development of oil and gas reservoirs. All classification indexes reflect economic properties from different angles: the starting standard for reserves reflects the economic boundary; reserve scale reflects the economic aggregate and strategic values; reserve abundance and productivity reflects the unit capacity of input-output efficiency; burial depth reflects the differences of drilling investment in the reservoirs with the same reserves; porosity and permeability reflect the recovery efficiency and investment recovery conditions; and sulfur content and density reflect the reserve quality and price after development.

Because analyses are conducted from the perspective of different elements, it is impossible to comprehensively evaluate the reserve quality if different elements of the same reserve have different ranges. The classification is based on the physical quantity, which fails to accurately evaluate the economic efficiency of the reserves because the economic properties are reflected from a technical perspective and are not described in economic terms. Moreover, some classification elements are strongly correlated and thus do not conform to the requirements of element independence. Moreover, reserve uncertainty, which could constitute the greatest risk in oil investment, is not reflected in the classification. In addition, the classification is relatively rough, and there is a certain gap from the adaption of ideal enterprise strategic arrangements and investment decisions.

Please cite this article in press as: Li W, et al., A new approach for the comprehensive grading of petroleum reserves in China: Two natural gas examples, Energy (2016), http://dx.doi.org/10.1016/j.energy.2016.10.125