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Research Article

Research on the Efficiency and Economic Impact of Energy-Saving Transformation of Residential Buildings in Different Climatic Regions of China

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In China, the transformation of existing buildings is confronted with various problems in aspects ranging from technology to policy and even to economic efficiency, which restrains the pace of existing building transformation. Aiming at these conditions, a building model is established with simulation software in the research herein to deeply analyze the energy-saving effect of building envelope transformation in different climatic regions and its economic efficiency based on regional and national policies. The research results show that any single technology is difficult to completely satisfy the requirements of current energy efficiency standards, and technical measures should be taken according to different climatic regions. For the northern heating area, the building envelope transformation must be carried out simultaneously with the transformation of heat metering. Policy formulation and fund determination for the energy-saving transformation of existing buildings in China should be more flexible based on transformation effect and rely more on social and commercial forces rather than solely on the promotion of government.

1. Introduction

Along with the acceleration of the urbanization process in China, the building energy consumption constantly increases. It is revealed by the research results of the Building Energy Research Center, Tsinghua University, that the unit area of buildings is increasing rapidly and the energy consumption intensity of buildings is rising moderately at the same time, both of which lead to the continuing increase of total energy consumption of buildings [1].

The vast majority of buildings constructed before 2000 are not energy-efficient in China. It is shown by data that, by the end of 2013, the existing floor area in China had exceeded 50 billion m^2, including 27 billion m^2 of existing urban floor area; however, urban energy-saving buildings merely took up 29.63% in the existing gross floor area, and more than 70% of buildings needed energy-saving transformation in the future. What is more, there is annual increment resulting from emerging urbanization process [2].

The problems of existing buildings are mainly manifested by the low average thermal insulation level of exterior wall, only 1/3 of that in developed countries at the same latitude in Europe [3], low efficient systems of heat supply and cooling, lag of heat metering reform, and so on. In order to change such a situation, a series of national and local policies and financial incentives have been implemented to support energy-saving transformation. However, these policies and measures still have various problems that hinder the energy-saving transformation of existing buildings. For example, the estimated cost for the energy-saving transformation of building envelope, heat metering, and pipe-network thermal equilibrium is higher than 220 Yuan/m^2 [2], and the need for capital investment will be larger if heat source transformation is added, but current subsidies for energy-saving transformation are not enough. For another example, the immature market mechanism impedes the enthusiasms and approaches of enterprises and residents for carrying out energy-saving transformation. Finally, there is no in-depth analysis of the energy-saving transformation and its cost efficiency in different climatic regions or analysis of the impact of transformation results on the end users.

2. Research Method

Aiming at aforementioned conditions, a building model is established with simulation software in the research herein to deeply analyze the energy-saving effect of building envelope transformation in different climatic regions.

In China, civil buildings are majorly classified into two kinds, namely, public buildings and residential ones. Judged from the energy-saving transformation of a single building, the energy-saving transformation of a public building involves broader items and includes not only the improvement of thermal insulation performance of building envelope but also the energy conservation of heat supply and cooling systems during the life-cycle use process; the comprehensive efficiency of energy-saving transformation is highly dependent upon both [4]. The condition of a residential building is relatively simple, and the energy-saving benefit can be effectively increased to a large extent by improving the thermal insulation performance of building envelope [5]. The research herein does not discuss the transformation of heat supply and cooling systems, so residential building is selected as the object of transformation.

There are five climatic regions for buildings in China. A typical city in each of the four regions among them is selected, respectively, as research object, that is, Harbin in the severe cold region, Beijing in the cold region, Shanghai in the hot-summer and cold-winter region, and Guangzhou in the hot-summer and warm-winter region, as shown in Figure 1. No city is selected in the mild region.

To deeply and meticulously analyze the specific effect of building envelope transformation on building energy efficiency in different climatic regions, a model is built in the research with simulation software ENERGYPLUS [6] by taking a 10-floor typical residential building as the prototype, as shown in Figure 2. This building has a total area of 7,836.48 m^2, shape coefficient of 0.2, window-wall ratio of 0.15, total area of exterior wall of 3,855.02 m^2, total area of exterior window of 208.08 m^2, and roof area of 783.65 m^2.

In the research, in accordance with the *Design Standard for Energy Efficiency of Residential Buildings in Severe Cold and Cold Regions* (JGJ26-2010) [7], *Design Standard for Energy Efficiency of Residential Buildings in Hot-Summer and Cold-Winter Region* (JGJ134-2010) [8], and *Design Standard for Energy Efficiency of Residential Buildings in Hot-Summer and Warm-Winter Region* (JGJ75-2003) [9], parameters related to the thermal performance of ENERGYPLUS model's building envelope are set, respectively, for benchmark building (1980s) and reference building (meeting above specifications) for different climatic regions. Examples of the thermal performance parameters of these two types of buildings are shown in Table 1, and the city shown in the table is Beijing.

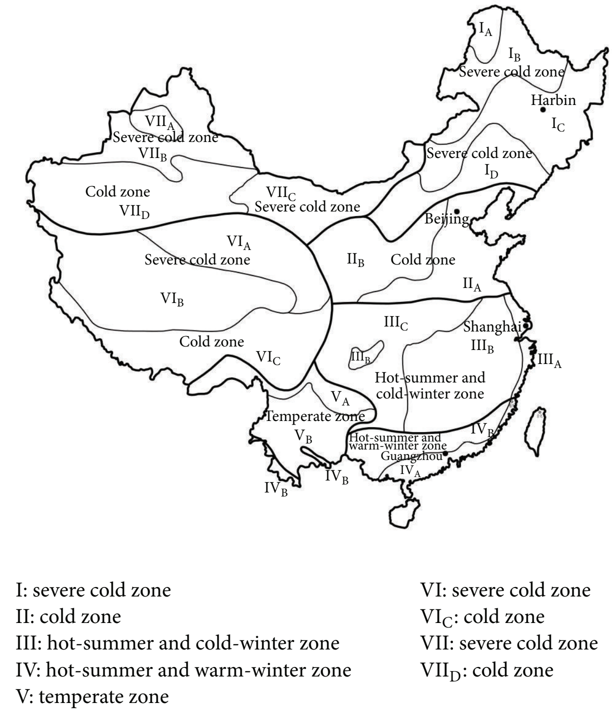

Figure 1: Diagram of climatic regions for buildings in China and selected cities. Source: ⟨code for design of civil buildings⟩ (GB 50352-2005).

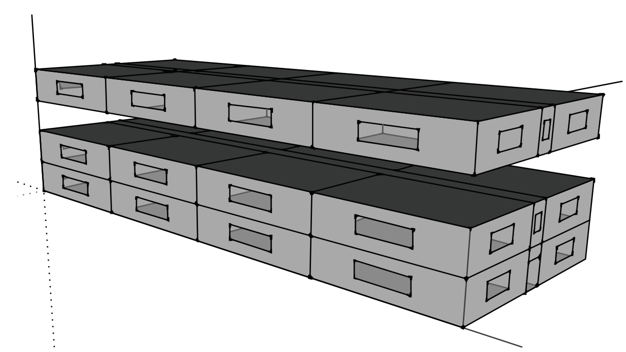

Figure 2: Schematic diagram of ENERGYPLUS residential building model. Source: self-drawing.

3. Analysis of the Simulated Energy Consumption Results after Energy-Saving Transformation

After the establishment of model, various parameters are input into ENERGYPLUS to calculate the energy consumption intensity, respectively, of benchmark building and reference building through simulation, as shown in Figures 3 and 4. It can be observed from the figures that the energy consumption intensity, respectively, in Harbin in the severe cold region and Beijing in the cold region is significantly reduced after the transformation of building envelope, especially by nearly a half in Beijing.

Table 1: Parameter comparison of thermal performance of prototype buildings in Beijing (self-drawing).

Item	Benchmark building (1980)	Reference building (meeting energy efficiency standard)
Wall	U value of exterior wall: 1.7 W/(m^2·K)	U value of exterior wall: 0.7 W/(m^2·K)
Roof	U value of roof: 1.26 W/(m^2·K)	U value of roof: 0.45 W/(m^2·K)
Window	U value of window: 6.4 W/(m^2·K)	U value of window: 3.1 W/(m^2·K)
Air change rate	1.5 times/hour	0.5 times/hour (according to the standard for cold region)
Running time	24/7	24/7
Cooling system	Indoor air conditioner, EER: 3.1	Indoor air conditioner, EER: 3.1
Heat source (central heating)	Natural gas boiler, efficiency: 0.8	Natural gas boiler, efficiency: 0.8
Pump	Constant volume	Constant volume
Heating period	11.15–03.15 (next year)	11.15–03.15 (next year)
Cooling period	06.15–08.31	06.15–08.31

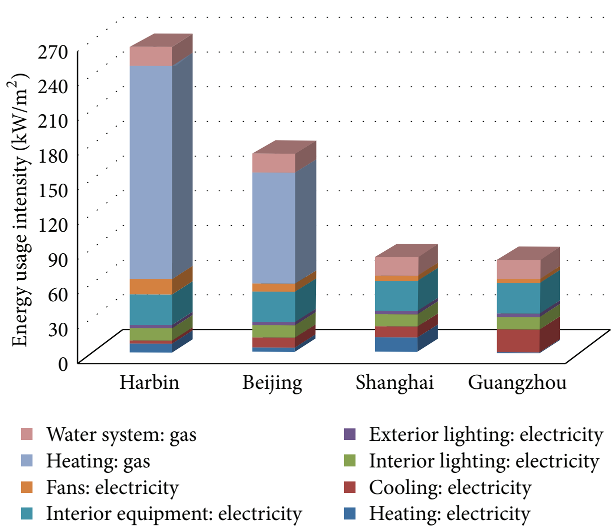

Figure 3: Schematic diagram of energy consumption intensities of benchmark buildings in different climatic regions. Source: self-drawing.

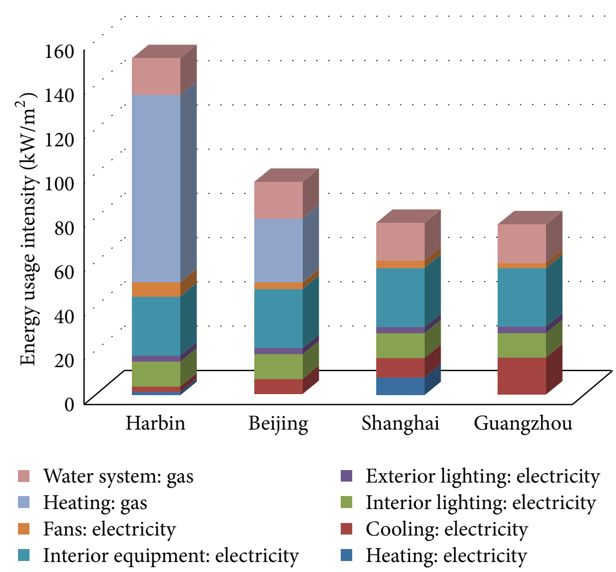

Figure 4: Schematic diagram of energy consumption intensities of reference buildings in different climatic regions. Source: self-drawing.

With the aim of making the effects of the transformation of such components as wall, exterior window, and roof in building envelope on the result of energy-saving transformation clear, the thermal performance changes of these three components are simulated separately for in-depth comparison and analysis based on the whole process of benchmark building, single component transformation building and reference building.

In the analysis of the energy consumption intensity of heating, it can be seen from Figures 5–7 that the energy consumption intensity of simulated building will be reduced by improving the thermal performance of any exterior envelope structure in any single component and making it meet the requirement of current energy-saving standard, and when all the items are consistent with the requirements, that is, forming the reference building, the energy consumption will reach the optimum value. For instance, the energy

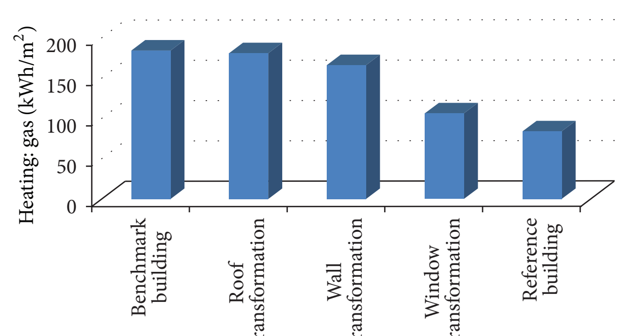

Figure 5: Schematic diagram of comparison between energy consumption intensities of heating in Harbin. Source: self-drawing.

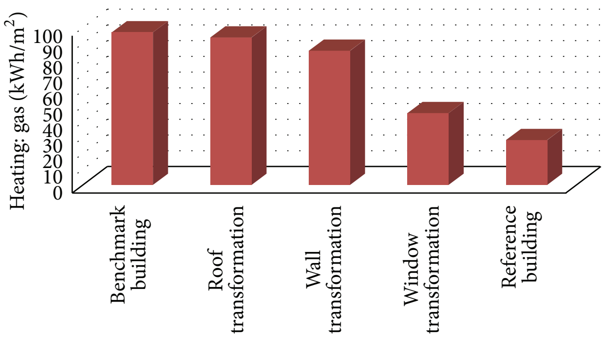

FIGURE 6: Schematic diagram of comparison between energy consumption intensities of heating in Beijing. Source: self-drawing.

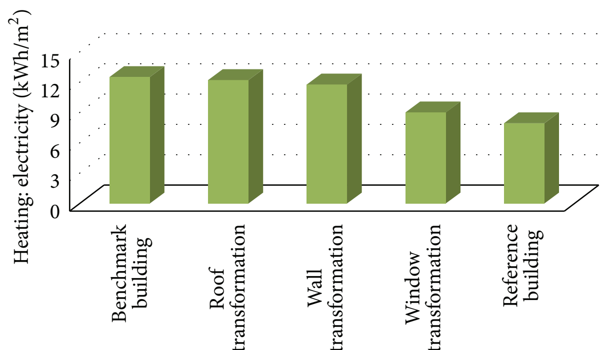

FIGURE 7: Schematic diagram of comparison between energy consumption intensities of heating in Shanghai. Source: self-drawing.

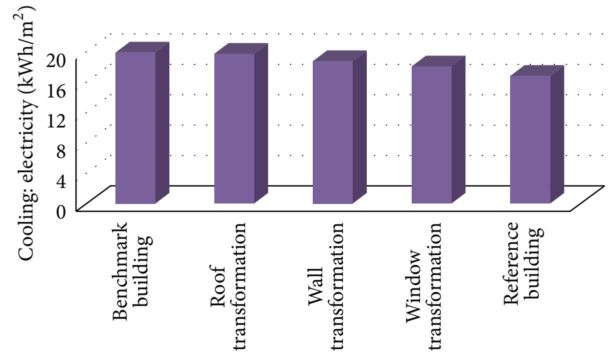

FIGURE 8: Schematic diagram of comparison between energy consumption intensities of cooling in Guangzhou. Source: self-drawing.

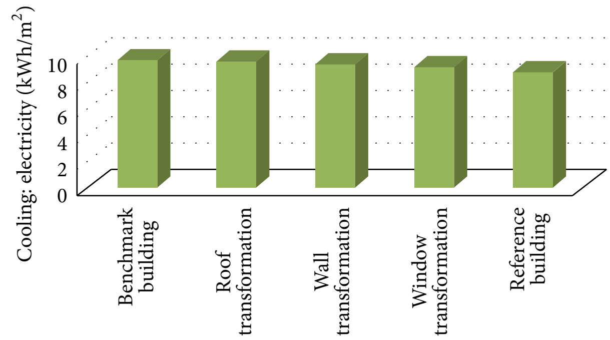

FIGURE 9: Schematic diagram of comparison between energy consumption intensities of cooling in Shanghai. Source: self-drawing.

consumption intensity of heating is decreased by 54% in Harbin and more significantly by 70% in Beijing. The impact analysis of the energy consumption of heating does not include Guangzhou, because it is in the hot-summer and warm-winter region, where the heating period is very short and the energy consumption intensity very low.

It can also be seen from the figures that the thermal performance change of window brings about the best energy-saving effect, because such a change in the research is not only reflected in the *U* value of window, but the effect of tightness performance change of window is also taken into consideration. The tightness of doors and windows is relatively poor in the buildings constructed in 1980s in China, so the value of air change rate is set as 1.5 times/hour in the model. The quality of buildings in China has been obviously improved in recent years, and the air change rate is about 0.3–0.5 times/hour in properly constructed residential buildings with high-quality doors and windows. The energy consumption of residential buildings in the south is mainly generated by air conditioners, and air infiltration through doors and windows or ventilation through windows can greatly shorten the running time of air conditioner; therefore the value of air change rate in the severe cold and cold regions is set as 0.5 times/hour and that in hot-summer and cold-winter and hot-summer and warm-winter regions as once/hour [10].

In the analysis of the energy consumption intensity of cooling, it can be found from Figures 8–11 that the reduction in cooling energy consumption is obviously smaller than that in heating energy consumption by improving the thermal performance of any exterior envelope structure and making it meet the requirement of current energy-saving standard. The comparison diagram of Harbin indicates that the enhancement of tightness of doors and windows even increases the energy consumption intensity of cooling in summer, and the thermal performance improvement of wall results in the most remarkable transformation effect.

It is revealed by the research above that, on the one hand, China should continue expanding the transformed area of existing buildings in that just the thermal performance improvement of envelope alone can be highly effective in the reduction of energy consumption intensity, especially in the north. On the other hand, the energy-saving transformation of exterior envelope structures alone is not enough to completely meet or surpass the national energy-saving standard unless it is combined with the energy-saving transformation of heat metering and pipe-network thermal equilibrium.

4. Analysis of the Economic Benefit of Energy-Saving Transformation

During the "11th Five-Year Plan" period, the transformation of existing buildings in China had been mainly concentrated

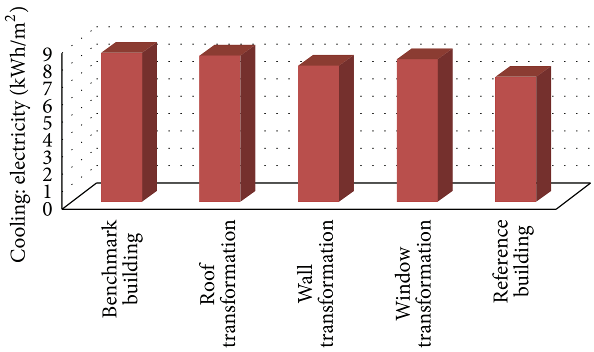

Figure 10: Schematic diagram of comparison between energy consumption intensities of cooling in Beijing. Source: self-drawing.

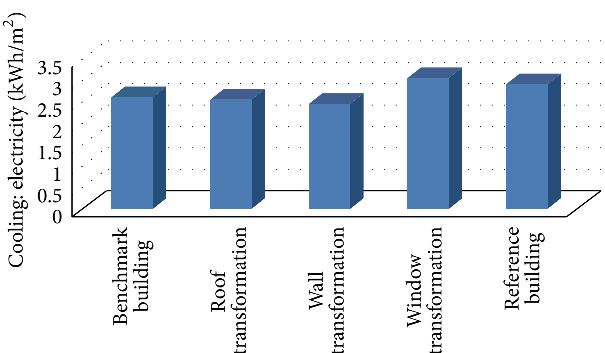

Figure 11: Schematic diagram of comparison between energy consumption intensities of cooling in Harbin. Source: self-drawing.

in the northern heating area. By the end of 2010, 182 million m^2 of existing residential buildings had been transformed in the aspects of heat metering and energy conservation [2]. In a bid to implement the spirit of the *Notice of the State Council on Printing and Distributing the Comprehensive Work Scheme of Energy Conservation and Emission Reduction* (GF [2007] number 15) and practically boost heat metering and energy-saving transformation of existing residential buildings in the northern heating area, the Ministry of Housing and Urban-Rural Development and the Ministry of Finance jointly or separately unveiled multiple management and incentive policies, mainly including

(1) Ministry of Finance and Ministry of Housing and Urban-Rural Development: *Interim Measures for Management over the Incentive Funds for Heat Metering and Energy-Saving Transformation of Existing Residential Buildings in the Northern Heating Area* (CJ [2007] number 957),

(2) Ministry of Housing and Urban-Rural Development: *Opinions on Boosting the Implementation of Heat Metering and Energy-Saving Transformation of Existing Residential Buildings in the Northern Heating Area* (JK [2008] number 95),

(3) Ministry of Housing and Urban-Rural Development: *Technical Guideline for the Heat Metering and Energy-Saving Transformation of Existing Residential Buildings in the Northern Heating Area* (JK [2008] number 126),

(4) Ministry of Housing and Urban-Rural Development: *Acceptance Measures for Projects of Heat Metering and Energy-Saving Transformation of Existing Residential Buildings in the Northern Heating Area* (JK [2009] number 261).

The implementation of these policies promotes the transformation process of existing residential buildings in the northern heating area to a certain degree. However, under the condition of asymmetric information, there is no way to find out whether the incentive funds meet the transformation requirements, the economic incentive obtained by the existing buildings' owners, their reservation utility, and the economic and environmental benefits after energy-saving transformation and whether the economic incentive obtained by the owners through contract is comparatively low [11].

According to relevant surveys, 360,000 m^2 of existing public and residential buildings had been transformed in Xi'an from 2007 to 2011, among which 320,000 m^2 belonged to existing public buildings transformed under the guidance of government. Only the building envelope was transformed, and the cost per square meter was as high as 300 Yuan. The residual 40,000 m^2 was transformed by the owners, with the incentive funds issued by the government. The reward for comprehensive transformation of building envelope was 50 Yuan/m^2, and that for exterior window transformation alone reached 30 Yuan/m^2 [12], higher than the provisions in the *Interim Measures for Management over the Incentive Funds for Heat Metering and Energy-Saving Transformation of Existing Residential Buildings in the Northern Heating Area* (see the following).

Special fund amount allocable to a place = reward benchmark of the climatic region where it is located × [∑(area of single transformation item in the region × corresponding single transformation weight) × 70% + area of transformation in the region × coefficient of energy-saving effect × 30%] × progress coefficient, where reward benchmark of the climatic region is classified into two categories: 55 Yuan/m^2 for the severe cold region and 45 Yuan/m^2 for the cold region.

Single transformation items refer to energy-saving transformation of building envelope, transformation of indoor heat metering and temperature control, and transformation of heat source and heat supply pipe-network thermal equilibrium, and weight coefficients for these three transformations are 60%, 30%, and 10%, respectively [13].

During the "12th Five-Year Plan" period, to implement the spirit of the *Notice of the State Council on Printing and Distributing the Comprehensive Work Scheme of Energy Conservation and Emission Reduction during the "12th Five-Year Plan" Period* (GF [2011] number 26), China has launched the transformation of existing residential buildings in hot-summer and cold-winter region and formulated the *Interim*

Table 2: Guiding price for different thermal insulation methods of exterior wall [22] (self-drawing).

System description	Price per m^2 (Yuan)	Remarks
EPS board with thin floated coat	84–87	Including labor cost of 15–18 Yuan
Thermal insulating mortar of EPS rubber-power particles	65	Excluding labor cost
Cast-in-place concrete of EPS board (coating, no net)	80	Including labor cost of 15 Yuan
Cast-in-place concrete of EPS board (coating, steel net-supporting board)	59	Excluding labor cost
Mechanically fixed EPS steel net-supporting board	59	Including 14 Yuan's cost for plastering mortar and installation of net-supporting board

Table 3: Energy-saving transformation cost of residential buildings in Harbin (self-drawing).

Transformation cost of Harbin	Roof transformation	Wall transformation	Exterior window transformation	Reference building
Construction cost (Yuan)	76,014.05	335,386.74	52,020	463,420.79
Construction cost/m^2	97	87	250	59.14 (floor area)

Table 4: Comparisons between heating expenses before and after transformation of existing residential buildings in Harbin (self-drawing).

Harbin	Benchmark building (1980)	Roof transformation	Wall transformation	Window transformation	Reference building (meeting energy efficiency standard)
Heating: natural gas (kWh/m^2)	184.83	181.47	166.81	106.55	84.17
Heating expense (Yuan/m^2) Note: with heat metering	45.25	44.78	42.72	34.29	31.15
Actual charge	40.35	40.35	40.35	34.29	31.15
Technical information	$U = 0.77$	$U = 0.3$			$U = 0.3$
	$U = 1.28$		$U = 0.55$		$U = 0.55$
	$U = 3.26$			$U = 2.5$	$U = 2.5$
	Air change rate: 1.5 times/hour			Air change rate: 0.5 times/hour	Air change rate: 0.5 times/hour

Measures for Management over the Subsidies for the Energy-Saving Transformation of Existing Residential Buildings in the Hot-Summer and Cold-Winter Region (CJ [2012] number 148). No relevant policy has been unveiled for the hot-summer and warm-winter region.

As a result, no matter whether it is for the northern heating area or other climatic regions, in-depth economic analysis is necessary, and it is significant for the rationalization and deepening of policy trend to calculate the cost efficiency of energy-saving transformation of building envelope in different climatic regions by combining simulated data with national and local incentive policies and pay attention to the economic and environmental benefits after transformation.

In the research, Harbin is taken as an example first of all for the economic analysis of the energy-saving transformation of existing residential buildings. Because Harbin is in the severe cold region, its energy consumption of heating is significantly higher than that of other cities. Hence, the research, with the focus on economic benefit, carries out economic analysis by combining national and local intensive policies to further clarify the actual expenses of transformation and work out the investment payback period.

According to relevant data, different thermal insulation systems of exterior wall have different price (Table 2). The most commonly used system of EPS board with thin floated coat is selected by the research. The thickness of EPS board is assumed to be 50 mm, and each increase of 10 mm will lead to 2-Yuan increase in the cost. PVC double-glazed window is adopted (thickness of air layer: 16 mm) at the price of 250 Yuan/m^2. The transformation cost can be calculated according to the simulated external thermal insulation thickness of exterior wall and roof and the corresponding areas and exterior windows, as shown in Table 3.

According to relevant information, there are two charge standards for the municipal heat supply of Harbin. In case there is no heat metering, the uniform charge is 40.35 Yuan/m^2; in case there is heat metering, the heat supply charge = basic heat supply charge (19.37 Yuan/m^2) + 0.14 Yuan/kWh [14]. Based on such standards, the comparison between heating expenses before and after transformation of existing residential buildings in Harbin is shown in Table 4.

It can be seen from Table 4 that, in case of charge through heat metering, the heating expense caused by actual heat consumption of existing residential buildings before transformation is higher than the uniform urban charge standard, and the same problem exists if only roof or wall is

Table 5: Comparisons between cooling expenses before and after transformation of existing residential buildings in Harbin (self-drawing).

Harbin	Benchmark building (1980)	Roof transformation	Wall transformation	Window transformation	Reference building (meeting energy efficiency standard)
Cooling: electric power (kWh/m^2)	2.61	2.55	2.45	3.06	2.91
Cooling expense ($Yuan/m^2$)	1.33	1.30	1.25	1.56	1.49
Technical information	$U = 0.77$	$U = 0.3$			$U = 0.3$
	$U = 1.28$		$U = 0.55$		$U = 0.55$
	$U = 3.26$			$U = 2.5$	$U = 2.5$
	Air change rate: 1.5 times/hour			Air change rate: 0.5 times/hour	Air change rate: 0.5 times/hour

transformed. This indicates that if energy-saving transformation is not carried out, the city will spend more money on this aspect each year, resulting in negative benefit and loss. As to reference building whose envelope has been comprehensively transformed, in case of charge through heat metering, the user will be able to save 9.2 $Yuan/m^2$, the energy consumption of city in heat supply will be reduced by more than a half, and the expense will decrease accordingly, thus showing a good economic benefit.

According to relevant information, the electricity charge for residential buildings in Harbin is 0.51 Yuan/kWh [15]. Based on this charge standard, the comparison between cooling expenses before and after transformation of existing residential buildings in Harbin is shown in Table 5.

It is demonstrated by Table 5 that the enhancement of tightness of doors and windows even increases the energy consumption intensity of cooling in summer, making the summer cooling expense of reference building that meets energy efficiency standard higher than that of the benchmark one. However, in view of the fact that Harbin is located in the severe cold region, its energy consumption of cooling is far lower than that of heating. On the basis of overall consideration, the reduction of heating energy consumption in winter should be taken as the primary target.

As previously mentioned, in the *Interim Measures for Management over the Incentive Funds for Heat Metering and Energy-Saving Transformation of Existing Residential Buildings in the Northern Heating Area*, the reward benchmark for the severe cold region is 55 $Yuan/m^2$, among which energy-saving transformation of building envelope, transformation of indoor heat metering and temperature control, and transformation of heat source and heat supply pipe-network thermal equilibrium take up 60%, 30%, and 10%, respectively. Therefore the reward for envelope transformation alone is 33 $Yuan/m^2$. According to the following formula:

$$\text{Payback period} = \frac{(\text{Transformation cost} - \text{Reward fund})}{(\text{Saved heating expense} + \text{Saved cooling expense})}, \quad (1)$$

we can work out that the payback period for the reference building that meets energy efficiency standard is 2.88 years and will be prolonged to 6.5 years in case of no reward fund for transformation and that the reward fund approximately amounts to 44% of the total investment.

Shanghai is taken as another example in the research for the economic analysis of the energy-saving transformation of existing residential buildings. Shanghai is in the hot-summer and cold-winter region where there is no heat supply pipe and network or central heating equipment, so electric heating is mainly adopted for heat supply at low temperature in winter. For this reason, the energy conservation of the city is realized largely by saving electric power. In the *Interim Measures for Management over the Subsidies for the Energy-Saving Transformation of Existing Residential Buildings in the Hot-Summer and Cold-Winter Region* (CJ [2012] number 148) [16], the hot-summer and cold-winter region is divided into the eastern, middle, and western parts, for which the subsidies are 15, 20, and 25 $Yuan/m^2$, respectively. Then, the subsidy amount allocable to a place = subsidy benchmark of the region where it is located $\times \sum$(area of single transformation item × corresponding single transformation weight). Single transformation items refer to transformation of exterior doors and windows, energy-saving transformation of exterior sunshade, and energy-saving transformation of building roof and exterior wall's thermal insulation, with weight coefficients being 30%, 40%, and 30%, respectively. Shanghai is situated in the eastern part of hot-summer and cold-winter region and consequently enjoys the subsidy of 15 $Yuan/m^2$. The electricity charge for residential buildings in Shanghai is 0.61 Yuan/kWh [17].

The transformation cost of residential buildings in Shanghai can be calculated according to the simulated external thermal insulation thickness of exterior wall and roof and the corresponding areas and exterior windows, as shown in Table 6.

See Table 7 for the comparison between heating and cooling expenses before and after transformation of existing residential buildings in Shanghai.

It can be observed from Table 6 that the heating expense is significantly reduced despite the small value, and the transformation of building envelope is not quite effective in cooling.

Table 6: Energy-saving transformation cost of residential buildings in Shanghai (self-drawing).

Transformation cost of Shanghai	Roof transformation	Wall transformation	Exterior window transformation	Reference building
Construction cost (Yuan)	64,475.65	304,546.58	43,096.8	411,719.03
Construction cost/m^2	81	79	210 (PVC single-glazed window)	52.54 (floor area)

Table 7: Comparisons between heating and cooling expenses before and after transformation of existing residential buildings in Shanghai (self-drawing).

Shanghai	Benchmark building (1980)	Roof transformation	Wall transformation	Window transformation	Reference building (meeting energy efficiency standard)
Heating: electric power (kWh/m^2)	12.47	12.17	11.73	8.98	7.91
Heating expense (Yuan/m^2)	7.60	7.42	7.16	5.48	4.83
Cooling: electric power (kWh/m^2)	9.75	9.65	9.44	9.22	8.83
Cooling expense (Yuan/m^2)	5.95	5.89	5.76	5.62	5.39
Technical information	$U = 1.5$	$U = 1$			$U = 1$
	$U = 2$		$U = 1.5$		$U = 1.5$
	$U = 6.4$			$U = 4.7$	$U = 4.7$
	Air change rate: 1.5 times/hour			Air change rate: once per hour	Air change rate: once per hour

According to the investment payback formula of energy-saving transformation of Harbin:

$$\text{Payback period} = \frac{(\text{Transformation cost} - \text{Reward fund})}{(\text{Saved heating expense} + \text{Saved cooling expense})}, \quad (2)$$

we can work out that the payback period for the transformation cost of reference building that meets energy efficiency standard is 11.27 years and will be prolonged to 15.78 years in case of no reward fund for transformation and that the reward fund approximately amounts to 29% of the total investment.

5. Conclusions and Discussions

Through the research, we can reach the following three conclusions:

(1) Any single transformation is difficult to completely satisfy the requirements of current energy efficiency standard. If only roof and wall are transformed, the investment payback period will be too long, and thus the economic benefit is relatively poor [18]. The change in the tightness of doors and windows has a great impact on the result of energy-saving transformation, so it should be taken as the key point in energy-saving transformation [19]. For the existing residential buildings in the northern heating area, the energy-saving transformation of building envelope has a more remarkable effect, and we should continue to vigorously promote such transformation in this region. As to the hot-summer and cold-winter region, besides necessary energy-saving transformation of building envelope, the source for heat supply in winter should also be resolved with great efforts. At present, the development of multiple distributed energy technologies provides more possibilities [20].

(2) It is revealed by economic analysis that the reward funds for transformation provided by the state cannot satisfy the expenditure of transformation. Because of asymmetric information, users have no idea about their own benefit, lack enthusiasm for transformation, and tend to be unwilling to participate in and spend money on it. However, although the national reward funds are not sufficient for covering the complete energy-saving transformation, the investment payback period will not be very long without the support of such funds. Hence, the EPC (Energy Performance Contracting) model may be employed for the transformation [21].

(3) For the northern heating area, the transformations of building envelope and heat metering must be carried out simultaneously. The reason is that as shown by the economic analysis only through heat metering can the managers grasp the specific energy consumption intensity and the users see the practical economic benefit and become active in taking part in the transformation. However, in reality, the management over the transformation of building envelope is presided over by the construction committee, whereas the transformation of heat metering is presided over

by the municipal services. The coordination and unification of the two urgently needs to be solved at the level of management.

For China as a country continually accelerating its process of new-type urbanization, digesting the existing energy-inefficient buildings is a great challenge while coping with the annual increment brought about by urbanization. For this reason, policy formulation for the energy-saving transformation of existing buildings and the determination of transformation funds should be more flexible based on transformation effect in the future. In addition, the energy-saving transformation should rely more on social and commercial forces rather than solely on the promotion of government.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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