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Research Paper

Energy Renovation of an Old University Building

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A B S T R A C T

Old buildings consume a lot of energy and no longer comply with the regulations, which creates interior discomfort. Our work consist highlighting the effect of the rehabilitation of the building on energy sav and thermal comfort. The case study is an old building converted into of We made a dynamic thermal simulation under TRNSYS 17 to analyz thermal and energetic behavior of the building. The results obtained insulating the opaque walls and replacing the openings are very conclu Surface losses decreased by 72%, the heating power decreased by 67% the air conditioning power decreased by 50%.

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1. Introduction

The residential sector is one of the major sources of energy consumption, with a high-energy conservation potential. Energy consumption reduction could be achieved through Energy-Efficient Renovation (EER). This paper [1] presents a systematic review of EER adoption influences and EER diffusion modeling. The review starts with an overview of EER adoption drivers, barriers, and policies, and then introduces the adoption influences, including socio-demographics, housing factors, social influences, and environmental attitudes. The significances of these influences vary across different studies, and studies focussing on influences cannot provide insights into the number of resources and efforts needed to overcome the barriers.

The calculation method proposed in the Hungarian TNM decree was used to calculate the energy consumption of heating and domestic hot water supply in winter [2]. Its effectiveness has been well verified by three cases of old urban buildings in Tianjin. On this basis, the urban buildings completed before 2005 in Beijing before and after the renovation were studied. Replacement of envelope materials and replacement of energy supply system components are adopted for the energy-saving renovation of the old urban buildings in Beijing. After the renovation, the energy-saving rate of the old urban buildings completed between 1978 and 1985 can reach 65.53%. The energy-saving rate of the buildings completed between 1986 and 1995 and that between 1996 and 2005 can reach 55.04% and 32.79%, respectively. Beijing has a high building density. Some buildings in Beijing are not suitable for demolition and reconstruction. For these buildings, optimizing their envelope structure and indoor control equipment is helpful to their energy-saving renovation. Increasing the policy subsidies for the renovation of old buildings and improving their effectiveness for a given period will achieve remarkable results in the energy-saving renovation of old buildings in Beijing.

The housing complex Traneparken has been chosen as a Danish case study for the project [3]. It has been retrofitted with new facades, new windows, additional insulation, mechanical ventilation with heat recovery, and a photovoltaic installation on the roof. The measured energy consumption for heating and domestic hot water before and after the renovation was 736 MWh/year and 506 MWh/year respectively. Hereby, the project has demonstrated that the renovation resulted in significant energy savings. This paper presents results from the Danish case study.

The added insulation and new ventilation systems improved the thermal comfort and air quality in the flats. The warmer walls and windows make it easier and more comfortable to utilize all square meters of the apartments. All flats now have a balcony overlooking the also refurbished green areas of the courtyard surrounded by the blocks of flats.

A PV system on the roof of one of the blocks helps reduce the energy consumption of the common laundry facility. The overall energy demand and energy bill for heating is reduced by 31 %. The electricity demand for ventilation has gone up, but the electricity production from the PV system covers around 60 % of this increase.

It was considered to be important that the tenants received what they expected, so from the beginning, a great deal of effort was spent on making sure that the expectations were adjusted to what could be realized in practice. The inhabitants/tenants had to be part of the decision-making process (tenants' democracy is mandatory in Denmark).

The building studied is a typical case of the seventies in Algeria [4]. The integration of thermal insulation can be considered an effective and reliable solution in semi-arid climates for this type of building: the total energy loads relating to air conditioning have been reduced. The solution that seems to constitute a good compromise is the complete insulation of the building. The implementation of these various measures has reaffirmed that the potential for energy improvement depends primarily on the envelope of the existing buildings, leading to an improvement in the conditions of comfort, and a greater sanitary quality of the spaces. The analysis has shown that the introduction of an insulator allows a significant lowering of the interior temperature and quite significant reductions in cooling energy demand (up to 37%). However, the insulation associated with the use of double glazing can reduce energy consumption by half. The various simulations undertaken have reaffirmed the preponderant role of the insulation of opaque and glazed walls in reducing air conditioning loads. However, the most economically justified improvement measure is the insulation of the roof associated with external insulation of the envelope and the use of low-emission double glazing.

2. Description of the building studied

The case studied is an old building that housed the National Institute of Commerce (INC Algiers). Located in the western suburbs of the city of Algiers at an altitude of 270 meters, this building currently houses the offices of the Renewable Energies Development Center (CDER). We use the TRNSYS17 calculation tool to analyze the thermal and energy behavior of the building.

The building studied

Table.1. composition of the walls before and after renovation (from outside to inside).

Opaque and glazed walls	Before renovation	After renovation
Exterior wall	Cement mortar Hollow brick Air blade Hollow brick plaster	Cement mortar Expanded polystyrene Cement mortar Hollow brick Air blade Hollow brick plaster
High ceiling	Cement mortar Hollow brick of heavy aggregate concrete plaster	Cement mortar Expanded polystyrene Vapor barrier(bitumen felt) Cement mortar Hollow brick of heavy aggregate concrete plaster
Openings	Single glazing	Double glazing
Door	Light wood	Heavy wood

3. Mathematical formulation

To study the heating requirements of the building, it is necessary to calculate thermal losses by surface, linear, and air exchange.

1. The need for useful heat depends on the thermal qualities of its envelope (thermal resistances), and its losses by ventilation [5].

$$Q_{L,heat} = [(k_s \times A) + (C_P \times \beta \times V)] \times HDD \quad (1)$$

The heating degree-day *HDD* is the sum of all degree days for each day of the chosen period, for which the non-heating temperature was higher than the temperature without heating.
The heating degree-days can be written as follows: [6]

$$HDD = \int_{\Delta t} (T_{NH} - T_{WH}) dt \quad (2)$$

Where: Δt is the chosen period,
The non-heating temperature (T_{NH}) is the temperature from which heating can be stopped, taking into account free internal contributions.
The temperature without heating (T_{WH}) is the temperature that would be obtained in an unheated, unoccupied building. This temperature is equal to the average outside temperature.
By making the energy balance, solar contributions intervene in the energy needs for heating. The utilization factor of heat gain is a function of thermal losses and solar contributions by glazing and opaque walls.
The net monthly energy needs for heating are determined as follows:

$$Q_{heatnet} = Q_{L\,heat} - \eta Q_{g\,heat} \quad (3)$$

2. Heat losses are calculated for the cooling period according to the same principle:

$$Q_{Lcool} = [(k_s \times A) + (C_P \times \beta \times V)] \times CDD \quad (4)$$

The cooling degrees days *CDD* is the sum of all degree days for each day of the chosen period, for which the non-cooling temperature is higher than the temperature without cooling.
The cooling degrees days can be written as follows:

$$CDD = \int_{\Delta t} (T_{NC} - T_{WC})\, dt \quad (5)$$

Where: Δt is the index of the chosen period,
The non-cooling temperature (T_{NC}) is the temperature from which air conditioning can be put on in buildings; this temperature is equal to the external temperature.
The temperature without cooling (T_{WC}) is the temperature that could be obtained in a building with cooling.
By considering solar and internal contributions, according to the 1st law of thermodynamics,

the conservation of energy in the house can be used, which gives:

$$Q_{coolnet} = Q_{L\,cool} + Q_{g\,cool} \qquad (6)$$

4. Building energy model

The energy analysis of a building is carried out through a series of scenario simulations using different solutions for the energy components. Practically, TRNSYS allows us to compare two alternative scenarios:

- A simulation of the base case which is the model to be developed and optimized. It deduces the real state of the building in terms of consumption.

-A simulation of the proposed case: builds on the model with the modifications and improvements dictated by the energy efficiency solutions available.

The building is represented by type 56 (multi zones), in which we enter the building data in Trbuild, such as the surfaces and materials making up the opaque and glazed walls, respecting the orientation of each wall. the desired comfort parameters and building occupancy scenarios are set, as well as the required output data. after various simulations of the program, results are obtained and represented by graphs.

5. Results and discussion

The METEONORM software gives the climatic data of the site and is then integrated into the program to simulate the thermal behavior of the building studied.

The case study is one floor of a building used as offices with a net volume of 903 m^3.

In the cooling mode, the set point temperature is fixed at 27 °C for all building zones; in the heating mode, the set point temperature is set at 21 °C.

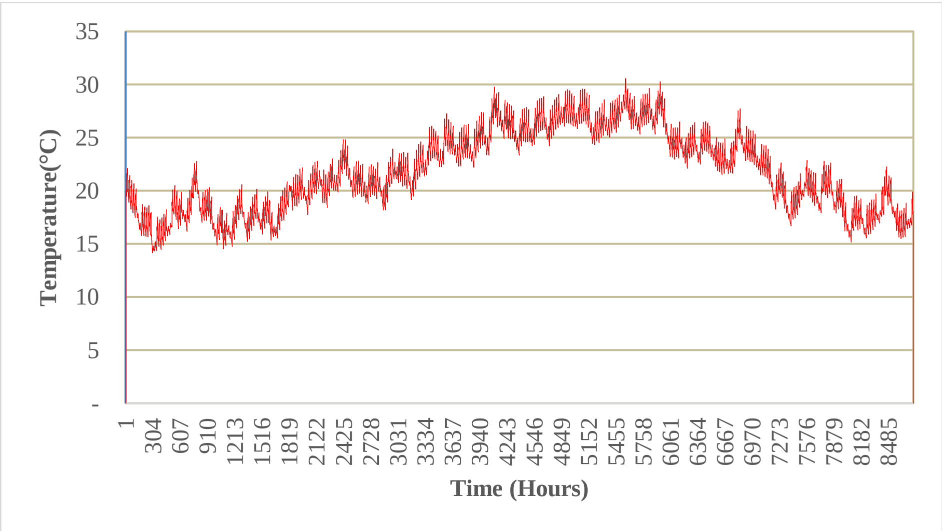

Fig.1. Unheated local temperature

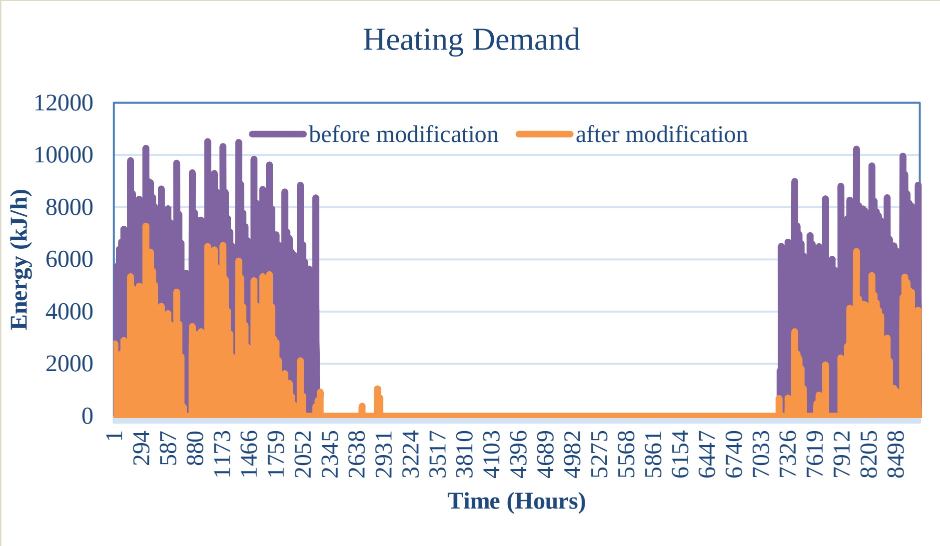

Fig.2. Annual Heating Demand

The ambient temperature of the premises is below 20 °C for time = 1- 1749 hours, which corresponds to the beginning of January until the end of March, then the temperature increases to more than 30 °C at t = 5565 hours (mid-August), then drops again below 20 °C at t = 7239 hours, which corresponds to the beginning of November.

We deduce that heating is necessary when the temperature is below 20 °C (Fig. 1). In Fig. 2, the heating demands are represented in both cases (before and after renovation); We see a significant difference in heating demands, and looking closer at the end of December, the following graph is clear:

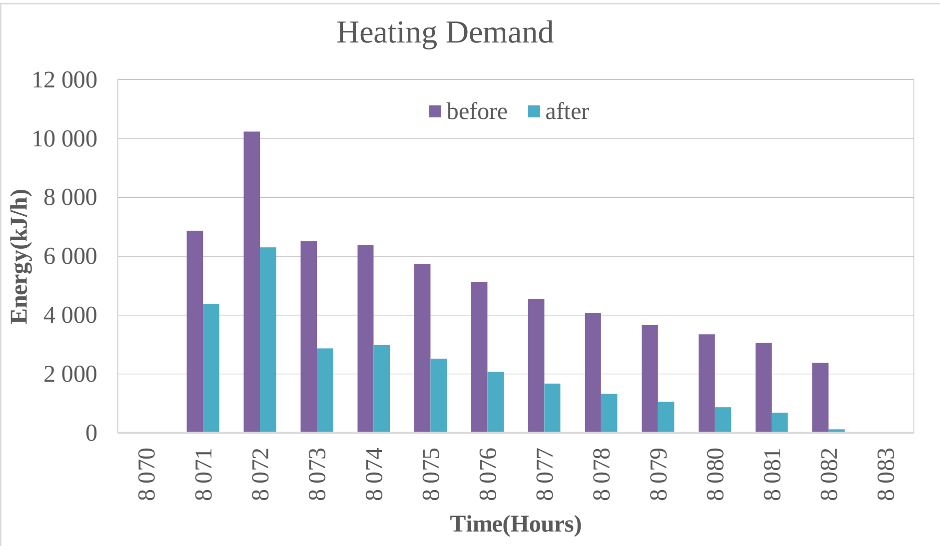

Fig.3. Heating Demand during December

In Fig. 3, at t = 8072 hours, the heating demand before the renovation of the building is 10000 kJ/h, whereas, after renovation, the heating demand is 6000 kJ/h, saving 4000 kJ/h.

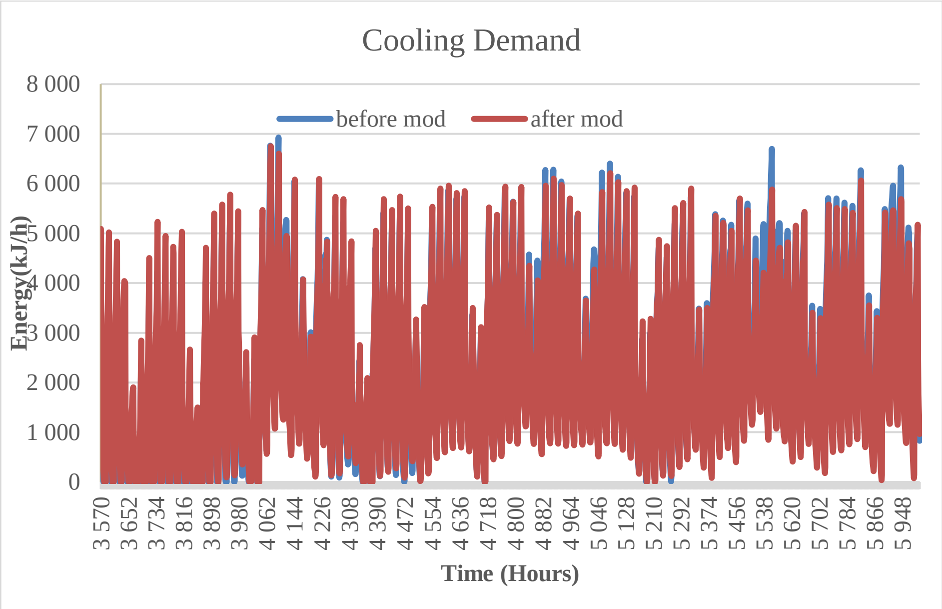

Fig.4. Cooling Demand during the summer period

The temperature values are above 25 °C from t = 3570 hours, which corresponds to the end of May, until t = 6000 hours, which corresponds to the beginning of October. So we need air conditioning during the period from June to mid-September (fig. 4).

The difference in air conditioning demand is clearer when taking a period t = 5484 h to 5608 h, which corresponds to the second half of August (fig.5).

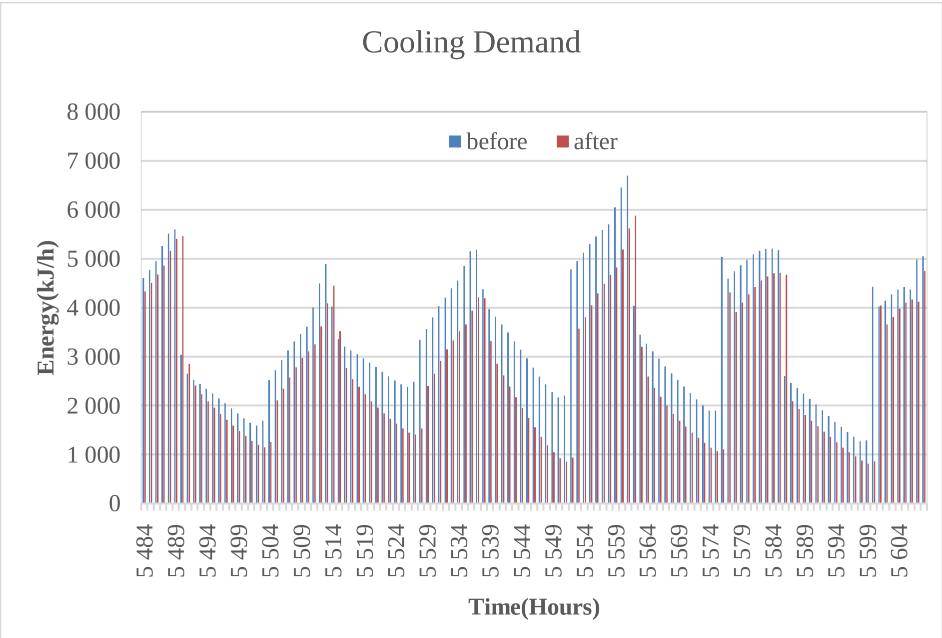

Fig.5. cooling demand during the second half of August

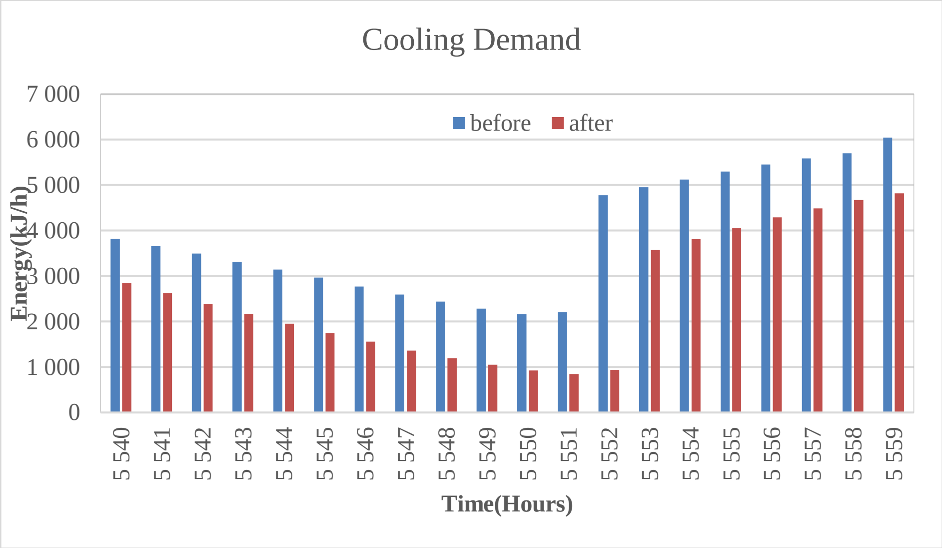

Fig.6. Cooling Demand for one day of August

By representing the values obtained for one day (fig.6), we can see the energy gain for cooling by applying energy rehabilitation to the building. At t = 5552 hours, the energy demand before renovation would be equal to 4780 kJ/h, on the other hand, after renovation, it would be 940 kJ/h. We have a savings of 3840 kJ/h,

6. Conclusion

Our article highlights the effect of the renovation of old, energy-intensive buildings on energy savings. By insulating the envelope and changing the single glazing to double glazing, the surface heat losses decreased, which means that the demand for heating and air conditioning is lower.

The results obtained after insulating the opaque walls and replacing the openings are very conclusive. The surface losses decreased by 72%, the heating power decreased by 67%, and the air conditioning power decreased by 50%.

Applying energy rehabilitation criteria, a saving of 4000 kJ/h for heating and 3840 kJ/h for air conditioning is noted.

Subsequently, we can integrate systems using renewable energies to cover the energy needs of the building.

Thereby remaining respectful of the environment and energy saving.

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