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Energy Conservation Evaluation Index System and its Application for Large Oil Companies

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China National Petroleum Corporation (CNPC), China Petrochemical Corporation (Sinopec) and China National Offshore Oil Corporation (CNOOC) are not only big energy producers, but also big energy consumers, and play important roles in the national economy. Energy conservation target responsibility assessment is an important way to promote energy conservation and emission reduction of enterprises. In this paper, an energy conservation evaluation index system of large oil company is established, which combines the quantitative index and qualitative index. With this index system, 10 subordinate enterprises of an large oil company are evaluated and graded. It provides support for oil companies to meet national energy conservation assessment requirements and improve energy conservation management level.

1. Introduction

With the sustained and rapid development of China's national economy, the demand for energy is also increasing. The Chinese government has paid great attention to energy conservation for a long time. Since 1998, the law of the People's Republic of China on energy conservation has been promulgated and implemented, and since 2007, the responsibility system for energy conservation objectives and energy conservation assessment and evaluation system have been implemented for local governments and key energy using companies, to continuously improve energy utilization efficiency. According to the data disclosed by the National Bureau of Statistics (PRC NBS, 2020), in recent years, China has met the sustained and high-speed development demand of the national economy with a relatively low growth rate of energy consumption, making due contribution to the global response to climate change, but the difficulty of energy conservation and consumption reduction has increased year by year, as shown in Table 1.

Table 1: Comparison of China's GDP growth and energy consumption growth (%)

Classification	2015	2016	2017	2018	2019
GDP growth rate	7.0	6.8	6.9	6.7	6.1
Energy consumption growth rate	0.9	1.4	2.9	3.3	3.3
Energy consumption reduction rate of GDP	-5.3	-4.8	-3.5	-3.0	-2.6

Due to its own resource endowment, large amounts of energy needed for the sustainable development of China's national economy needs to be imported. According to the data released by the National Bureau of Statistics, in 2005, China's energy production and demand gap were about 160 mega tons of standard coal equivalent (Mtce), and by 2015, it was expanded to 680 Mtce. During the 13th Five Year Plan period, the import energy volume remained at nearly 900 Mtce, nearly 20 % of energy consumption needs to be solved by import. Due to the resource characteristics of rich coal, poor oil and little gas, the imported energy is mainly

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crude oil and natural gas. With the continuous development of national economy, the dependence of crude oil and natural gas on foreign countries is increasing. Liu et al. (2020) declared China has surpassed the United States in 2017 and became the world's largest crude oil importer. In 2018, China surpassed Japan and became the largest natural gas importer. In 2019, China's dependence on foreign crude oil exceeded 70 % for the first time, and the contradiction between oil and natural gas production and demand was very prominent.

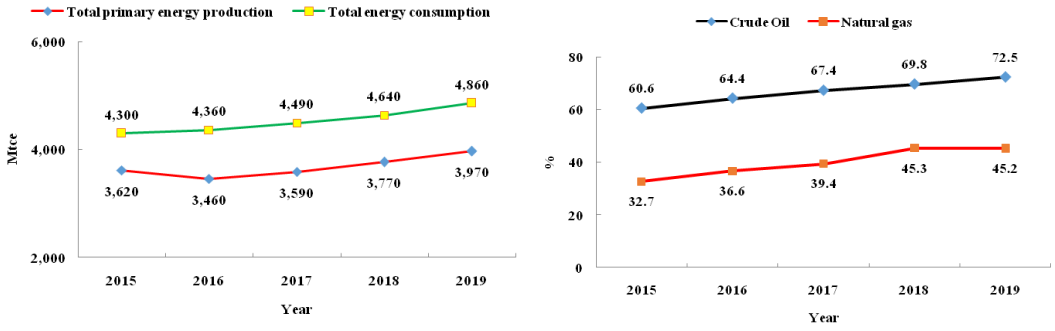

Figure 1: (a) Energy production and consumption and (b) External dependence of crude oil and natural gas

Petroleum and chemical industry is a key energy-consuming industry. Li (2019) said that in 2018, the energy consumption of the petroleum and chemical industry reached 587 Mtce, the second-largest energy consumption industry, accounting for about 13 % of the total energy consumption of the country. The annual energy consumption of large oil companies such as CNPC and Sinopec is about 100 Mtce. Among the 99 "100" key energy users whose annual energy consumption is more than 3 Mtce published by the National Development and Reform Commission(PRCN DRC, 2019), there are 23 oil and petrochemical enterprises, 9 of which belong to CNPC, 10 of which belong to Sinopec, and 1 belong to CNOOC.

The state's assessment on the responsibility of energy conservation objectives of key energy users gradually increased. Since the 11th Five Year Plan, the total energy consumption of enterprises included in the national energy conservation assessment decreased from 180,000 tce to 5,000 tce, and the number of enterprises has increased from 1,008 to 17,000. The assessment area also expanded from a single industrial field to various fields such as construction, transportation, trade circulation, public institutions, etc. The assessment index from energy conservation quantity changed to total energy consumption and energy consumption intensity. The scope of enterprises included in the assessment and the difficulty of assessment are gradually increasing, which puts forward higher requirements for energy conservation management of the enterprises.

The assessment of energy conservation target responsibility is an important starting point for enterprises to strengthen energy conservation management and improve energy efficiency level. At present, scholars put forward the corresponding energy conservation evaluation index system for the study of different industries. He (2011) introduced and applied an evaluation index system of energy conservation and emission reduction of coal enterprises, which is composed of five parts: energy consumption, resource recycling, pollutant emission, comprehensive environmental treatment and scientific and technological management support. The first four are quantitative indicators, while scientific and technological management support is qualitative indicators. Zhang et al. (2014) established energy efficiency evaluation index system for fossil-fuel power plant including comprehensive index and equipment efficiency index. Song (2017) proposed the energy-efficient building evaluation index system including building energy conservation evaluation, envelope evaluation, heating and air conditioning evaluation, lighting system evaluation, operation management evaluation, etc. Wang (2016) proposed a port energy conservation evaluation index system including energy management index and energy consumption index, which includes 6 categories and 34 assessment points.

Lu (2011) analyzed the restrictive factors that effected the evaluation indicator of energy conversion of oil field enterprises, given the adivces of carrying out the examination of comprehensive unit consumption of work load, increasing the examination of operation efficiency of key energy consuming equipment and increasing the examination of energy saving measures. Chen (2015) presented a model of energy conversation evaluation system for offshore oil field or gas field development projects based on AHP. Yu et al. (2017) put forward the calculation method of energy conservation assessment index for refined oil marketing enterprises. Zhu et al. (2017) established a new evaluation index system for comprehensive evaluation of circulating cooling water system. This system includes energy consumption index, energy efficiency index, operation quality index and pollution discharge index.

CNPC and other large oil companies cover oil and gas exploration and production, refining and chemical, gasoline and diesel sales and oil transportation and other business areas. At present, the energy conservation

evaluation index system proposed by the predecessors research cannot meet the energy conservation assessment and management needs of large oil companies. It is necessary to carry out further research and establish an energy conservation evaluation index system that can meet the national energy conservation assessment requirements and the internal management needs of the company.

2. Energy conservation evaluation index system

Based on the requirements of national energy conservation assessment and management needs of oil companies, an energy conservation evaluation index system combining quantitative index and qualitative index is established.

2.1 Principles of construction

This paper studies the requirements of the Chinese government for the assessment of the responsibility of energy conservation objectives of enterprises since 2005 and the new requirements for the implementation of online energy monitoring, the establishment of energy management system and the construction of energy management and control center for key energy users since the 13th Five Year Plan, the current situation and development trend of energy conservation assessment in petroleum and petrochemical industry, established energy conservation evaluation index system based on scientificity, systematization, applicability, operability and guidance.

2.2 Energy conservation evaluation index system

The energy conservation evaluation index system of petroleum companies is divided into three levels: Target level, Criterion level and Index level. The target level includes quantitative indicators and qualitative indicators. The criterion level includes 10 categories such as total energy consumption, energy economic benefits and energy saving quantity.
The index layer includes 32 assessment indicators, which can be divided to 7 categories of quantitative indicators (which including 35 detailed indicators) and 25 qualitative indicators, which are shown in Table 2 and Table 3.

Table 2: Summary of quantitative evaluation indexes

Index level	Detailed quantitative index name
C_1	$C_{1,1}$: Total energy consumption; $C_{1,2}$: Total fuel and power consumption.
C_2	$C_{2,1}$: Consumption of raw coal; $C_{2,2}$: Consumption ofcrude oil; $C_{2,3}$: Consumption ofnaturalgas; $C_{2,4}$: Consumption ofrefined oil.
C_3	$C_{3,1}$: Energy consumption per unit output value; $C_{3,2}$: Energy consumption per unit addedvalue; $C_{3,3}$: Energy consumption per unit operating revenue.
C_4	$C_{4,1}$: Energy saved of output value; $C_{4,2}$: Energy saved of products; $C_{4,3}$: Energy saved of technical measures.
C_5	$C_{5,1}$: Comprehensive energy consumption per unit oil and gas production in oilfield; $C_{5,2}$: Electricity consumption per unit oil and gas production in oil field; $C_{5,3}$: Comprehensive energy consumption per unit oil and gas production in gas field; $C_{5,4}$: Comprehensive energy consumption of oil refining; $C_{5,5}$: Energy consumption per unit energy factor of refinery; $C_{5,6}$: Electricity consumption of oil refining; $C_{5,7}$: Comprehensive energy consumption of ethylene products; $C_{5,8}$: Electricity consumption of ethylene products; $C_{5,9}$: Comprehensive energy consumption of ethylene and propylene products; $C_{5,10}$: Comprehensive energy consumption of synthetic ammonia products; $C_{5,11}$: Comprehensive energy consumption of refined oil sales; $C_{5,12}$: Electricity consumption of refined oil sales; $C_{5,13}$: Comprehensive energy consumption of oil and gas transportation.
C_6	$C_{6,1}$: Efficiency of mechanical production system; $C_{6,2}$: Efficiency of water injection system; $C_{6,3}$: Efficiency of gathering system; $C_{6,4}$: Efficiency of power supply and distribution system; $C_{6,5}$: Efficiency of heating system; $C_{6,6}$: Efficiency of power generation system.
C_7	$C_{7,1}$: Efficiency of heater; $C_{7,2}$: Efficiency of boiler; $C_{7,3}$: Efficiency of fan; $C_{7,4}$: Efficiency of pump.

Table 3: Evaluation index system of energy conservation in oil companies

Target level	Criterion level	Index level
Quantitative index A_1	Total energy consumption B_1	Total energy consumption C_1
		Total fuel and power consumption C_2
	Energy economic benefit B_2	Energy input / economic benefit output C_3
	Energy saving quantityB_3	Quantity of energy saving C_4
	Energy technology efficiency B_4	Production unit consumption index C_5
		Key energy consumption system indicators C_6
		Efficiency of key energy consuming equipment C_7
	Organization and leadership B_5	Establish an energy conservation leading group C_8
		Define the comprehensive energyconservation management department and provide full-time energy conservation management person C_9
		Sound energy conservation management system and clear division of responsibilities of the management departments C_{10}
	Target responsibility system B_6	The energy conservation planning has strong guidance, and is adjusted and implemented timely in combination with the actual production C_{11}
		Energy saving target decomposition is included in performance assessment at all levels, and incentive and restraint mechanism for energy saving is established and improved C_{12}
		Establish enterprise energy management system and pass certification or evaluation C_{13}
		Equip energy measuring instruments according to national standards and conduct regular verification C_{14}
		Realize online collection and real-time monitoring of energy consumption data C_{15}
		Establish original data and account of energy consumption, and assign special person to do statistical analysis C_{16}
		Carry out energy audit every five years C_{17}
Qualitative index A_2	Basic management B_7	Implement energy conservation monitoring as planned, and implement rectification measures C_{18}
		Actively carry out energy efficiency benchmarking and analysisand the level of energy efficiency greatly improved C_{19}
		Implement quota management for energy consumption of main devices, products and equipment C_{20}
		Access management of key energy consuming equipment, energy using technical products of new reconstruction and expansion projects C_{21}
		Actively carry out energy conservation publicity and training C_{22}
		Actively undertake the preparation and revision of energyconservation technical standards C_{23}
		Set up special funds for energy conservation technology transformation and research C_{24}
	Technology progress B_8	Actively promote the application of new energyconservation technologies and make rational use of new energy C_{25}
		Formulate and implement annual energy conservation technology transformation plan C_{26}
		Actively carry out scientific research on energy conservation C_{27}
	Implementation of laws and regulations B_9	Implement energy conservation laws and statutes C_{28}
		Eliminate backward energy consumption production process and equipment C_{29}
		Implementation of energy conservation review system for fixed asset investment projects C_{30}
	Energy management and control B_{10}	Develop energy management and control promotion plan C_{31}
		Promote construction of energy management and control C_{32}

3. Case study

The energy conservation evaluation index system presented in Section 2 is applied for the evaluation of 10 enterprises.

3.1 Evaluation score calculation and grade division

According to the production characteristics of each enterprise, quantitative and qualitative indicators are selected to form the assessment and evaluation indicator system, and the scores of the assessed enterprises are calculated. The total score of the assessed enterprise can be obtained by adding the scores of each evaluation index, as shown in Eq(1) and Eq(2).

$$S_T = \sum_{i=1}^{32} S_{c_i} \tag{1}$$

$$S_{c_i} = \sum_{j=1}^{N_{i,j}} S_{c_{i,j}} \quad \forall i = 1 \cdots 7 \tag{2}$$

where S_T is total score, S_{C_i} indicates the score of C_i. For the quantitative index C_1-C_7 each indicator also includes sub indicators $C_{i,j}$, $S_{C_{i,j}}$ denotes the score of $C_{i,j}$, $N_{i,j}$ represents the total amount of $C_{i,j}$.

The quantitative evaluation index is mainly verified by checking the energy consumption account of the enterprise and the calculation process of the unit consumption index, and the score is calculated according to the comparison between the evaluation value and the actual value. Among them, C_1-C_4 is the national evaluation index, if the actual value exceeds the evaluation index, the score will not be given, it is considered that the enterprise has not completed the assessment. For C_8-C_{32} and other qualitative indicators, they are mainly verified by viewing the organizational establishment documents, established rules and regulations, minutes of meetings and other materials. The weight coefficients for C_1 to C_{32} are shown in Table 4, the corresponding relationship between assessment score and rating level is shown in Table 5.

Table 4: Evaluation index score weight coefficient

Index	A	B	C	D	E
C_1-C_4	1.2	1.1	1.0	0	0
C_5-C_7	1.2	1.1	1.0	0.9	0.8
C_8-C_{32}	1.0	0.7	0.5	0.3	0

Table 5: Energy saving assessment level (score)

Score of assessment	$S_T \geq 90$	$90 > S_T \geq 75$	$75 > S_T \geq 60$	$S_T < 60$
Comprehensive evaluation	excellent	good	qualified	Unqualified

3.2 Application of the energy conservation evaluation index system

The selected indexes are shown in Table 6 and Figure 2 shows the evaluation results for the 10 enterprises.

Table6: The selected energy conservation evaluation index

Index	Oil and gas production enterprises	Refining and chemical enterprises	Marketing enterprises
C_1	$C_{1,1}$, $C_{1,2}$	$C_{1,1}$, $C_{1,2}$	$C_{1,2}$
C_2	$C_{2,1}$, $C_{2,2}$, $C_{2,3}$	$C_{2,1}$, $C_{2,4}$	$C_{2,1}$, $C_{2,4}$
C_3	$C_{3,1}$	$C_{3,2}$	$C_{3,3}$
C_4	$C_{4,1}$, $C_{4,3}$	$C_{4,2}$	$C_{4,2}$
C_5	$C_{5,1}$, $C_{5,2}$, $C_{5,3}$	$C_{5,4}$, $C_{5,5}$, $C_{5,6}$	$C_{5,11}$, $C_{5,12}$
C_6	$C_{6,1}$, $C_{6,2}$, $C_{6,4}$	$C_{6,5}$, $C_{6,6}$	——
C_7	$C_{7,1}$, $C_{7,2}$, $C_{7,4}$	$C_{7,1}$, $C_{7,2}$, $C_{7,3}$	$C_{7,2}$
C_8 to C_{32}			

Results show that, the scores of all enterprises are higher than 60 points, but the assessment index C_3 of enterprise $C_{R,3}$ is not completed, so its assessment grade is directly determined as unqualified. As shown, the scores of Oil and Gas production and Refining enterprises are relatively high, while the scores of Marketing enterprises are generally low, mainly due to the low energy consumption, the lack of full-time energy conservation manager, and the related energy management organization system is not perfect. Although the

quantitative assessment indicators can be completed, but the qualitative assessment indicators need to be improved for the Marketing enterprises. Because C_3 is easy to be affected by market factors and relatively uncontrolled, it is difficult to complete the assessment index for Refiningenterprises.

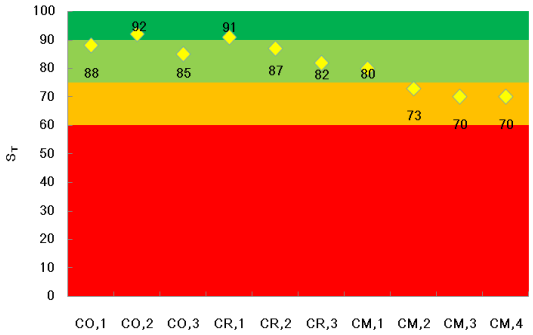

Figure 2: Scores of the evaluated 10 enterprises

4. Conclusions

In this paper, the index system which combines quantitative index and qualitative index is proposed to evaluate the effect of energy conservation in large oil companies. The evaluation results of 10 enterprises of a large oil company show that the evaluation index system can effectively evaluate the energy conservation work of the enterprises, and indicate the direction for the enterprises to strengthen the energy conservation management level. In the next step, AHP can be used to study the weight of each evaluation index, so as to evaluate the energy conservation achievements of enterprises more scientifically and reasonably.

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