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Supporting System for Building Energy Efficiency Promotion in Shaanxi

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Abstract:

The construction of targeted and effective energy efficiency support system is an important technical measure to ensure the implementation of the building energy efficiency road map. Based on the climate conditions, technology and the economic status in Shaanxi Province, through data collection, questionnaire survey, expert discussion and so on, supporting system for building energy efficiency promotion in Shaanxi is constructed and optimized. The research shows that the support system of energy efficiency in Shaanxi Province should be composed of policy system, technology, economy, ability and market; with the mean ≥ 3, the full frequency of ≥ 20%, the coefficient of variation ≤ 0.2 as the criterion, recent optimal indicators and long-term optimal indexes are determined, and Shaanxi Province and other provinces are quite different in technology and market support system.

Keywords: *Building energy efficiency, Support system, Policy system, Market system.*

I. INTRODUCTION

The rapid growth of total construction volume and building energy consumption has brought great pressure to resources and environment in China. Hence, it is imperative to further promote the improvement of building energy efficiency, which is also a strategic measure of sustainable development. Relevant researches having been made by all parts of the country according to their own features [1-3]. Wu Yong of China Building Energy Conservation Association, Li Yinan of Tianjin University and Xu Kexi of Chongqing University have carried out research work on this issue. By means of data statistics and expert questionnaires, the gradient and time node of building energy efficiency improvement and the supporting system of building energy efficiency improvement have been put forward nationwide [4,5].

On the basis of determining the gradient and time node of building energy efficiency improvement in Shaanxi, taking full account of the current situation of Shaanxi, a research on support system of building energy efficiency improvement suitable for the development of Shaanxi was carried out in this paper through a large number of field surveys and questionnaires, which provides scientific support for policy formulation, scientific research

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investment and market guidance in the next step, and is a strong guarantee for the successful realization of the goal of building energy efficiency promotion in Shaanxi.

II. RESEARCH SCHEME OF SUPPORTING SYSTEM FOR ENERGY EFFICIENCY PROMOTION

2.1 Indicator Construction of the Supporting System

During the construction of indicators for the initial supporting system, a lot of research work has been carried out, the existing policies, systems, measures and methods to promote building energy efficiency at home and abroad have been collected, the relevant parties, such as government departments at different levels, planning and design institutions, construction and material production enterprises, scientific research units, consulting institutions and universities, have been interviewed, and their opinions and suggestions have been fully listened to. The implementation status and effectiveness of the existing policies and measures in Shaanxi have been understood, and the first-hand information has been obtained. On this basis, a questionnaire on the support system of building energy efficiency improvement in Shaanxi was preliminarily constructed. All the indicators of the questionnaire were divided into five categories: policy indicator system, technical indicator system, economic indicator system, capacity indicator system and market indicator system (see Fig 1). In the questionnaire process, experts further improved these indicators system, and scored the rationality and effectiveness, and ultimately selected the indicators system suitable for the climate conditions and development conditions of Shaanxi.

2.2 Questionnaire Method-Delphi Method

Delphi method is based on the system procedure, using the way of anonymous opinions (experts cannot discuss with each other, do not have horizontal contact, only have relations with investigators). Through multiple rounds of investigation, experts' opinions on the questions in the questionnaire are repeatedly consulted, summarized and revised. Finally, experts' basically consistent views are summarized as the result of prediction. Because of the anonymity or back-to-back method, each expert can make his own judgment independently, and will not be affected by other complicated factors. It is precisely because of the above characteristics of Delphi method that it stands out among many means of judgment, prediction and decision-making.

The main body of this questionnaire is all stakeholders of building energy conservation in Shaanxi, including government departments, design institutes and scientific research institutes, universities, industry associations and other relevant institutions (see Fig 2). A total of 105 questionnaires were sent out, and 75 valid questionnaires were collected, with a questionnaire recovery rate of 71.4%. The samples are representative. The participants in the questionnaire are reasonably distributed, covering experts in building energy conservation from 8 different fields. Among them, architecture and HVAC specialists account for a large proportion (see Fig 3). The number of experts with intermediate or higher titles accounts for 77% of the total number of participants, and the number of experts with more than 5 years' experience accounts

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for 80%. From the distribution of experts, the results of this survey can be a more comprehensive summary of the views of various fields and stakeholders, which is conducive to the formulation of a practical building energy efficiency support system.

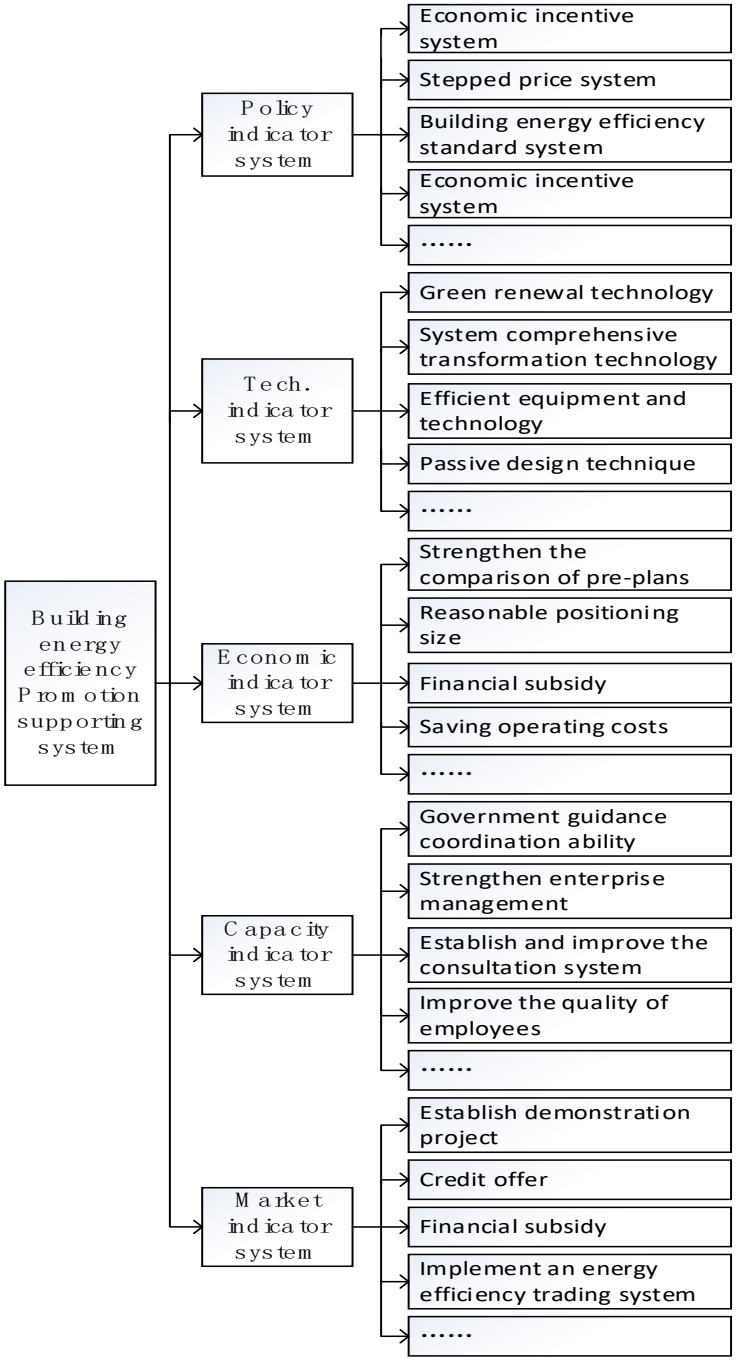

Fig 1: building energy efficiency Promotion supporting system

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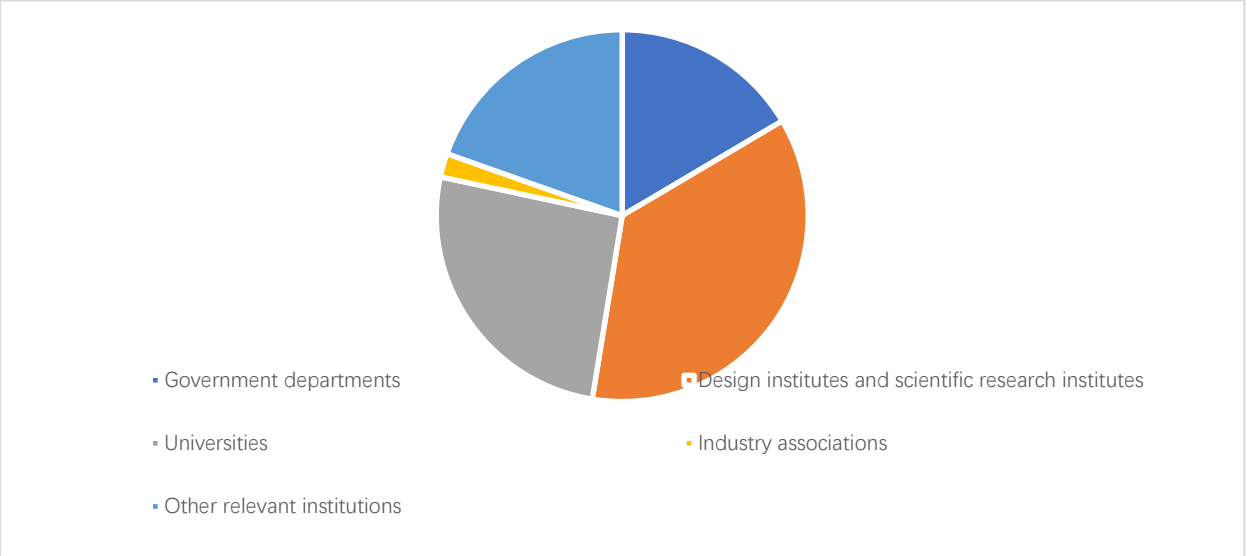

Fig 2: institutional distribution

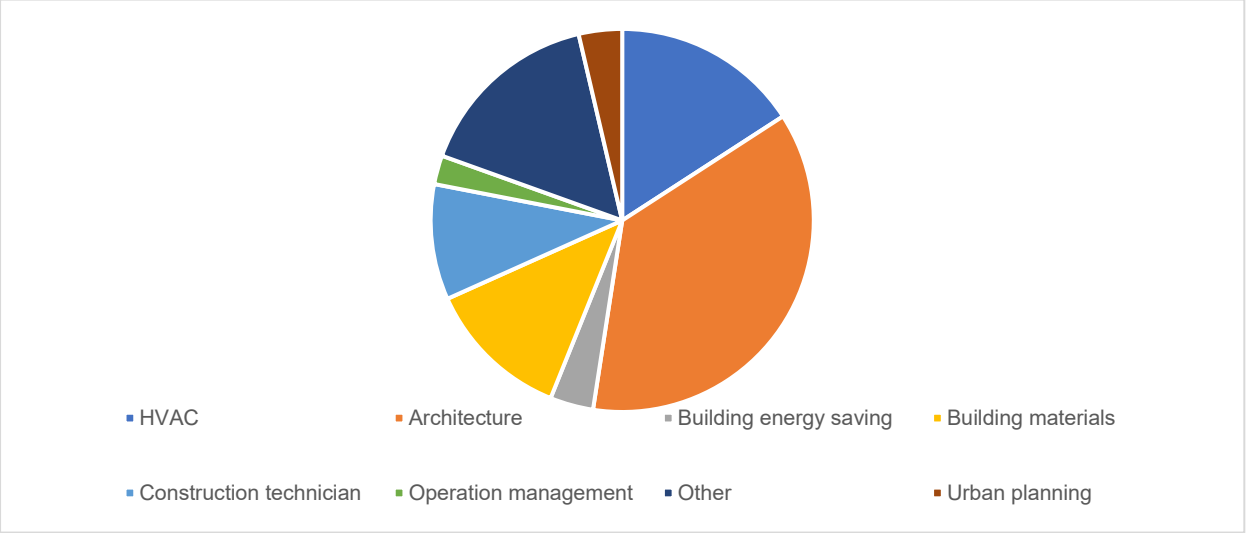

Fig 3: occupational distribution

2.3 Selection Method of Indicators

Experts carry out feasibility judgment and effectiveness evaluation on each specific indicator, dividing the effectiveness evaluation into 5 levels (1-completely ineffective, 2-less effective, 3-generally effective, 4-more effective, 5-very effective). The average value of each indicator was compared and analyzed by the research group. The higher the average score is, the higher the recognition degree of experts to this indicator is, the stronger the role of building energy efficiency improvement is. It is considered that the indicator with average score less than 3 has a general effect on building energy efficiency improvement, so it will not be discussed directly. In order to prevent data anomalies, the full score frequency and coefficient of variation are also considered. Full score frequency refers to the ratio of the number of experts who give

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full score (5 points) to the total number of experts who evaluate the scheme. The coefficient of variation is an indicator to indicate the degree of data dispersion: the smaller the value, the higher the degree of coordination of expert opinions and the better the convergence. The formula is as follows:

$$\sigma_j = \sqrt{\frac{1}{m_j}\sum_{i=1}^{m_j}(C_{ij} - M_j)^2} \quad (1)$$

$$V_j = \frac{\sigma_j}{M_j} \quad (2)$$

In which σ_j means Standard deviation for all experts on the evaluation of the j program;

m_j means Number of experts who evaluated the j program;

C_{ij} means The score of the expert i who evaluated the j program;

V_j means The coefficient of variation of the j program;

M_j means The arithmetic mean for all evaluations of the j(j=1, 2,...,n) program;

The selection of indicators is carried out according to statistical criteria (full score frequency > 20%, coefficient of variation < 0.2) [6]. Only when both criteria are not met, can the indicators be regarded as an objectionable indicator, and then the expert demonstration is carried out again.

III. INDICATOR ANALYSIS OF SUPPORTING SYSTEM FOR BUILDING ENERGY EFFICIENCY PROMOTION

3.1 Constructing Policies and Systems

To classify policies and systems into one category is not a specific measure, method or norm, but a general term of measures or methods of the same category because they have certain macro-nature. In such a system, the initial indicators of the questionnaire were set at 20. From the survey results, the average and full score frequency of the long-term scores of these indicators are generally higher than the recent scores, and the full score concentration of the long-term expert scores is also higher than the recent ones. It is thus clear that experts hold a conservative attitude towards the short-term effect of macro-policy measures, but are optimistic about the long-term effect, because it takes a long time for macro-policy to be transformed into concrete practical operation methods, so the long-term effect is better than that in the short term. 5 indicators with the best short-term effect and 5 indicators with the best long-term effect were selected, as shown in TABLE I.

Recent scores show that the top two items are related to economy, indicating that the best measure to improve building energy efficiency in Shaanxi in the short term is economic incentive, which is in line with the status quo of Shaanxi. At present, the most powerful policies in Shaanxi are economic incentive policies, such as financial subsidies, volume rate incentives, credit support and so on. The other three are: 1) the system of building energy conservation promotion, restriction and prohibition; 2) the standard system of civil building energy conservation; 3) the system of building energy measurement by item.

The long-term indicator with the highest score is the application and promotion system of renewable energy construction, which indicates that experts believe that the ultimate solution to

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the problem of building energy efficiency improvement is from the supply side, and the application and promotion of renewable energy is expected to solve the energy supply pressure and carbon emissions problems faced in the process of energy efficiency improvement. The standard system of building energy efficiency has a good score both in the short term and in the long term. Therefore, Shaanxi should speed up the formulation of the standard system of civil building energy efficiency suitable for the development of the province, in order to promote the development of building energy efficiency. In addition, although the medium and long-term building energy efficiency improvement plan and policy system have not been in the top five in recent years, they have got relatively high scores in the long term, which indicates that in order to achieve the goal of building energy efficiency improvement smoothly, the medium and long-term upgrading plan and corresponding policy support system should be formulated.

TABLE I. Scores and ranking of policy and institution system indicators

SHORT-TERM OPTIMAL INDEX	SCORES	RANKING	LONG-TERM OPTIMAL INDEX	SCORES	RANKING
Economic Incentive System for Building energy efficiency	3.62	1	Application and Promotion System of Renewable Energy Buildings	4.20	1
Implementing Stepped Energy and Resource Prices	3.60	2	Standard System for Energy Efficiency of Buildings	4.18	2
System of Promotion, Restriction and Prohibition of Building Energy Efficiency	3.45	3	System of Promotion, Restriction and Prohibition of Building Energy Efficiency	4.16	3
Standard System for Building Energy Efficiency	3.44	4	Economic Incentive System for Building Energy Efficiency	4.16	4
Sub-item Measurement System of Building Energy	3.42	5	Medium and Long Term Building Energy Efficiency Promotion Plan and Policy System promulgated by the Government	4.15	5

3.2 Constructing a Technical Support System

Technical support system is mainly related to building energy efficiency improvement technology. In the questionnaire, a total of 21 key technologies or technology development trends were listed. Through the analysis of the results obtained by questionnaire and expert discussion, it is found that the long-term effect of technical support system indicators is better than that of the short term, and the average short-term and long-term scores of all indicators are

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greater than 3. It is thus evident that the establishment of technical system has a strong effect on building energy efficiency improvement. Five indicators were selected for illustration in the short term and in the long term, respectively, as shown in TABLE II.

TABLE II. Scores and ranking of technical support system indicators

SHORT-TERM OPTIMAL INDEX	SCORES	RANKING	LONG-TERM OPTIMAL INDEX	SCORES	RANKING
Change from Energy Efficiency Reform to Green Renewal [7,8]	3.67	1	Establishing Engineering Technology Center to Promote Technology Research and Development and Application	4.34	1
Change from Single Technical Reform to Systematic Comprehensive Reform	3.52	2	Effective equipment and technology should be selected	4.33	2
Establishing Engineering Technology Center to Promote Technology Research and Development and Application	3.51	3	Transforming technology to passive mode	4.30	3
Effective equipment and technology should be selected	3.50	4	Strengthening the Design and Reform of Enclosure Structure	4.30	4
Transforming technology to passive mode	3.38	5	Encourage energy-efficient leaders who provide holistic solutions	4.28	5

The indicator with the highest score in the short term is the transformation from energy-saving transformation to green renewal, which shows that the best way to improve building energy efficiency in Shaanxi in the short term is to strengthen the green transformation of existing buildings. In Shaanxi, building energy efficiency improvement is not only for new buildings, but also for existing buildings, which play a key role in overall energy efficiency improvement. No statistical data of Shaanxi have been found. The national energy-saving design standards for buildings have been strictly implemented in 2004, and the energy-saving renovation of non-energy-saving buildings in northern heating areas has been promoted in 2007. According to the statistical results, from 1981 to 2004, there was a strong positive correlation between the growth rate of urban central heating area and the total amount of central heating, but since 2004, the growth rate of total energy consumption of central heating was significantly

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slower than that of central heating area [1,9,10], which shows that energy-saving renovation of buildings has a very obvious effect on building energy-saving, and strengthening the energy-saving renovation of existing buildings should be continued.

The indicator with the highest long-term score is to establish engineering technology center to promote technology research and development. Experts believe that energy efficiency improvement ultimately falls to technology, and more investment should be made in technology. The research group has done a lot of simulation work on energy consumption of heating and air-conditioning in different climate conditions and different types of buildings in Shaanxi. It is found that under the existing technology, the marginal benefit of heating and air-conditioning is getting lower and lower by thickening the wall insulation layer and improving the performance of windows. It is not economical to reduce energy consumption by these two ways at this stage unless a new type of thermal insulation material or a new type of thermal insulation material appears, or fresh air and total heat exchange systems, or new passive architectural design methods are introduced, all of which require technological research and development and accumulation.

There are three indicators that appear in both the short-term and the long-term optimal indicators, namely: to establish engineering technology centers to promote technology research and development; to select efficient equipment and technology; to transform technology into passive-oriented, active-assisted. These three indicators show not only the importance but also the direction of technological research and development, that is, the architectural design should be developed in the passive direction and the equipment should be developed in the direction of low energy consumption and high efficiency.

3.3 Constructing an Economic Support System

TABLE III. Scores and ranking of economic support system indicators

SHORT-TERM OPTIMAL INDEX	SCORES	RANKING	LONG-TERM OPTIMAL INDEX	SCORES	RANKING
Strengthen the comparison of pre-plans	3.76	1	Reasonable positioning size	4.38	1
Reasonable positioning size	3.6	2	Strengthen the comparison of pre-plans	4.36	2
Financial subsidy	3.58	3	Increased social and environmental benefits	4.27	3
Saving operating costs	3.48	4	Saving operating costs	4.27	4
Increased social and environmental benefits	3.38	5	With the development of economy, the incremental cost is reduced.	4.20	5

The economic support system is mainly related to economic indicators, and 12 specific indicators were set in the questionnaire. According to the scores of the questionnaire and the

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results of expert demonstration, five indicators were selected in the short term and in the long term (see TABLE III).

Comparisons show that the short-term and long-term indicators have a high degree of consistency. Although the order of the 5 indicators is different, but there are four indicators are the same, and the coefficient of variation of the four indicators are all below 0.2, and the full score frequency is more than 20%, indicating that experts have a very high recognition of the four indicators. When constructing the supporting system of building energy efficiency promotion in Shaanxi, the role of these four indicators in improving energy efficiency should be fully considered: design optimization, reasonable scale, operation cost saving and social and environmental benefits.

The indicator of financial subsidy only appears in the optimal indicator in the short term, which shows that experts believe that financial subsidy can only be used as a short-term means, and the long-term effect is not obvious.

3.4 Constructing a Capacity Support System

TABLE IV. Scores and ranking of ability to support the system indicators

SHORT-TERM OPTIMAL INDEX	SCORES	RANKING	LONG-TERM OPTIMAL INDEX	SCORES	RANKING
Sub-metering technology, Intelligent Operation, service level monitoring and other technical measures will be incorporated into the energy efficiency design standards of public buildings.	3.59	1	Blacklist should be set up for those responsible for serious violations of laws and regulations	4.34	1
Strengthen debugging ， acceptance and supervision	3.56	2	Establishing a perfect consultation system	4.28	2
Blacklist should be set up for those responsible for serious violations of laws and regulations	3.56	3	Establishing Innovation Awards to Encourage Green Innovation	4.28	3
Establishing a perfect consultation system	3.54	4	Improving the Quality of Professional Operators	4.27	4
Establishing Innovation Awards to Encourage Green Innovation	3.47	5	Improving the Comprehensive Quality of the Staff on the Job	4.26	5

Capacity support system is mainly the capacity indicators of the main bodies related to

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building energy efficiency. More than 40 specific indicators were set in the questionnaire. Through questionnaires, 5 indicators were selected for short-term and long-term, respectively, as shown in Table IV.

The table shows that the indicator with the highest score in the short term is to incorporate technical measures such as sub-item measurement, intelligent operation and service level monitoring of new public buildings into the energy-saving design standards of public buildings, indicating that experts are very confident about the performance of this technology in energy saving and should be strongly promoted. However, this is a comprehensive implementation capability, which can be achieved not only by the government's mandatory incorporation into energy-saving design standards of public buildings, but also by specific technical support and professional staffing. Therefore, to truly incorporate these technologies into energy-saving design standards, mature technical conditions, the promotion and cooperation of transport and management personnel and the vigorous promotion of the government are needed. The second and third of the optimal indicators in the short term are to strengthen government management, and to strengthen the attention of relevant subjects to the improvement of building energy efficiency. The fourth is to establish a sound consulting system, so that the builders and operators fully consider the building energy efficiency at the beginning of the design. It is worth mentioning that the indicators ranked third, fourth and fifth in the short term are reflected in the optimal indicators in the long term, which shows that these three abilities have good effects in the short and long term, and should be paid attention to.

In the long-term optimal indicators, there are two related to the quality of personnel, namely, improving the quality of professional operators and improving the overall quality of employees. The government should also strengthen the capacity-building in practical policy-making, because the implementation of any new technology and standards cannot be separated from the on-the-job personnel. Only when the on-the-job personnel fully recognize and understand, can the measures be truly implemented.

3.5 Constructing a Market Support System

Specific indicators of the market support system are mainly related to measures and methods to standardize and promote market development. 16 indicators were set in the initial questionnaire. 5 indicators with the highest short-term and long-term scores were selected through questionnaire and expert demonstration, respectively, as shown in Table V.

It is clearly observed from the table that the first three of the optimal indicators in the short term are related to the economy, giving economic stimulus to activate the market and accelerate the improvement of building energy efficiency, which from the side proves that the policies of financial subsidies, tax preferences and credit support implemented by most provinces and municipalities in Shaanxi and even in the whole country are very effective. The research group found that if government departments increase financial subsidies, building energy efficiency will be implemented well, such as energy-saving renovation of existing buildings and promotion and application of high-star green construction. The fourth indicator in the short term is to give building owners and users a direct feeling of green and low-carbon life through

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demonstration projects, which has been implemented by the state, and the recognition can be found from the various demonstration zones and demonstration buildings built throughout China. The fifth indicator in the short term is that the competent departments of different types of construction industry carry out the management of the same kind of buildings and publicize the results. Experts believe that it is very useful to highlight the advantages of high-energy-efficient buildings through the benchmarking management of the same kind of buildings, and let the building owners carry out their own energy efficiency upgrading and transformation. Now it has not been done enough in Shaanxi in this regard.

TABLE V. Scores and ranking of market support system indicators

SHORT-TERM OPTIMAL INDEX	SCORES	RANKING	LONG-TERM OPTIMAL INDEX	SCORES	RANKING
Local governments give preferential policies to energy-efficient buildings	3.53	1	Direct Experience of Green Low Carbon Life for Building Owners and Users through Demonstration Project	4.22	1
Providing loan discounts and guarantees for contract energy management	3.53	2	Providing loan discounts and guarantees for contract energy management	4.22	2
Incentive Policies for Energy Efficiency Promotion	3.52	3	Incentive Policies for Energy Efficiency Promotion	4.20	3
Direct Experience of Green Low Carbon Life for Building Owners and Users through Demonstration Project	3.50	4	Local governments give preferential policies to energy-efficient buildings	4.20	4
The competent departments of different types of construction industry carry out the management of the same kind of buildings by "benchmarking" and publicize the results	3.44	5	Implement building energy efficiency trading system (e.g. carbon emissions trading system)	4.17	5

Among the long-term optimal indicators, the first is to give building owners and users a direct feeling of green low-carbon life through demonstration projects, which shows that experts believe that attention should be paid to the main body of the market, letting them feel the advantages of green low-carbon life, and consciously improving the building energy efficiency is the key. The second, third and fourth are incentive policies, which show that in the long term, even if building owners fully recognize the advantages of energy-efficient buildings, they also need some incentive means, because energy-efficient buildings have certain positive externalities. Sometimes, it does not necessarily bring real benefits to building owners at present, but also requires government subsidies. The fifth is the implementation of building

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energy efficiency trading system, such as carbon emissions trading system which has been tried out in some provinces and cities in southern China with good effect, which shows the recognition of experts. The carbon emission trading system suitable for the development of the province should also be put forward in Shaanxi.

IV. A COMPARATIVE ANALYSIS WITH OTHER REGIONS

Dr. Xu Zhenqiang of Digital Urban Engineering Research Center of China Urban Science Research Association, has conducted a comprehensive study on the green building policies of 25 provinces and municipalities in China. Different provinces and municipalities have adopted different policies to improve building energy efficiency. Even if the same policy is adopted, its implementation degree is different, which shows that provinces should take measures according to local conditions when they construct their supporting system for building energy efficiency improvement [11].

The construction of building energy efficiency promotion support system in Shaanxi should be different from other areas, mainly because of the different starting points of building energy efficiency, different climate and different economic conditions. Among the indicators of market support system, those with higher scores in Shaanxi are mainly preferential policies and economic incentives for market participants, while those in terms of consumption guidance have lower scores. Experts believe that the effect of consumption guidance on building energy efficiency improvement in Shaanxi is poor, but it may play a good role in more developed areas with relatively high housing prices and a small proportion of incremental costs where residents are insensitive to this part of the price, have a higher pursuit of quality of life, but also pay more attention to the ecological environment. In the technical support system, the indicator of strengthening the design and renovation of the envelope structure has a low score. Through simulation analysis, it is found that in order to achieve the short-term energy efficiency gradient in Shaanxi, it is only necessary to increase the thickness of insulation layer in many areas. In cold regions like Northeast China, the insulation layer is already very thick. With the increase of insulation layer thickness, its marginal benefit is declining. Thickening insulation layer has lost more than it deserves, which requires a new type of envelope structure design. Consequently, this kind of indicator will not be optimized in these provinces.

V. CONCLUSIONS

Supporting system for building energy efficiency improvement is a powerful guarantee to achieve the goal of building energy efficiency promotion smoothly, which should be built according to local conditions. Based on the current situation of climate, economy, technology and market development in Shaanxi, the following suggestions for supporting system for building energy efficiency improvement in Shaanxi were put forward in this paper:

1) The supporting system for building energy efficiency improvement in Shaanxi should be composed of five secondary indicators: policy system, technical support system, economic support system, capacity support system and market support system.

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2) Each secondary indicators of the supporting system for building energy efficiency improvement in Shaanxi Province includes several third-level indicators. Through questionnaires and expert discussions, the three-level indicators of short-term and long-term optimum are obtained. The short-term optimum includes: establishing economic incentive system for building energy efficiency; transforming existing building energy efficiency into green renewal; fully selecting schemes in the early stage; incorporating technical measures such as sub-item measurement, intelligent operation, service level monitoring into energy efficiency design standards of public buildings; and giving preferential policies to energy efficient buildings by local governments. The long-term optimum includes: establishing the extension system of renewable energy construction application; considering various factors comprehensively, reasonably locating the scale; establishing blacklist for the main body responsible for serious violations of laws and regulations; giving the building owners and users a direct feeling of green low-carbon life through demonstration projects.

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