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"Gheorghe Asachi" Technical University of Iasi, Romania

A QUANTITATIVE ANALYSIS OF ENERGY CONSERVATION AND EMISSIONS REDUCTION POLICY

Yanhua Zhang[1,2*], Silin Chen[1,2], Jihong Fan[3]

[1]The College of Economic and Management, Hubei University of Technology, Nanli Road No.28, Hongshan District, Wuhan City, Hubei Province, China
[2]The Research Center of Circular Economy Development in Hubei, Nanli Road No.28, Hongshan District, Wuhan City, Hubei Province, China
[3]Three Gorges Hydropower Development Co., Ltd, Fucheng Avenue No. 288, High tech Zone, Chengdu City, Hubei Province, China

Abstract

It is of great significance to quantitatively analyze the effectiveness of energy conservation and emissions reduction policies and to clarify the benefits and formulation principle soft policies. We collect information on these policies between 2012 and 2016 from the public information platform of the Hubei provincial government. By building a quantitative evaluation model of policy effectiveness and policy synergy, we empirically analyze the trends of their synergistic evolution. The results show that the number of these policies in Hubei province show an upward trend, but the average policy effectiveness is declining; the degree of synergy between policy measures and targets has gradually decreased to a stable range since 2012. Therefore, the Hubei provincial government has placed great importance on them, but there are conflicts among different policies and measures, which make it difficult to achieve the desired policy goals. Finally, we provide suggestions for the formulation of policies in Hubei province.

Key words: energy conservation and emissions reduction, policy effectiveness, policy evaluation, policy synergy

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1. Introduction

"Energy conservation" refers to "takes all measures that are technically feasible, economically reasonable, and environmentally and socially acceptable" to improve the efficiency of energy resources (Fu et al., 2008; Shi and Guo, 2017). "Emissions reduction" emphasizes the protection of the ecological environment and the reduction of pollutant and greenhouse gas emissions at all stages of energy development, production and use (Lin and Huang, 2011; Yang, 2014). Energy saving and emissions reduction are controlled through various measures in various fields, so as to achieve the purpose of sustainable development. It is the main method for China to cope with the international pressure on greenhouse gas emission reduction, the contradiction between energy supply and demand, and the ecology degradation. It is an important point to balance economic growth and sustainable development.

Since the "11th Five-Year Plan" period, policy restrictions had been strengthened, and a long-term policy framework for 2030 had been gradually formed. The Chinese government launched carbon trading pilots in seven provinces and cities. Among them Hubei had the most active transactions, with the market share ranking first in the country. Although the carbon emission market has initially achieved some results, there are still obvious defects in the mechanism due to externalities. Energy conservation and emissions reduction are multidisciplinary and complex, any single or excessive use of the policy

* Author to whom all correspondence should be addressed: e-mail: zyhcqupt@163.com

might have adverse effects on the effectiveness of it (Gong et al., 2020). Therefore, the coordinated use of a variety of macro control tools can better achieve the established goals.

For policy synergy issues, Meijers and Stead (2004) believed that policy synergy refers to the government's management of cross-border issues in the policy formulation process. These issues go beyond the existing policy domain boundaries and the responsibilities of individual departments, and require synergy among multiple entities. Kim (2011) added that the government should adopt policy synergy and other measures to maintain the stability of the policies regarding environmental changes. Peng et al. (2008) found that the impact of innovation policy synergy on economic and technological performance has significant directional differences.

The majority of the literature on energy conservation and emissions reduction policies focuses on the analysis of their deficiencies and implementation dilemmas. Few studies focus on the synergies of policies. The initial attempt to quantify policies began in 1978. Libecap (1978) classified and categorized various laws and regulations related to property rights, and used the results of quantitative processing to analyze the effects of policies. Cools and Brijs (2012) quantified the measures of Flanders traffic policies, such as traffic stability, energy taxation and parking fees, using the four evaluation criteria: "Hard", "Soft", "Push" and "Pull". Liu and Sun, (2007) utilized statistical analysis methods to study the historical evolution of Chinese innovation policy from 1980 to 2005. Yin et al. (2006) promulgated our foreign investment industrial policies and the investment catalogues issued by China in 1987, 1995, 1997 and 2002 as the target by weighting various industrial policy categories, measuring foreign industrial policy indices, and studying the effectiveness of foreign investment industrial policies. Peng et al. (2008) used technological innovation policy as an example, adopted a quantified approach, measured the policy from different dimensions, and used the quantified results to explore the evolutionary path of policy synergy and its impact on economic performance.

This method laid the foundation for the following research. Zhang et al. (2014) collected energy conservation and emissions reduction policies in China from 1978 to 2013. These authors developed quantitative standards for policies in three dimensions (policy intensity, policy measures, and police targets), quantified the collected policies, and constructed a model to analyze the evolution of the synergy of these policies using quantitative data. Based on previous conclusions, this article explores the current coordination status and synergistic effects of current energy conservation and emissions reduction policies in Hubei province, and provides some suggestions for the government to formulate guiding policies. The location of Hubei province is shown in Fig. 1. This paper collected the energy conservation and emissions reduction policies of Hubei province from 2012 to 2016. Using the above quantitative policy research methods, relevant policies were discussed from the aspects of policy effectiveness, measures synergy and targets synergy.

Fig. 1. Geographical location of Hubei Province in China

2. Methods

2.1. Design of the evaluation system

In order to measure the synergy of policy content, this article quantifies energy conservation and emissions reduction policies from three aspects: policy intensity, policy measures and policy targets. Policy intensity is an indicator that reflects the degree of the policy's legal effectiveness. In general, the higher the level of institutions promulgated by policies and laws, the greater the legal effectiveness of the policy and the higher the score of the policy intensity. Policy measures refer to the methods and means adopted by governments to achieve an established purpose in formulating and implementing policies. Policy targets are those purposes that should be achieved by a policy. The three dimensions of quantification compensate for the deficiencies of single indicators in reflecting policy content and, thus, better reflect the content validity of policies.

2.2. Construction of quantitative model of indicators

In the following, the policy intensity, policy measures, and policy targets are scored, and preliminary data are obtained. Generally speaking, the stronger the policy, the more specific the measures used, the clearer the goals achieved, and the higher the overall effectiveness. Therefore, this paper adopts the quantitative model of Zhang et al. (2014), the model is shown in Equation1 and 2. Equation 1 is used to calculate the overall effectiveness of policies each year. Equation 2 is used to calculate the average effectiveness of policies each quarter. The exact expression for both is as follows (Eqs. 1-2):

$$YTPE_i = \sum_{j=1}^{N_i} pe_j \times pm_j \times pg_j \quad (1)$$

$$YPE_i = \frac{\sum_{j=1}^{N_i} pe_j \times pm_j \times pg_j}{N} \quad (2)$$

where: $YTPE_i =$ the overall policy effectiveness in year i; $YPE_i =$ the average policy effectiveness in year i; $N_i =$ the number of policies in year i; $pe_j =$ the policy intensity score of articles j policy; $pm_j =$ the total score of policy measures of article j policy; $pg_j =$ the total score of policy targets of article j policy; $i =$ the year from 2012 to 2016;

The synergy of the policy measures or policy targets describes a situation where a policy uses multiple measures or achieves multiple goals. Generally speaking, the greater the intensity of the policy, the more specific the measures used in the same policy or the clearer the goals achieved, the better the coordination of policy measures or the synergy of policy objectives. Therefore, this paper mainly refers to Peng's (2008) measurement model of technological policy synergy. Eq. (3) is used to calculate the synergy of the policy measures each year. Eq. (4) is used to calculate the synergy of targets each year. The exact expression for both is as follows (Eq. 3):

$$PMJ_i = \sum_{j=1}^{N} pe_j \times pm_{jk} \times pm_{jl} (k \neq l) \quad (3)$$

where: PMJ_i - the synergy of the policy measures in quarter i; pm_{ik}, pm_{jl} - the scores of the k or l policy measures in j policy; k, l - the two measures that are selected from six measures, which include personnel measures, administrative measures, fiscal and taxation measures, financial measures, guiding measures and other economic measures.

The synergy of the policies targets each year (Eq. 4):

$$PGJ_i = \sum_{j=1}^{N} pe_j \times pg_{js} \times pg_{jt} (s \neq t) \quad (4)$$

where: PGJ_i - the policy synergy in year i; pg_{js}, pg_{jt} - the scores of the sth and tth policy targets in the article j policy;, s, t - the two targets that are selected from seven targets, which include prevention of pollution, improvement of energy conservation and emissions reduction, establishment of concepts, promotion of industrial upgrading, improvement of energy utilization efficiency, optimization of energy consumption structure, and technological transformation.

2.3. Basis of energy conservation and emissions reduction policies

Based on the actual situation of Hubei province, we combine the quantified standards developed by Zhang et al. (2014) with the quantitative technological innovation policy standards developed by Peng et al. (2008) to develop the quantitative standards for policy intensities, policy measures and policy targets.

First, we collect 563 policies on energy conservation and emissions reduction issued by the People's Government of Hubei Province and the General Office of the People's Government of Hubei Province from the Hubei Government Information Disclosure Platform. Among these policies, there are 97 related policies from 2012 to 2016. We conduct a preliminary screening of the policies that are highly relevant to the target polices. Then, classify and quantify these policies within 3 dimensions: policy intensities, policy measures and policy targets. Thus, a policy repository is established. According to the level and policy type of the promulgation agency, the values of 1, 2, 3, and 4 points are allocated to each policy to reflect the magnitude of the policy intensity. The specific quantitative standards are listed in Table 1. According to research on the classification of policy

measures by Kim (2011), Murphy et al. (2012) and Peng et al. (2008), as well as the summary of Zhang et al. (2014), we divide the main measures of these policies into personnel measures, administrative measures, fiscal and taxation measures, financial measures, guidance measures and other economic measures.

In the process of quantification, the values of 5, 4, 3, 2, 1 will be assigned to each policy measure according to the detailed degree of measures and the effectiveness of the implementation (Gong et al., 2019). The quantitative criteria are partly shown in Table 2. The main policy targets of energy conservation and emissions reduction policies are divided into pollution prevention, improvement of energy conservation and emissions reduction, establishment of energy concepts, promotion of industrial upgrading, improvement of energy utilization efficiency, optimization of energy consumption structure, and promotion of technological transformation. According to the attitude of government toward the policy target and the degree to which the policy achieves its target, it is assigned either 5, 4, 3, 2, or 1 point. The quantification standards are partly shown in Table 3.

3. Results and discussion

3.1. Evolution of the number and effectiveness of policies

Fig. 2 shows the evolution of the number, average, and overall effectiveness of energy conservation and emissions reduction policies in Hubei province from 2012 to 2016. The number of policies has been increasing in the past five years. Among them, from 2014 to 2015, the number of policies decreased slightly, but the average effectiveness increased. 2015 is the last year of China's "12th Five-Year Plan", and it is also a crucial year that determines whether the targets can be achieved during the "12th Five-Year Plan" period, which directly reflects the increase in the average effectiveness of policies. Although the Chinese government attaches more and more importance to energy conservation and emissions reduction, in the process of policy formulation, it is always busy with short-term goals. As a result, the formulation of these policies is not systematic and strategic, which is not conducive to the improvement of the effectiveness of policy implementation.

Table 1. Quantitative standards for energy conservation and emissions reduction policies (Zhang et al., 2014)

Policy intensity Score	***Score Criteria***
Score 4	Measures, regulations, provisions, decisions and interim measures promulgated by the Provincial People's Government (order of the provincial government)
Score 3	Opinions and notifications issued by the Provincial People's Government
Score 2	Implementation opinions and notifications issued by the General Office of the Provincial People's Government
Score 1	Notices and implementation opinions promulgated by the General Office of the Provincial People's Government

Table 2. Quantitative standards for energy conservation and emissions reduction policy measures (Zhang et al., 2014)

Measures	***Score***	***Quantitative standards for policy measures***
Personnel measures	5	Established a special agency to promote energy conservation and emissions reduction; clarified this agency's responsibilities
		Trained talents improved the level of benefits, and formulated relevant systems
		Formulated performance appraisal measures for energy conservation and emissions reduction; improved the incentive and punishment mechanism
	3	Clearly proposed to improve energy conservation and emissions reduction-related institutions
		Commended outstanding personnel and punished those who violate the rules
		Evaluated energy conservation and emissions reduction achievements; linked the assessment results with the performance of personnel
		No enforcement measures have been formulated or the recognition and punishment methods are unclear
	2	Only mentioned or related to the above terms
	1	No personnel measures were mentioned
Guidance measures	5	Vigorously guided individuals or enterprises in energy conservation and emissions reduction, and formulated specific implementation measures or plans for publicity
		Formulated methods for implementing demonstration projects or pilot projects
		Developed a catalogue of product technology promotion
		Developed a detailed guidance system
	3	Explicitly proposed the need to vigorously implement the promotion of energy conservation and emissions reduction; strengthened the implementation of logo management for energy conservation and environmental protection products
		Explicitly stated the need to formulate a list of product consumption recommendations
		Explicitly proposed to formulate guidance measures related to energy conservation and emissions reduction
		No relevant implementation measures or related directories have been established
	2	Only mentioned or related to the above terms
	1	No guidance measures were mentioned

Table 3. Quantitative standards for energy conservation and emissions reduction policy targets (Zhang et al., 2014)

Measures	*Score*	*Quantitative standards for policy measures*
Establishment energy conservation and emissions reduction concepts	5	Requested to increase the promotion of energy conservation and emissions reduction in the province to raise related awareness
		Legally requires recognition of relevant groups
		Requested to form detailed plans to raise public awareness
	3	Formulated an implementation plan to increase energy conservation and emissions reduction
		Formulated specific measures for public participation in supervision or evaluation
		Formulated the implementation method of demonstration or energy conservation logo management
	2	Requirements system only involves the above items, but no relevant measures have been introduced
	1	No mention of any idea or scheme for energy conservation and emissions reduction
Improvement of energy utilization efficiency	5	Mandatory elimination of high energy-consuming backward equipment and renovation
		Formulated a clear energy-saving enforcement target and heat-measurement retrofit goals to support all aspects of energy conservation
		Formulated a definitive constraint on energy consumption reduction
		Implemented energy regulation from legislative, price and cost aspects; strengthen the management of power consumption
	3	Formulated a plan for implementing the elimination of backward production capacity and upgrading
		Established fiscal, taxation, and financial support options or price-based cost incentives to support energy conservation
		Formulated an energy-saving product promotion program
		Established guidelines for energy consumption limits
	2	Only involved the above clauses, but relevant measures have not been introduced
	1	No measures or policies to improve energy efficiency

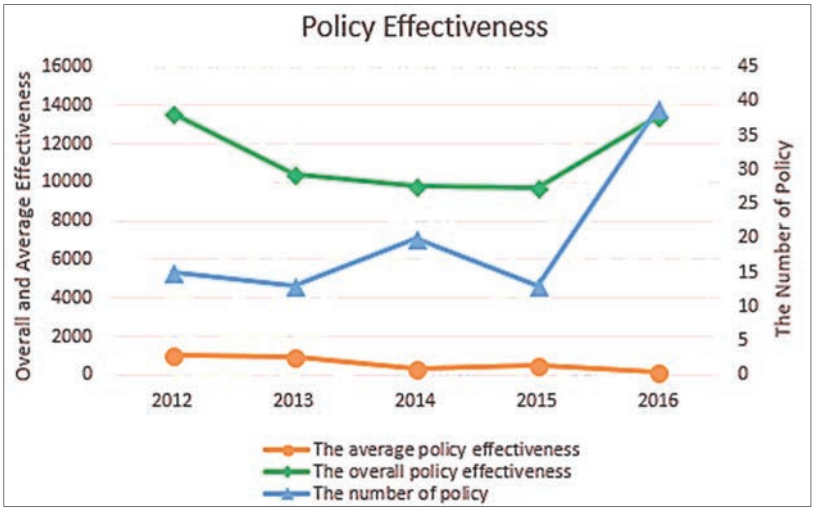

Fig. 2. The analysis of the evolution of the policy quantity, overall policy effectiveness and average policy effectiveness

In order to understand the underlying reasons for the increase in the overall effectiveness of Hubei's policies, this article decomposes the factors that affect the effectiveness of the average policy and draws the evolution path of the average policy intensity score, average policy measure score, and average policy target score over time (Fig. 3). It can be clearly seen that although the average policy measure score and average policy target score fluctuate from year to year, the trend of change is consistent. The fluctuation of the average policy intensity score is also in line with the beginning and end of the 12th Five-Year Plan.

The change in the overall effectiveness of policies is mainly determined by the amount of policy changes, and there is a certain positive correlation, that is, the increase in the overall effectiveness depends on the increasing number of policies instead of theirlegal effects. This dependence on policy number also leads

to a continuous decline in policy measure scores, target scores and average dynamic scores from 2012 to 2016. The excessive reduction in the effectiveness of polices is not only detrimental to the formulation and implementation of systematic and strategic policies, but also makes polices plans more complicated and ineffective. Therefore, the government should strengthen these policies to make them moderate.

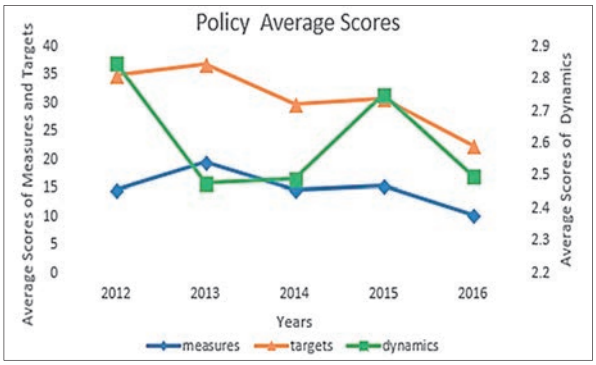

Fig. 3. The analysis of the evolution of the average score of policy intensity, policy measures and policy targets

3.2. Analysis of the synergy evolution of policy measures

For the issue of policy synergy, Huang et al. (2004) believed that the policy itself needs to be consistent. Wang and Wei (2007) emphasized that different policies should be organically coordinated. Steil et al. (2002) and Peng et al. (2008) confirmed the contribution of policy synergy to economic performance, and believed that policy coordination mainly includes sector synergy, measure synergy and goal synergy. Because the research on policy synergy is helpful to analyze the principle of policy formulation and reveal the game relationship behind the policy, this paper will explore the synergy of measures and targets in Hubei province.

As shown in Fig. 4, there is a strong synergy in different measures. The changes in the synergy of policy measures over the past five years have the following characteristics. First, the policy has been transformed into a synergistic action of multiple measures. In 2012, the policy measures synergy was relatively dispersed, and then became concentrated, because multiple policy measures have been given equal weight since that time. Second, the synergy between financial measures and administrative measures was gradually gaining attention. In Hubei province, where the economic growth is regarded as the main development theme, too many administrative measures are required to affect the energy consumption of enterprises to reduce emissions, and this requirement may hinder its economic development and the people's prosperity. However, the scope and intensity of guidance measures and fiscal measures are limited, so the government should seize the financial measures, which have not received sufficient attention. Similarly, other economic measures should further assist the government in planning and increase the scope and depth of policies.

Fig. 5 shows that financial measures, and other economic measures, fiscal and tax measures and personnel measures also exhibit certain synergy relationship with guidance measures. Among them, guidance measures and other measures are increasingly closer in synergy. The synergy between financial measures and guidance measures indicates that government departments begin to reduce administrative measures by taking advantage of economic leverage and the market mechanism to achieve energy conservation. The synergy between personnel measures and guidance measures demonstrates that our government attaches importance to the guidance system and personnel training.

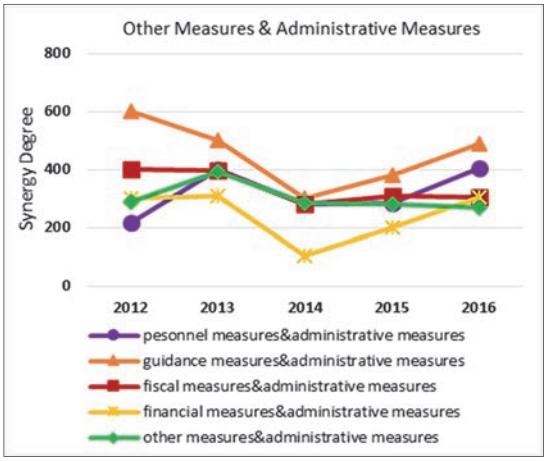

Fig. 4. The analysis of the evolution in the synergy between administrative measures and other measures

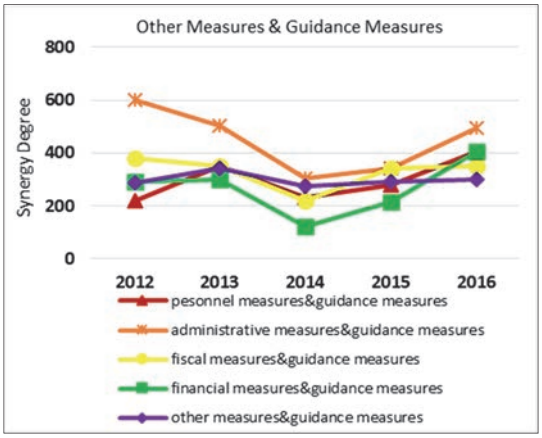

Fig. 5. Analysis of the evolution in the synergy between guidance measures and other measures

3.3. Analysis of the synergy evolution of policy targets

Reducing energy consumption and pollutant emissions is the main aim of energy conservation and emissions reduction policies. Fig. 6 focuses on the synergy between other policy targets and the improvement of energy utilization efficiency. With the improvement of the efficiency, most of the targets have a high degree of synergy. It is concluded that the

implementation should focus on changing the pattern of economic growth.

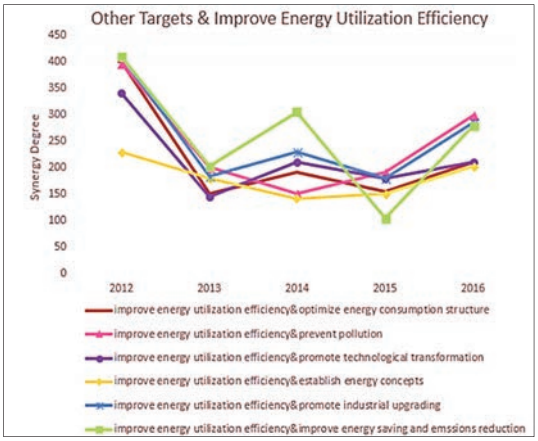

Fig. 6. Analysis of the evolution in the synergy between the improvement of energy utilization efficiency and other targets

Fig. 7 shows that there is a good synergy between pollution control and other policy targets. The synergy between pollution prevention and energy conservation and emissions reduction remains high, which indicates that the effect of these polices is equal to pollution prevention. In fact, people are an integral part of police implementation. If the government wants to implement effective policies, it must raise people's awareness.

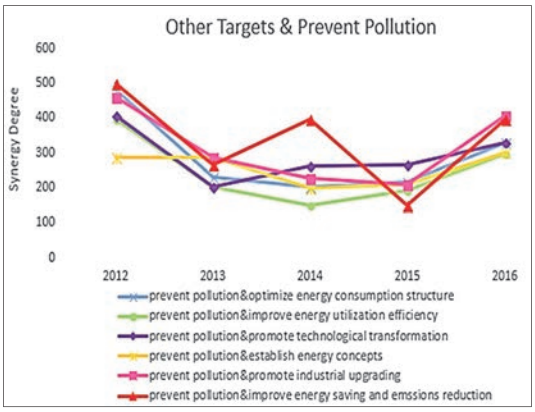

Fig. 7. The analysis of the evolution in the synergy between pollution prevention and other targets

However, our government pays little attention to this aspect and does not take advantage of the initiative of the masses. Due to the serious pollution phenomenon, Hubei province has given priority to the coal-dominated energy consumption structure. The follow-up policies should also emphasize optimizing the structure of energy consumption and the synergy of policy targets.

4. Conclusions

This paper collects energy conservation and emissions reduction policies in Hubei province from 2012 to 2016 and then score the policies based on quantitative standards. According to the quantitative data, we analyze the synergy evolution of these policies. The main conclusions are as follows:

First, the government of Hubei province is paying increasing attention to energy conservation and emissions reduction. The overall effectiveness of these policies increased between 2012 and 2016, but their average effectiveness decreased, which demonstrates that there are some defects in policy formulation: The new policies lack of systematic and strategic. It shows that the formulation of these policies focuses on short-term goals rather than long-term planning and fails to include the concept of sustainable development.

Second, in the coordination of policy objectives, there is a high correlation among optimizing the structure of energy consumption, establishing the concept, controlling pollution, promoting industrial upgrading, improving the effectiveness, promoting the transformation of technology and improving the efficiency of energy utilization. This finding indicates that the government has a clear goal, a good energy-saving industry layout and diversified energy conservation industry development.

Third, from the overall perspective, the score that economic leverage guides members of society to actively participate in this movement is not high, which indicates that Hubei province's capital investment is not enough. In addition, in the scoring of e policies, personnel measures' scores are low. This finding shows that government does not attach importance to the achievement of targets in the assessment of leading cadres, which helps to play their value-oriented role. In the policy review, it is found that there is a lack of energy conservation and environmental protection supervision, law enforcement and monitoring platform establishment for key pollution sources.

Fourth, in policy scoring, the industrial structure adjustment project, new technology promotion project, and circular economy demonstration project are mentioned in most of the policies, which shows that the Hubei provincial government has fundamentally reduced pollutant emissions, solved the source of energy consumption and emission problems, and better achieved a set of goals.

Finally, we make certain suggestions. First, strengthen the cooperative operation mechanism between the main departments in Hubei province. Second, strengthen the intensity of policy formulation and take effective measures to enrich the contents of the management system. Third, strengthen the coordination and combination of different policy measures.

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