Multi-dimensional Analysis Of The Exploitation And Utilization Of Shale Gas And Coal-bed Methane Based On The Analytic Hierarchy Process

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Abstract. Shale gas and coal-bed methane are very important unconventional resources. Shale gas and coal-bed methane are the most effective supplement of the conventional fossil energy, and the quantity of these resources are abundant. So the shale gas and coal-bed methane have been gained comprehensive attention all over the world. At present China has basically realize commercial production of coal-bed methane industry, but the shale gas is still in the experimental stage. This paper analyzes shale gas and coal-bed methane based on energy strategy level, energy utilization level, mining technology level and environment level. The weight of these factors was analyzed by using analytic hierarchy process (AHP). The results show that in China the coalbed methane should be the priority development, and then the shale gas. And put forward some suitable suggestion and comments, to ensure China's energy structure development orderly, healthy and rapidly.

Introduction

Shale gas is a kind of unconventional gas, which is in the shale bed or mudstone bed with free state or adsorbed state. Shale gas development was successful in industrial development Only in North America [1]. The shale gas is lower productivity, because the pressure of the shale gas is low, the saturation degree is low. Coalbed methane is also a kind of unconventional gas, which is stored in the coal seam, and the main ingredients are methane. The government has introduced many policies to encourage the development and utilization of coalbed methane, science 2007 [2,3]. Compare and analysis the shale gas and the coalbed methane in many level to determine the production value is very important for China to allocate capital resources and protect the resources and environment reasonably [4,5,6]. This paper analyzed shale gas and coalbed methane based on energy strategy level, energy utilization level, production technique level and environment problem level, and obtained the weight of these factors by using analytic hierarchy process (AHP) [7]. And put forward suitable suggestions and comments, to ensure the energy structure development orderly, healthy and rapidly in China.

Method and Procedure of AHP

(1) The hierarchical structure

Based on the analysis of the problem, complicated problem is decomposed into some elements, these elements are subdivided into several groups according to different properties, and these formed the hierarchical structure.

(2) Generate the judgment matrix

Each time two elements are selected, aij is the relative importance of representative element. All of the comparison results formed the judgment matrix.

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

(3) Judgment matrix test evaluation

①Quantification of elements

The Satty graphic evaluation method is used to quantify the elements of the judgment matrix.

②Consistency check

In the Satty model method, the numbers 1 to 9 are used to evaluate the importance of the two elements in the same level, but some decimal circular and round could undermine the matrix consistency, for example, nonzero eigenvalues λmax=m, and when the degree of importance of the elements i, j, k are very close, experts may meet the problem when they compare the elements. And the problem j is more important than i, i is more important than k, k is more important than j. So, inconsistent phenomenon may happen in the judgment matrix. In the AHP method, the concordance rate CR is used to check consistency.

$$C_{ij} = 1 / C_{ji} \qquad \lambda_{\max} = \frac{1}{m}\sum_{i=1}^{m}\frac{(A\delta)_i}{\delta_i} \tag{2}$$

$$CR = CI / RI \qquad CI = \frac{\lambda_{\max} - m}{m-1} \tag{3}$$

Where CI is the consistency of the indicators, m is the order of the judgment matrix, λmax is the biggest characteristic value of the judgment matrix, RI is random consistency index, as shown in Table.1.

Table.1 Random consistency index

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

When CR increase consistency of matrix is reduced, and When CR reduced matrix consistency increased. When λmax=n, CR=0, matrix is the same. Usually, when CR＜0.1, matrix pass the consistency check. Otherwise, the elements need to be compared once again.

③Determine the relative weight of each element

After the judgment matrix pass consistency test, calculate the eigenvalue Aλ=nλ, we can get λ=(λ1, λ2, λ3…λn)T, and the normalized results is the weight of elements.

Establish the Hierarchical Analysis Model of the Energy Utilization

Establishment of the Hierarchical Structure Model. First determine the main factors influencing the energy utilization, and then determine the weights of main factors. By analogy, calculate the weight of the underlying index. The energy utilization system Includes 4 levels.

(1) Objective layer A. It fully reflects the trend of energy utilization and influence, and is the overall goals of energy utilization. (2) System layer B. The overall objective of energy utilization is divided into 4 system layers: energy strategy, energy utilization, production technique and environmental problem. (3) Index layer C. Each system layer is divided into 2 elements, and these 8 elements are the specific indexes that influence the objective layer. (4) Project layer D. The project layer includes shale gas and coal-bed methane, and the target is to choose which energy sources should be developed preferentially. The hierarchical structure model was shown in Fig.1.

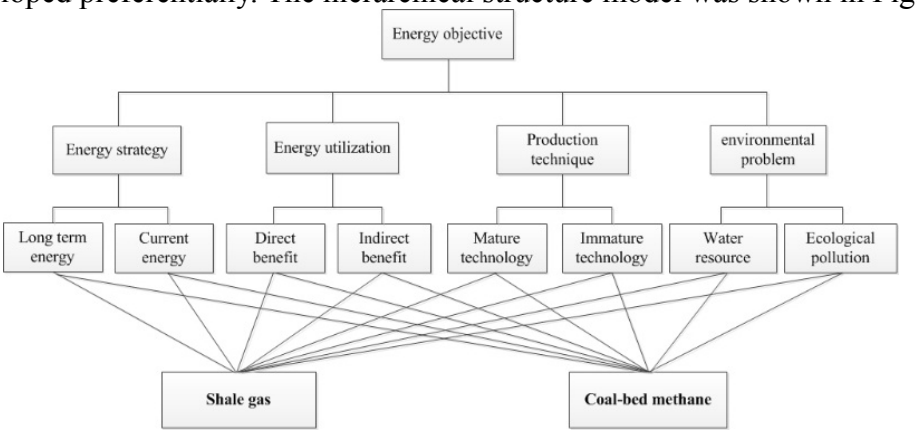

Fig.1 Hierarchical structure model

Analysis of the Main Factors. (1)Energy strategy. The development of the coalbed methane in China was relatively early, and China had executed the subsidy policy, since 2007. The development of coalbed methane is developing rapidly. Shale gas in China is only in its infancy, the technology is still immature, and shale gas drilling costs too much currently. So the development of coalbed methane should be given first priority, in the current energy strategy level. (2)Energy utilization. Coalbed methane is a kind of unconventional natural gas, which is associated with coal and occurrence in the coal seam. Once the coal mining, coalbed methane will pass of roadway ventilation to the atmosphere, and these coalbed methane is wasted. And coalbed methane is a major accident of coal mine safety production in China. Shale gas occurrence in shale, as long as we don't produce shale, shale gas will not be escaped into the atmosphere temporarily. In the coming decades, the shale may not be mining, but the coal has to exploit. (3)Production technique. Exploration methods, technology and production process of the coalbed methane are comparatively perfect after 20 years development. But the shale gas resources survey and exploration in China are still in the exploration of the early stage, and the potential of the shale gas has not been evaluated roundly yet. (4) Environmental problem. Benefit from the progress of fracturing technology, shale gas can be fully developed. Multistage hydraulic fracturing technology is the primary technology in the shale gas development in the world, and this technique consumes a lot of water. The Midwest areas are the acute shortage of water areas in China, as shown in Fig.2, and the shale gas exploration favorable areas are also in the Midwest areas.

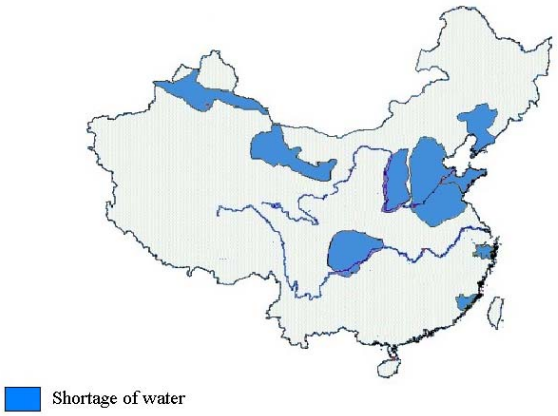

Fig.2 The shortage of water areas in China

Construct the Judgement Matrices

The judgment matrixes were established based on importance indexes:

Table 1 The weight of energy reasonable use

Items	Weight	Items	Weight
Energy strategy	0.3001	Production technique	0.3950
Energy utilization	0.1733	Environmental problem	0.1317

Table 2 The judgment matrix of long term energy

Items	Coalbed methane	Shale gas	Weight
Coalbed methane	1.0000	0.3333	0.2500
Shale gas	3.0000	1.0000	0.7500

Table 3 The judgment matrix of current energy

Items	Coalbed methane	Shale gas	Weight
Coalbed methane	1.0000	5.0000	0.8333
Shale gas	0.2000	1.0000	0.1667

Table 4 The judgment matrix of direct benefit

Items	Coalbed methane	Shale gas	Weight
Coalbed methane	1.0000	1.0000	0.5000
Shale gas	1.0000	1.0000	0.5000

Table 5 The judgment matrix of indirect benefit

Items	Coalbed methane	Shale gas	Weight
Coalbed methane	1.0000	5.0000	0.8333
Shale gas	0.2000	1.0000	0.1667

Table 6 The judgment matrix of mature technology

Table 7 The judgment matrix of immature technology

Items	Coalbed methane	Shale gas	Weight
Coalbed methane	1.0000	5.0000	0.8333
Shale gas	0.2000	1.0000	0.1667

Table 8 The judgment matrix of water resource

Items	Coalbed methane	Shale gas	Weight
Coalbed methane	1.0000	7.0000	0.8750
Shale gas	0.1427	1.0000	0.1250

Items	Coalbed methane	Shale gas	Weight
Coalbed methane	1.0000	0.2000	0.1667
Shale gas	5.0000	1.0000	0.8333

Table 9 The judgment matrix of ecological pollution

Items	Coalbed methane	Shale gas	Weight
Coalbed methane	1.0000	3.0000	0.7500
Shale gas	0.3333	1.0000	0.250o

Based on the judgment matrixes, the weight of the coalbed methane is 0.6355, and the weight of the shale gas is 0.3645.

Result Analysis

The proportion of the consistency of the energy rational utilization judgment matrix, CR=0.0574, and the proportion of the consistency of other judgment matrix is 0, CR is less than 0.1, and the consistency of judgment matrix is acceptable. In the project layer, the weight of the coalbed methane is 0.6355, and the weight of the shale gas is 0.3645. So, exploitation of coalbed methane should be given priority.

Conclusions

(1) In the project layer, the weight of the coalbed methane is 0.6355, and the weight of the shale gas is 0.3645. So, exploitation of coalbed methane should be given priority.
(2) From the economic benefits, social benefits and environmental benefits, development of coalbed methane can achieve the benefit of the three aspects: save the energy resources, promote the safe production of coal mines and adjust the energy structure.
(3) From the technical feasibility, exploration methods, technology and production process of the coalbed methane are comparatively perfect after 20 years development, but the shale gas resources survey and exploration in China are still in the exploration of the early stage. So, exploitation of coalbed methane should be given priority.

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