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Comparative analysis on Bairin left banner rural residence transformation scheme

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ABSTRACT

This paper compares and optimizes the effect of rural residence energy saving transformation by means of several important indexes on the basis of analyzing the relation of various transformation measures and amount of energy saving and indoor temperature through the field survey to Inner Mongolia Bairin Left Banner rural residence energy saving transformation. The efficient energy saving transformation schemes are obtained according to the results of comparison and optimization.

Key words: Rural residence, energy saving transformation, scheme comparison

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INTRODUCTION

China has put forward a strategic decision of constructing resource-saving society after the deep research on domestic and overseas political economy and social development history. '12th Five-Year Plan' clearly presents that we should implement the target of "the transformation area of existing residence architecture of northern area with heating provision increases to 0.58 billion m2 from 0.18 billion m2 within 2010-2015"proposed by 12th Five-Year Plan for Energy Saving and Emission Reduction No. 40 Document in 2012 of the State Council. [1] [2]With the popularization of building energy saving transformation, different regions carry out rural residence energy saving transformation according to the characteristics of natural and architecture of respective region by use of the combination of various transformation items. Such transformation in which some differencesexist is known as transformation scheme. With different schemes of Inner MongoliaBairin Left Banner rural residence transformation as the example, this paper carries out some field surveysto understand the rural residence transformation and energy saving efficiency, analyzes and compares by means of two important indexes which affect the efficiency of rural residence energy saving transformation (i.e. saved energy consumption and increased winter indoor temperature), and selects the optimal transformation scheme of rural residence and proposes the improvement advice to the found problems.

CURRENT STATUS OF RURAL RESIDENCE ENERGY SAVING TRANSFORMATION OF NORTHERN AREA

The climate in our northern area is monsoon climate of medium latitudes, with high temperature in summer, cold and dry and with the average temperature less than 0 in winter. The northern rural residences mainly adopt concrete wall, adobe wall and brick wall, and these walls are relatively thick to withstand the cold winter wind. The windows are mainly exposed to the sun with single side to reduce the loss of indoor heat and increase the intake area of sunshine to improve the indoor temperature with the sunshine. Ondols, heating walls, hot wall, pit furnace, and other heating facilities are built[3].

At present, the outer wall, windows and doors of the rural residence are generally transformed in northern area. The outer wall insulation mainly adopts outer polystyrene board to preserve the heat, which is economic and reasonable with a good effect of heat preservation. There are several aspects for energy saving of doors and windows as follows: 1)window frame adopts the material with low heat conductivity; 2) change the glass to improve the heat resistance of glass; 3) adopt the sealing rubber strip with good performance, which can improve the gas tightness [4]. However, some problems exist in the current rural residence, such as the lack of effective policy incentive system and potent punishment system in construction supervision and acceptance, as well as that the awareness about energy saving is weak, etc. For a long time, China is short of effective incentive policy guidance and construction of energy-saving green architecture. For the saving of energy sources, lands, water resources and materials, the actual laws and regulations in China also lack of specific method for rewards and punishment to force each stakeholder to participate in as required.Although Energy Saving Management Regulation for Civil Architecture and the design standard of 50% energy saving for three climate areas preliminarily form a perfect standard system for civil architecture energy saving, the comprehensive standard system for building energy saving, land saving, water saving, material saving and environment protection remains to be further established. Although China has built a relatively complete energy saving design specification, some problems such as poor construction quality and disqualified construction acceptance still exist. The building energy saving design of certain unit is only performed at the stage of approval to just deal with the approval authority to save the cost, which is not implemented completely. For this, a strong regulation and punishment system is also required. In the aspect of public consciousness, the public lacks of consciousness for energy-saving architecture, and the requirement for energy-saving architecture is not strong. With market and customer as the orientation, correspondingly the development of energy-saving architecture also lacks of enthusiasm in the operation. This is also an important reason of restricting the advance of China building energy saving. Thejoint effort of public, media, professional organization and all aspects of society is required to improve the public consciousness for energy saving.

COMPARISON OF BAIRIN LEFT BANNER RURAL RESIDENCE ENERGY SAVING TRANSFORMATION SCHEMES

Basic State of Bairin Left Banner

Located at the southeast foot of Great Khingan mountains south section, north of Chifeng, Inner Mongolia, Bairin Left Banner has 126km from south to north and 70km from east to west, with a total area of 6458.86 km^2. By the end of 2008, the whole area governs 5 towns, 3 sumus, 15 townships, with a population of 355,600. Bairin Left Banner has a temperate continental monsoon climate. The four seasons are distinct, windy and dry with large temperature difference in spring, rainy with high temperature in summer, early frost with strong wind in autumn, severe cold with most north winds in winter.

Under the guidance of expert, Bairin Left Banner project adopts relevant building energy saving technology and uses building energy saving materials produced in Bairin Left Banner to transform the existing rural residences for the energy saving. Through energy saving transformation, this project increases the indoor temperature and comfort level, and reduces the energy consumption and pollution.

Selection of Energy Saving Transformation Schemes

In 2012, we carried out a questionnaire survey to 169 transformed rural residences of 3 villages of Bairin Left Banner. The items of rural residence transformation of Bairin Left Banner include doors and windows, outer wall, floor, suspended ceiling, heating facilities, suspended ondol, inner wall, cooking utensils. In general, based on the difference of number of transformation items, the transformation schemes can be classified into two-item transformation, three-item transformation, four-item transformation and five-item transformation.

Generally speaking, two-item transformation mainly focuses on doors and windows + floor, doors and windows + suspended ceiling, suspended ceiling + floor, doors and windows + outer wall insulation; three-item transformation mainly focuses on doors and windows + suspended ceiling + floor, doors and windows + suspended ceiling + cooking utensils, doors and windows + suspended ceiling + outer wall insulation; four-item transformation mainly focuses on doors and windows + suspended ceiling + floor + heating facilities, doors and windows + suspended ceiling + floor + cooking utensils, doors and windows + suspended ceiling + outer wall insulation + cooking utensils; five-item transformation mainly focuses on doors and windows + suspended ceiling + floor + cooking utensils + heating facilities, doors and windows + suspended ceiling + outer wall insulation + floor + cooking utensils, as shown in Table 1.

Table 1 Combining Form

Combining Form			
Two-item transformation	Three- item transformation	Four-item transformation	Five-item transformation
Doors and windows + floor	Doors and windows + suspended ceiling + floor	Doors and windows + suspended ceiling + floor + heating facilities	Doors and windows + suspended ceiling + floor + cooking utensils + heating facilities
Doors and windows + suspended ceiling	Doors and windows + suspended ceiling + cooking utensils	Doors and window + suspended ceiling + floor + cooking utensils	Doors and windows + suspended ceiling + outer wall insulation + floor + cooking utensils
Ceiling + floor	Doors and windows + suspended ceiling + outer wall insulation	Doors and windows + suspended ceiling + outer wall insulation + cooking utensils	
Doors and windows + outer wall insulation			

SELECTED INDEX SOURCE AND EFFECT

Cost index

The cost for transformation is an important index by which we can measure whether each item of rural residence transformation is reasonable or not, therefore when comparing each transformation scheme of Bairin Left Banner, the cost is the basic quantification of measuring the amount of energy saving and temperature change.

In the items of rural residence transformation of Bairin Left Banner, different schemes are obtained on the basis of combination of 8 independent transformation items such as doors ad windows, outer wall, floor, suspended ceiling, heating facilities, suspended ondol, inner wall, cooking utensils, etc, according to actual condition. The cost for transformation of single item is as shown in the Table 2.

Table 2 Transformation Cost of Single Item

	Doors and windows	Outer wall	Floor	Suspended ceiling	Heating facilities	Suspended ondol	Inner wall	Cooking utensils
Cost (Yuan)	3672	13440	4197.6	4430.8	2000	1500	3927.6	1300

From Table 2 we can see that the highest cost for the outer wall transformation is 13440 Yuan, secondly the transformation costs of suspended ceiling and floor are respectively 4430.8 Yuan and 4197.6 Yuan; thirdly the transformation cost of inner wall, doors and windows, heating facilities and suspended ondol and cooking utensils is the least, with the amount of 1300 Yuan.

Because the standard for the two-item transformation, three-item transformation, four-item transformation and five-item transformation has been selected, the transformation cost of each scheme is as shown in the Table 3.

Table 3 Cost for Standard Transformation Scheme

	Two-item transformation	Three-item transformation	Four-item transformation	Five-item transformation
Scheme standard	Doors and windows + outer wall	Doors and windows + suspended ceiling + floor	Doors and windows + suspended ceiling + floor + heating facilities	Doors and windows + suspended ceiling + floor + cooking utensils + heating facilities
Cost (Yuan)	17112	12300.4	15600.4	16900.4

From Table 3 we can see that the lowest cost for three-item transformation (doors and windows + suspended ceiling + floor) is 12300.4 Yuan. Because the single cost for outer wall transformation is large, the cost for two-item transformation even exceeds the cost of five-item transformation. The cost price of 17112 Yuan is the most expensive transformation scheme.

Energy Index

The energy usage amount before and after transformation can be indicated visually. The amount of energy saving of a transformation scheme is one of the important indexes by which we measure whether the transformation scheme is

feasible. The survey statistics performed in Bairin Left Banner indicates that the present main energy source for daily use and heating in winter in this area is coal and electricity.

Temperature change index

The increase of indoor temperature in winter is the ultimate purpose of each rural residence transformation item of northern area. Therefore, before and after the transformation, the change of indoor temperature in winter is another important index of researching whether the transformation scheme is effective.

COMPARISON ANALYSIS ON THE COMBINATION OF TRANSFORMATION SCHEMES

This paper compares the energy saving transformation schemes by means of the efficiency of energy saving and indoor temperature increase. The efficiency of saving energy is analyzed from the cost of energy consumption and the money amount of energy saving after transformation. The temperature variation per unit cost is used to reflect the efficiency of indoor temperature increase [6] [7].

Efficiency of Energy Saving

Calculate and obtain the amount of energy saving corresponding to the transformation cost per unit through the statistic analysis on the cost for each transformation combination and the amount of energy saving after transformation, i.e. amount of energy saving per unit cost. The above relation can be expressed with the following mathematical formula:

C_g is used for expressing the money amount of energy consumption before transformation; C_g' is used for expressing the money amount of energy consumption after transformation,

$\therefore \Delta C_g = C_g - C_g'$.

C is used for expressing the transformation cost, thus the amount of energy saving per unit cost can be expressed as:

Amount of energy saving per unit $\cos t = \dfrac{\Delta Cg}{C}$ .The specific data is as shown below:

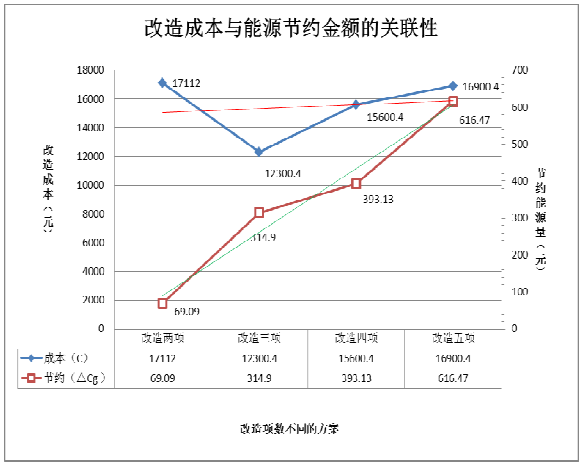

Fig. 1 Correlation between Transformation Cost and Money Amount of Energy Saving

From the trend curve in Fig.1 we can see that a direct ratio relation exists between transformation cost and amount of energy saving. The energy saving amount increases with the transformation cost. The amount of energy saving per unit cost is obtained through the above formula, as shown in Table 4.

Table 4 Amount of Energy Saving per Unit Cost

	Two-item transformation	Three-item transformation	Four-item transformation	Five-item transformation
Cost (C)	17112	12300.4	15600.4	16900.4
Before transformation	3178.16	1421.53	1790.7	2233.84
After transformation	3109.07	1106.63	1397.57	1617.37
Saving	69.09	314.9	393.13	616.47
Amount of energy saving per unit cost	0.004	0.026	0.025	0.037

From the above table we can see that the maximum amount of energy saving per unit cost of five-item transformation is 0.037, and the amount of energy saving per unit cost of two-item transformation is the minimum, which is only 0.004. Two-item transformation and four-item transformation respectively rank 2 and 3 with the value of 0.026 and 0.025. Therefore, the optimal scheme for saving energy is the five-item transformation in saving energy.

Efficiency of increasing room temperature

Calculate and obtain the room temperature increase corresponding to transformation cost per unit through statistic analysis on the cost of each transformation combination and the room temperature increase in winter before and after transformation, i.e. temperature variation per unit cost. The above relation can be expressed with the following mathematical formula:

T is used for expressing the room temperature in winter before transformation; T′ is used for expressing the room temperature in winter after transformation,

C is used for expressing the transformation cost, thus the temperature variation per unit cost can be expressed as:

Temperature variation per unit cost= $\frac{\Delta T}{C}$

The specific data is as shown in Fig.2:

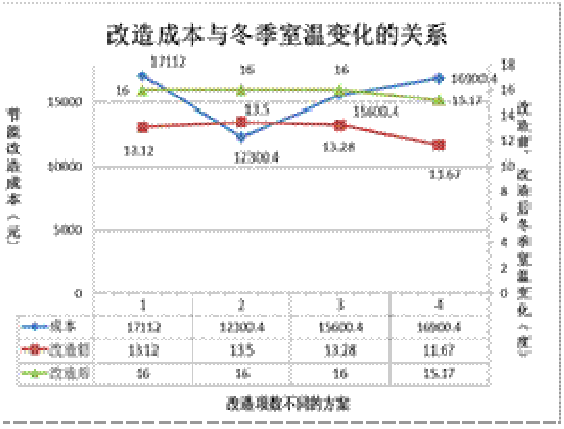

Fig. 2 Relation between Transformation Cost and Room Temperature Change in winter

Table 5 Temperature Variation per Unit Cost

Items of transformation	Optimal scheme	Cost	Before transformation	After transformation	Temperature variation	Temperature variation per unit cost
Two-item transformation	Doors and windows + outer wall	17112	13.12	16	2.88	0.00016
Three-item transformation	Doors and windows + suspended ceiling + floor	12300.4	13.5	16	2.5	0.0002
Four-item transformation	Doors and windows + suspended ceiling + floor + heating facilities	15600.4	13.28	16	2.72	0.00017
Five-item transformation	Doors and windows + suspended ceiling + floor + cooking utensils + heating facilities	16900.4	11.67	15.17	3.5	0.00021

Design Standard for Civil Architecture Energy Saving (JBJ26－86) published in 1980s stipulates that the room temperature in winter in northern area should reach to 18°C, and the fluctuation of ±2°C is qualified. That is to say, the minimum room temperature in winter in northern area must be above 16°C. After energy saving transformation, the room temperature in winter is increased significantly, and the residences which adopt the schemes of two-item transformation, three-item transformation and four-item transformation reach to the standard 16°C. Although 17 rural residences which adopt the scheme of 5-item transformation have not reached to the standard, its temperature increase is the maximum. This is because that the room temperature of rural residences which adopt the scheme of

5-item transformation in winter before transformation is lower than other rural residences, and the foundation for heating of residence is too poor. Through the above formula, we can obtain the temperature variation per unit cost, as shown in Table 5.

From the table we can see that the maximum temperature variation per unit cost of five-item transformation is 0.00021, and the temperature variation per unit cost of two-item transformation is the minimum, which is only 0.00016. Three-item transformation and four-item transformation respectively rank 2 and 3 with the value of 0.0002 and 0.00017. However, the scheme of five-item transformation has not yet reached to the standard after transformation, thus the optimal scheme in the item of increasing temperature is three-item transformation.

CONCLUSION

The following results are obtained through analyzing the above four transformation schemes, see Table 6.

From the statistical data of two-item transformation and ranking of various indexes, although only two items are transformed, the cost is the maximum, and the amount of energy saving and the temperature increase per unit cost are the minimum. The sample of two-item transformation is doors and windows + outer wall. The transformation scheme of doors and windows and outer wall is the main transformation item in most northern areas, and the transformation effect is always not bad. Nevertheless, from the data we can see that the transformation scheme of doors and windows + outer wall is not popularized in Bairin Left Banner area because of the single transformation cost of outer wall of 13440 Yuan, which is the maximum in all single items of transformation. The single item of outer wall does not bring about large energy saving amount and temperature increase, on the contrary, it offsets the amplification of the two indexes by average, which correlates the policy guidance and financial support and the income level of residents of this area. In most northern areas such as Beijing, Hebei, in the rural residence transformation, specific transformation items and contents are specified, and the outer wall insulation is listed as the item which must be transformed. The policy of Bairin Left Banner provides certain transformation fund to the peasants, but the specific transformation item is decided by the peasants. Because that the income of local peasants is limited and there is the requirement for transformation temperature increase, the expensive outer wall transformation is replaced by other transformation combination whose price is moderate and effect of insulation is not bad. Therefore, under the present policy guidance and peasant income level of Bairin Left Banner, the transformation of outer wall is the item selected in Bairin Left Banner area.

From the statistical data of three-item transformation and the ranking of various indexes, the cost for three-item transformation is the minimum in all transformation schemes, and the difference between it and the second (four-item transformation) is large. It ranks 2 in the amount of energy saving per unit cost. In temperature variation per unit cost, because after transformation it meets the requirement of above 16°C and the difference between it and five-item transformation is only 10^{-4}per unit cost, it is selected as the most appropriate and economic transformation scheme after overall analysis.

From the statistical data of four-item transformation and ranking of various indexes, the performance of each data is moderate. Compared with three-item transformation, the item of heating facilities is added. The increased cost does not exceed the amplification of two indexes by average. The peasant households with simple heating facilities can adopt this method.

From the statistical data of five-item transformation and ranking of various indexes, the scheme of five-item transformation is suitable for the rural residence with large energy consumption, poor insulation foundation, and many items of transformation required. The comprehensive and thorough transformation can greatly increase the amount of energy saving and temperature.

Table 6 Data Summary of Transformation Schemes and Ranking in the Comparison of Various Indexes

Data Summary of Transformation Schemes and Ranking in the Comparison of Various Indexes								
	Two-item transformation and ranking		Three-item transformation and ranking		Four-item transformation and ranking		Five-item transformation and ranking	
Transformation cost	17112	4	12300.4	1	15600.4	2	16900.4	3
Amount of energy saving per unit cost	0.004	4	0.026	2	0.025	3	0.037	1
Temperature variation per unit cost	0.00016	4	0.0002	1	0.00017	3	0.00021	2

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