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Sensitivity analysis of existing residential building energy consumption influencing factors in cold regions

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Abstract

Urban green reform of existing residential buildings is an important way to achieve totals, the control of energy consumption, the reduction target of carbon dioxide emissions per unit of GDP, and the target of green building construction. In this paper, study the existing residential buildings in cold region cities and towns, research the building basic information, household behavior, indoor thermal environment and family composition. To get the basic conditions of living buildings in the cold regions, and the factors that affects the energy consumption. Meanwhile, the paper also uses the way that simulates the annual energy consumption of existing residential buildings, get the factors of existing residential building that affects the energy consumption in cold regions, so as to provide the green transformation of the existing residential building.

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Keywords: Cold regions; Existing residential buildings; Green transformation; Energy factors; Sensitivity;

1. Introduction

At present, most of existing residential buildings in China generally have the problems that the resources and energy consume large, living and comfort level are low, the using functional is poor and so on, if remove the non-green living buildings of using a shorter length, it is not only a waste of resources and energy, causing secondary pollution and damage for the ecological environment. So "establish a green, low carbon development concept,"[1] carrying out the green transformation and comprehensive environmental performance evaluation is very necessary. It is very important to develop green residential building, the green transformation of existing residential buildings, reducing residential

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building energy consumption and greenhouse gas emissions, achieving the target of carbon dioxide emissions per unit of GDP in 2020 by 40% -50% for China [2]. In this paper, studies the existing residential buildings in cold region town, statistics the existing residential buildings basic information, analysis the indoor thermal environment, the used heat mode, air conditioning using, and household composition and so on. For the typical existing residential buildings in cold, by using the DeST-H software to simulate the annual dynamic, to get the sensitivity factors for existing residential building envelope effects the building energy consumption, study the effective way of green transformation for existing residential buildings, to provide a theoretical basis and technical support for the green renovation of existing residential buildings.

2. Methods

Research focused on both energy consumption and indoor environmental quality for residential building, the main purpose is getting the influence factors for residential building energy status and indoor environmental quality in cold regions, the research mainly takes face-to-face questionnaires, Internet and mobile platform questionnaires, a total of 178 questionnaires issued, 171 were recovered, the recovery rate was 96%. In the recovered sample survey, a full range of energy consumption data sample is considered for valid sample, not filling out the questionnaire or missing consumption data, using the equivalent of a month's data interpolation to improve the data and the questionnaire as a valid sample, for the blank questionnaires were considered for invalid samples. Finally, the effective recovery has 150, the effective rate is 87.7%. Meanwhile, through the power company, Water Company and gas companies gets energy prices. Accordingly, the data obtained by the research route is effective.

- Construction of basic information survey: completion time, the building area, building and household where the total number of layers floor, building orientation, type of construction, type of window, indoor air quality, fire alarm, electrical intelligence.
- The behavior survey: domestic hot water sources, diet, the fashion of ventilation mode, water recycling, and use of lighting.
- The indoor thermal environment survey: fashion of air conditioning mode, heating mode, air-conditioning set temperature, room temperature, comfort and so on.
- Family members and consumption survey: family size and occupation, time at home, monthly gas and electric consumption, household income, energy conservation awareness and so on.

Table 1. Payment and recovery of the questionnaire.

Climatic zone	Cold region	Cold areas
Research time	2015.4.10	2015.4.10
Issuing shares	110	68
Copies recovery	108	63
Valid copies	88	62

3. Results

Survey of existing residential buildings completion time and the construction area, figure 1, only one was completed before 1990, which completed in 1990-2000 accounts for 8% of the total survey. Between the 2000-2005 and 2005-2010, the completion of buildings accounts for 11.3% and 13.3%, after 2010 it accounts for 66.7% of the total. More than half of the survey are completed after 2010, existing residential buildings completed for 2000-2005 and 2005-2010 are 24%, only 8% of the buildings are completed before 2000. Figure 2, the amount for building area

of 70 m² is 14, accounting for 9.3% of the total survey, the amount for building area between 70-90 m² is 63, accounting for the total survey 42%, the amount for building area between 90-110 m² is 36, accounting for 24%, the amount for building area between 110-130 m² is 20, accounting for 13.3%, the amount for building area between 130-150 m² is 12, only five existing residential buildings ,their construction area are over 150 m². So the building units of existing residential buildings are medium and large, only a small parts are small apartment building in cold regions.

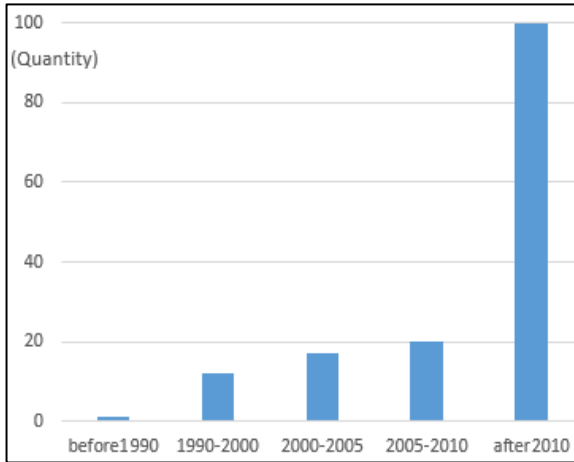


Fig. 1. Completion Year

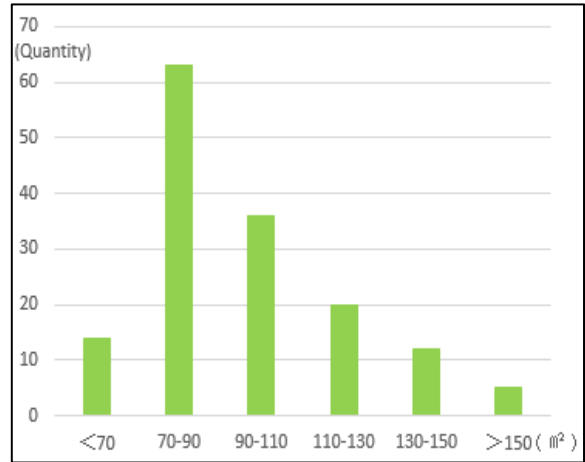


Fig. 2. Building area

The investigation of building structure and building orientation for existing residential buildings: figure 3, the amount of architectural structure of brick accounts for 93.3% of the total survey, the amount of reinforced concrete structures and steel reinforced concrete structure accounted for 5.3%, 1.33% of the total building structure is architectural structure of brick. 90% of survey buildings are completed after 2000, so the architectural structure of brick are most used for the survey, the reinforced concrete structures and steel reinforced concrete structure are less used. Figure 4, the amount for building faces north-south accounts for 93.3% of the total survey, the amount for building faces east-south accounts for 3.3%. Building orientation of designed primarily north-south for existing residential buildings.

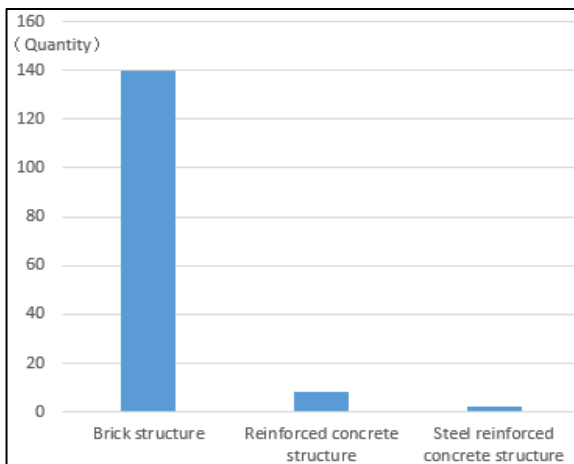


Fig. 3. Construction Drawings

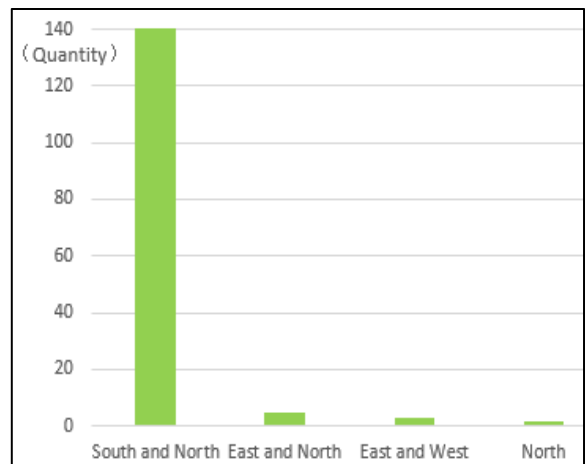


Fig. 4. Building orientation

The building layers and living layers investigation for existing residential buildings: figure 5, the amount for building layers are below 10 layers is 66, the amount for building layers are between 10 and 15 is 24, the amount for building layers are between 15 and 20 is 18, the amount for building layers are over 20 floors is 42. So you can see the most existing residential buildings in cold area and cold regions, the building layers mainly are below 10. Figure 6, the number of people for residents living below the 10 layers is 109, the number of people for residents living between 10 and 15 layers is 27, only having 9 people live between 15 and 20 layers. It can be seen residents living mainly in the lower part of the building, only a small portion of households living in high-rise construction site in the cold regions and cold area.

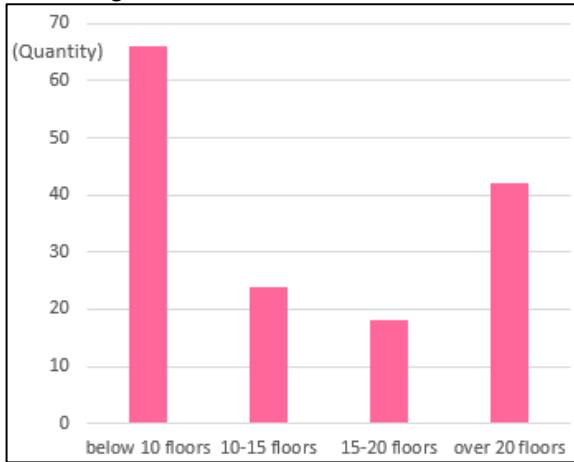


Fig. 5. Building Number of floors

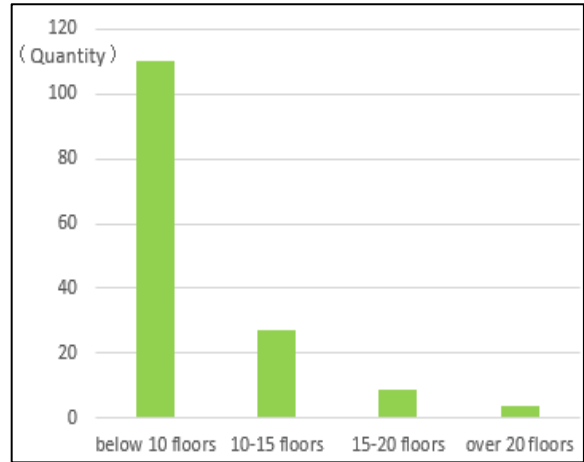


Fig. 6. Living floors

The main source of hot water investigation for existing residential buildings: figure 7, the main styles of residential hot water have gas water heaters, electric water heaters, solar water heaters and district heating, the amount for using gas water heaters is 21, accounting for 14% of the survey, the amount for using electric water heaters is 93, accounting for 62%, the amount for using solar water heaters is 33, accounting for 22%, only have 3 residents used the district heating water. 90% existing residential buildings of survey are completed after 2000, the investigated existing residential buildings of using electric water heaters and solar water heaters are most, and some use gas water heater in the cold regions and cold area.

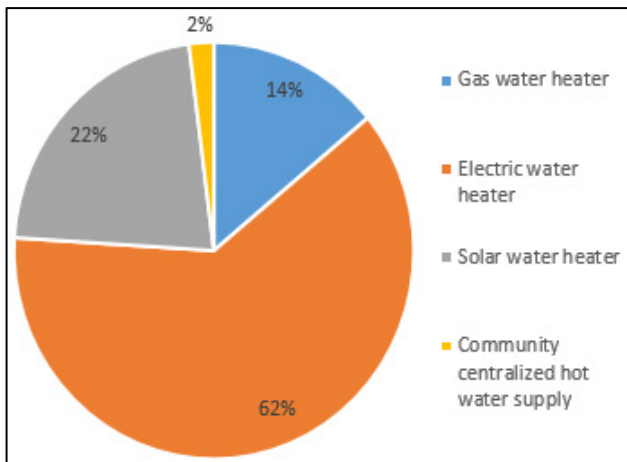


Fig. 7. Domestic Hot Water Source

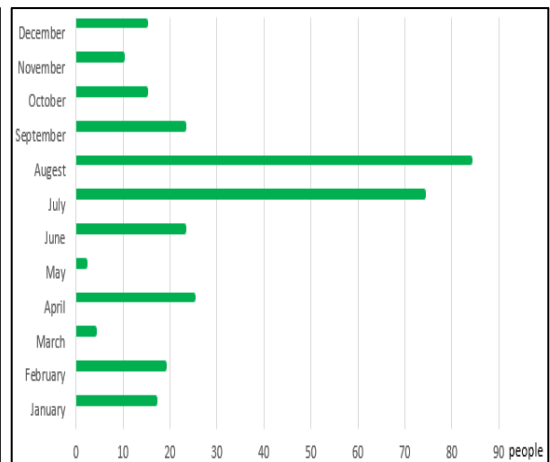


Fig. 8. Air conditioning use

The air conditioning investigation for existing residential buildings: Survey has been conditioned in the form of existing residential buildings, it mainly used is the split air conditioning. Figure 8, in July and August, the outdoor temperatures of the month are relatively high in the cold regions and cold area, most people use air conditioning in summer. In April and October, some people use air conditioning, In April and October, before the heating and after the heating, in which outdoor temperature is too low, and no heating, so some heat by using air conditioning. In December, January and February, there are some people using air conditioning, because the three months is very cold, it is the lowest outdoor temperature in the cold regions and cold area, some residents may use additional heating and air conditioning during this period in order to ensure the indoor temperature. So it also can see the pattern for air conditioning use throughout the year in the cold regions and cold area.

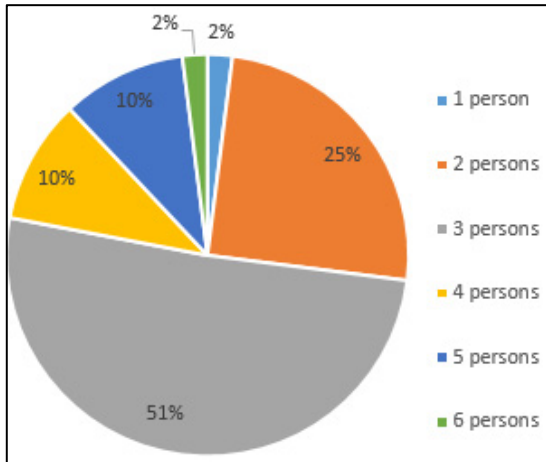


Fig. 9. Family members

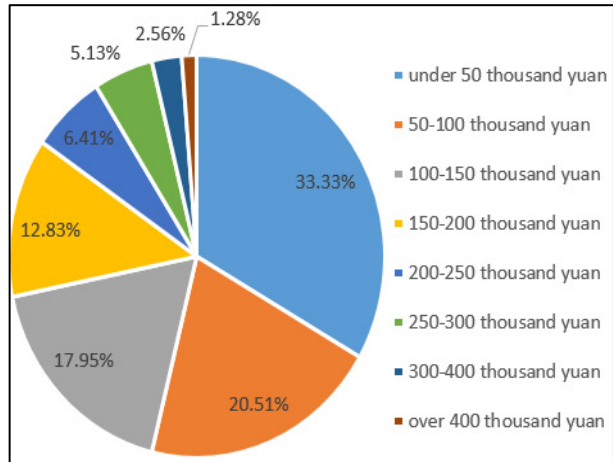


Fig. 10. Family income

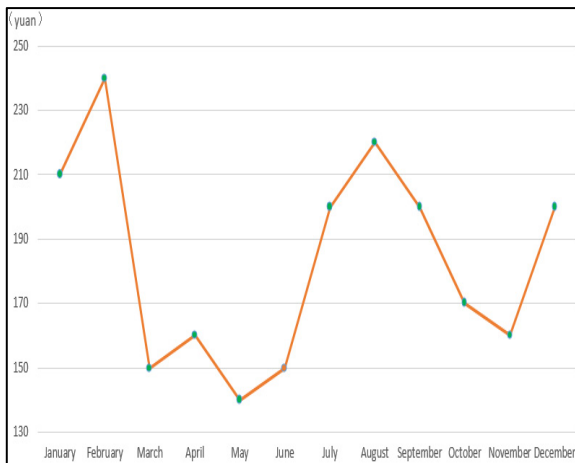
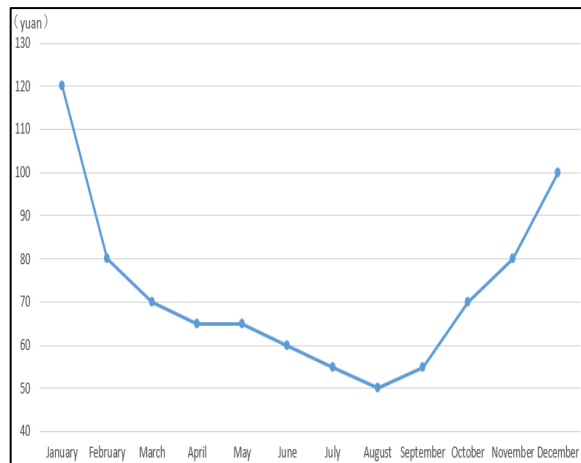


Fig. 11. Monthly tariff Fig.



12. Monthly gas bills

The family composition and economic investigation: in the results of the survey, it can find each family composed of 1 to 6 people, by calculating the average number of persons per household, it gets 2.87 people. Figure 9, the amount for traditional three-person family accounts for 51% of the total number, 25% of the total number are two-person family, and the amount for four-person family is 10%. The same time, the investigation for household income can be got, about 30% of households, their households income are below 50,000 yuan, and the amount for household income

between 50,000 and 100,000 yuan accounts for 20%, there are about 50% of households, their household income are over 150000 yuan. It can be seen, two-people family and three-people family regions are relatively more in the cold regions and cold area, and the family household income of 100,000 yuan and less number is also the majority.

Monthly energy consumption investigation for existing residential buildings: the investigation of the existing residential buildings is aimed at electricity and gas. Figure 11, draw electricity consumption peak appears twice, the first is from July to September, because outdoor temperature is higher from July to September, the three months mainly use air conditioners and fans. The second peak occurs from December to February, outside temperature is low, it is also in the winter heating period, some families use extra electricity heating, infrared heating and air conditioning heating etc. In addition, in the winter the use of household appliances will be relatively frequent. From July to September, there will use a lot of water, and until December to the second-year February the amount is larger, reaching a maximum in January. July to September, because it is summer, households should use water for bathing every day, not only increases the amount of water, increased the amount of gas and electricity. Figure 12, July to September, amount of gas is less, the weather is hot, some households will have dinner in outside, thus should reduce the energy consumption of home cooking, and it can reach the maximum in January, that is Chinese traditional Spring Festival, during the time, family and friends reunite more, cooking, hot water, electricity, gas etc. It can be obtained from the above, the energy consumption of existing residential buildings has obvious seasonal in the cold regions and cold area.

4. Discussion

The influence sensitivity simulation for building energy: Through the existing residential building energy consumption and indoor environmental quality research, it can obtain that the building envelope, households located in the building location, the main source of domestic hot water, air-conditioning using and household behavior and other factors can have a significant impact on energy consumption for existing residential building. Above process analysis only get the influence factors of the energy consumption for existing residential building, the sensitivity of each factors was not in-depth comparison, therefore, in order to further understand the factors sensitivity, the rest of this article will be based on actual energy using patterns for existing residential buildings, by using the DeST-H software to simulate the annual dynamic, analyzing the influence factors sensitivity of energy consumption for typical urban existing residential building. However, due to the limited length of the article, only prepare energy consumption factors sensitivity for the building envelope heat transfer coefficient and window heat transfer coefficient of residential building.

Selecting the model of Shenyang City, simulated construction area is 90 m², a living room, two bedrooms, a bathroom, building is slab floor, building faces north-south, reinforced concrete structure, there are 3 people living in the house, figure 13 and figure 14 are the plan and perspective view of the model.

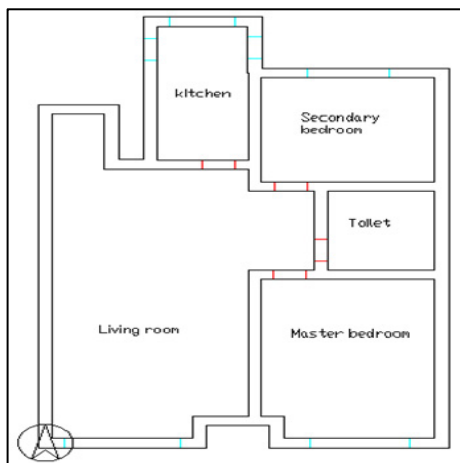


Fig. 13. Plan

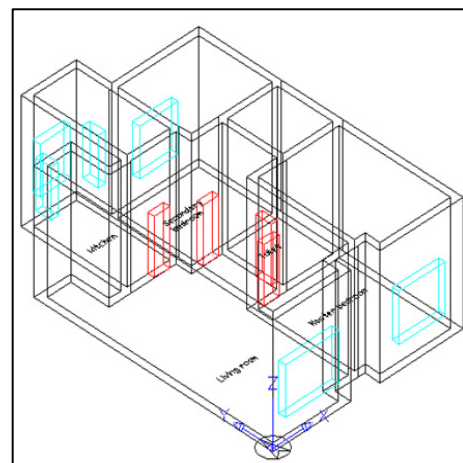


Fig. 14. Perspective

The energy consumption sensitivity of facades heat transfer coefficient for existing residential building: window performance under the premise remains the same, the sensitivity of facades thermal performance, by changing the external wall heat transfer coefficient, getting the resulting of building heating energy consumption, the total annual energy consumption and cooling, and aggregated into figure 15. Figure 15, in the cold regions and cold area, under the reality of energy model for existing residential building, winter heating energy consumption of existing residential buildings reduce with improving the thermal performance of walls, and the air-conditioning energy consumption for summer cooling is can also reduce, but reduction is small. Therefore effect heat transfer coefficient of the walls of existing residential building heating energy consumption by calculating is 0.9983, the sensitivity of influence factors for air conditioning energy consumption is 0.9967, and sensitivity of influence factors for annual energy consumption is 0.9993.

The energy consumption sensitivity of the window heat transfer coefficient for existing residential buildings: Under the facade of the performance remains the same premise, studying the thermal performance sensitivity of windows. By changing the heat transfer coefficient, getting the resulting of building heating energy consumption, cooling energy consumption and total annual energy consumption, and aggregated into figure 16, Figure 16, in the cold regions and cold area, with window heat transfer coefficient reduced ,the energy consumption for heating in winter is reduced, and it is obvious impact on air-conditioning energy consumption for summer cooling, the reduction is smaller and smaller, the total energy consumption of the building is also reduced. Therefore, the sensitivity coefficients obtained by calculating the sensitivity of influence factors for window heat transfer coefficient respectively, the sensitivity of influence factors for heating energy consumption in existing residential buildings is 0.8671, the sensitivity of influence factors for air conditioning energy consumption is 0.9233, the sensitivity of influence factors for the annual energy Consumption is 0.9327.

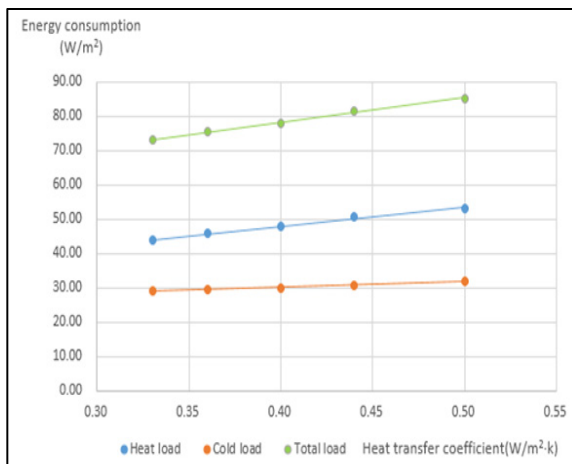


Fig. 15. Influence of wall

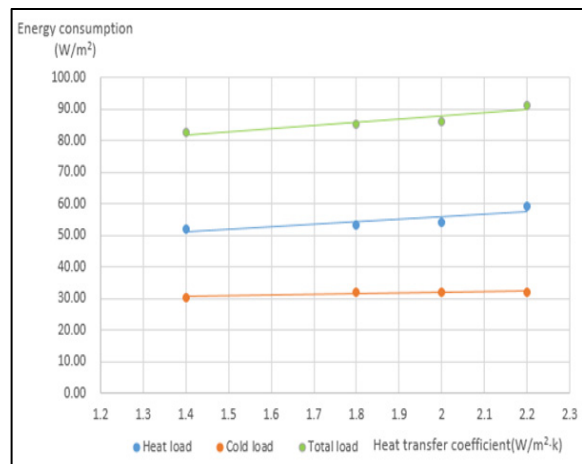


Fig. 16. Influence of window

5. Conclusions

Through existing residential building energy and indoor environmental quality research in the cold regions and cold area, analysis to obtain the building envelope, households located in the building location, the main source of domestic hot water, air-conditioning using and household behaviors etc. The energy consumption factors of existing residential building. Through using DeST-H software, to simulate the existing residential building envelope, include the heat transfer coefficients of the walls and windows for energy affect sensitivity. Existing residential buildings in the cold regions and cold area, for cooling air-conditioning energy consumption, target of energy-saving in the summer, it focuses on taking use of green renovation to improve the thermal performance of walls, it will achieve better results, but the size of walls is large, so improving the thermal performance of windows will also get better results for using equal money. For heating energy consumption, the energy-saving target in the winter, it focuses on taking use of green

renovation to improve the thermal performance of external walls, it will also achieve better results. For the total annual energy-saving target of existing residential buildings, then the green renovation to improve the exterior wall, the thermal performance will get better results than using outside windows to improve thermal performance. Therefore, through the sensitivity of influence factors for analyzing building energy consumption in the article, it can preferably provide a theoretical basis and technical support for the green renovation of existing residential buildings in the cold regions and cold area, and come up with concremented suggestions and comments, so green transformation can achieve better results and economy.

Acknowledgements

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