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Impact of various parameters on the energy consumption of residential buildings

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Abstract

The aim of our study is to vary different energy parameters to observe their influences on the annual heating needs of a building apartment. Multiple cases of thermal resistances, glazing areas and orientations have been analyzed by using dynamic simulations. We wanted to check the importance of accurate data of the building envelope thermal resistances on the heating demand. It was found then small errors (0,25÷0,3 m^2K/W) on the thermal resistance can have a large impact on the heating demand (from 5% to 25%). The use of standard thermal resistances values based on the age/structure are a good solution to reduce the errors and will contribute to a clearer and more correct comparison of buildings energy consumptions.

Key words : energy certification, heating demand, compactness factor, thermal resistance

Rezumat

Scopul studiului nostru este de a varia diferiți parametri ai anvelopei unei cladiri pentru a observa influența lor asupra consumului de energie pentru incalzire. Au fost studiate mai multe cazuri in care a fost variata rezistența termica, suprafata vitrata și orientarea, acestea fiind analizate prin intermediul simulărilor numerice in regim dynamic (calcul orar). Am vrut să verificam importanța rezistențelor termice asupra consumului de energie si impactul unor erori asupra acestui. S-a constatat ca pentru erori mici (0,25 ÷ 0,3 m2K/W) privind rezistența termică acestea au un impact major asupra consumului de energi (de la 5% la 25%). Utilizarea de valori standard pentru rezistențele termice pe baza vârstei clădirii/structurii reprezintă o soluție bună pentru a reduce erorile și va contribui la o comparație mai clară și corectă a consumurilor de energie clădirilor. Utilizarea de astfel de valori este deja pusă în aplicare în metodologia din Franța.

Cuvinte cheie : consum energie, rezistențe termice, clasificare energetică

1. Introduction

With 44 % of the energy balance of France, the building sector is the most energy-consuming. This sector also contributes with more than 23 % for the national greenhouse gas emissions. Two-thirds majority of these consumptions concerns the residential sector. The mean average consumption of final energy is about 17 435 kWh per housing in 2010, against 20 931 kWh per housing in 1990. The gas and the electricity are the primary sources of energy consumed, mainly for the heating, which represents about 68 % of the total consumption. Since 1973, the average mean consumptions of heating by surface has dropped by 58 %. This progress was made possible thanks to the Energy Directives (RT2005 and RT2012) for new buildings. So, the total average mean consumption passed from 352 kWh/m² in 1973 to 186 kWh/m² in 2011 (-1.2 % a year, on average). However, during the same period, the mean average consumption of specific electricity has more than doubled, from 13 kWh/m² in 1973 to 30 kWh/m² in 2011. This phenomenon is understandable in particular by the progress of the equipment in household electrical appliances, hi-fi and office automation [1-2].

The assessment of the buildings' energy performance (DPE in France) is a real energy ID card of the house by detailing the energy performance of the building for standard climate and use of the building.

There are two ways to evaluate the DPE [3] for the buildings. Firstly by using a conventional method like 3CL-DPE method, valid only for housing with individual heating whatever is their year of construction, by taking into account the thermal characteristics of the building (climatic zone, insulation, glazing) and the systems of heating and ventilation settled. The second way is to evaluate buildings' energy performance from the energy bills of the last three years (often used for housing before 1948, apartments warmed collectively, and tertiary buildings). The method 3CL-DPE has been integrated in numerous software in France to make the studies more easily.

To carry out our study we are going to use a more complex and precise software available in France allowing a dynamic thermal simulation. This software is called TRNSYS 17.0 and it is a tool of simulations that has showed its performances and was the object of several validations [4-6]. The purpose of our study is to vary several building parameters to observe their influence on the annual heating demand. It will allow us then to analyze the impact of these parameters on energy certificate of a building [8-9].

2. Project study

Today, the use of numerical simulations for the thermal behavior of the building allows to obtain a prediction of the energy consumption. It also allow to vary a large number of parameters subject to numerous uncertainties. For an energy certification, it is important to know very well these parameters to be able to estimate correctly the real needs. Our study case was done using the geometry of an apartment.

The various parameters studied in this study are:

- the thermal resistance of the outside walls
- the thermal resistance of the floor adjacent to a basement
- the thermal resistance of the roof
- the orientation of the apartment
- the glazed surface

We shall set as the base a standard apartment of a building built in the 70s. The considered apartment contains a wall adjacent to the staircase, internal walls and the outside wall. The volume considered for the apartment is 84.1 m^3.

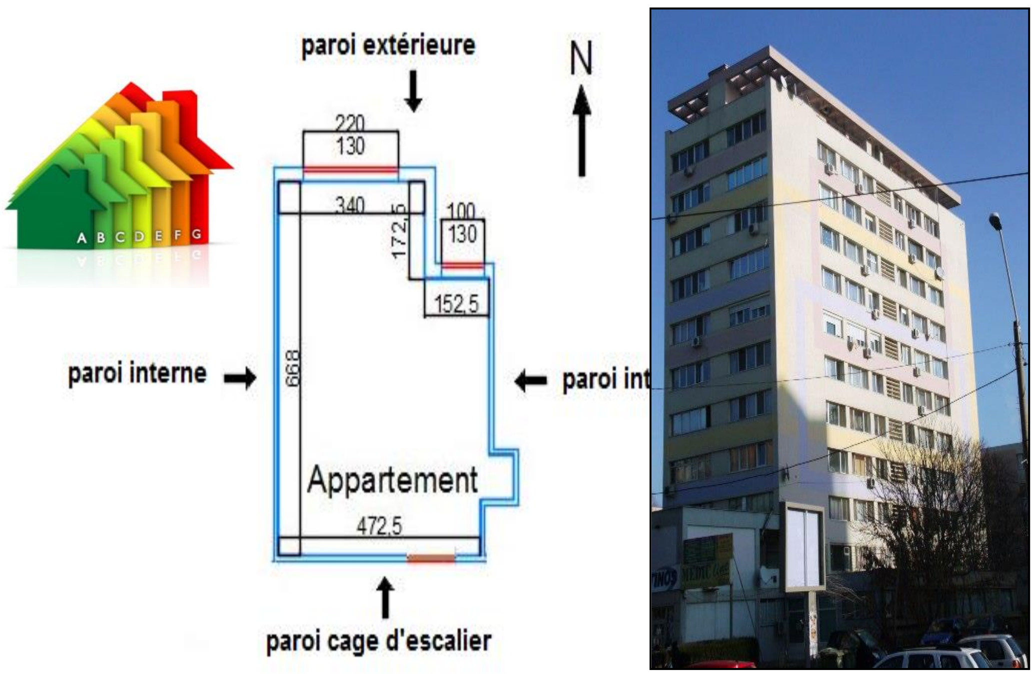

Figure 1. Geometry and heat loss surface of the studied appartment

The values of thermal resistance of our basic case are : $R_{wall\text{-}outside}$=0.74 m²K/W, R_{roof}=1 m² K/W, R_{floor}=0.55 m²K/W. These base case scenario values were obtained after studding a large database of energy audits of multiple-flats buildings.

These values of resistance correspond to corrected values, including thermal bridges. As regards the orientation, we choose to put walls glazed to the North. For the climate, we have considered that the apartment is situated in the city of Lyon, France (altitude 200m).

3. Results

Study case part 1

Usually, the majority of heat losses comes from vertical walls in direct contact with outside. It is even truer if the wall is large and badly isolated [7]. Firstly, we are going to study the impact of the resistance of the outside wall on the heating demand.

Case 1 : Apartment situated in the middle of the building

The more the thermal resistance of the wall is big, the less it has of influence on the variation of the need for heating.

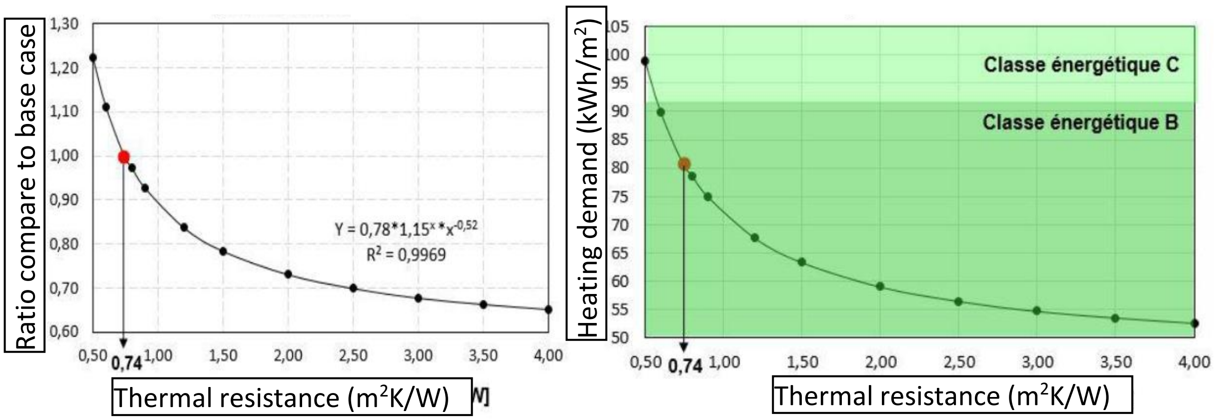

Figure 1. Impact of external walls thermal resistance on the heating demand (S/V=0,22 m^2/m^3)

The compactness factor (sum of heat loss surfaces divided by the heated volume) is very important for heating demand of an apartment. In other words, an apartment situated in the middle of the facade of a building which has only a single external wall will be more sensitive to a variation of the thermal resistance. The compactness value is 0,22 m^2/m^3.

Case 2: Apartment situated at the last floor of the building

In this case, we have considered that the roof is also a heat loss surface. This case could be similar to an apartment positioned in the last floor of a building. For this case the compactness factor value is 0,59 m^2/m^3.

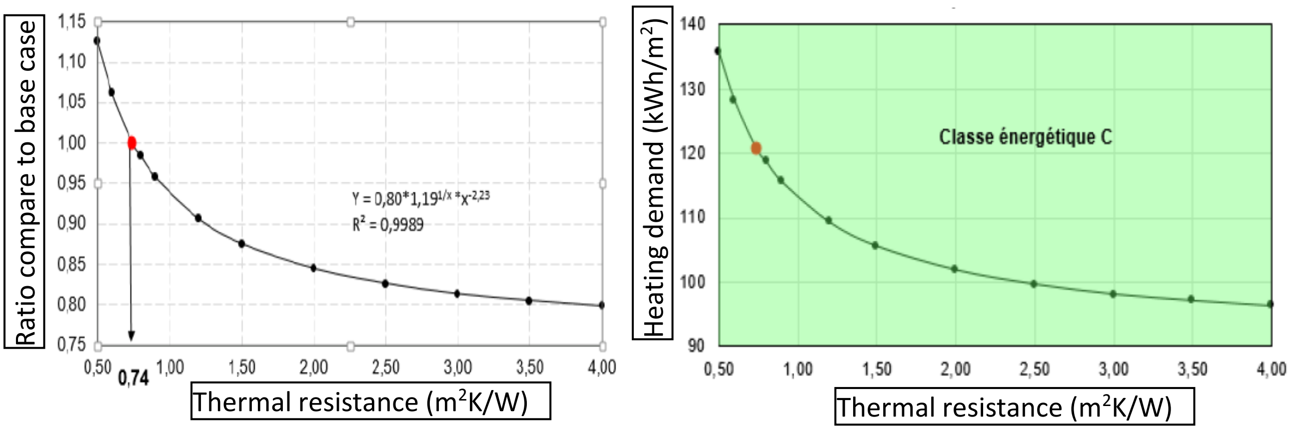

Figure 2. Impact of external walls thermal resistance on the heating demand (S/V=0,59 m^2/m^3)

Case 3: Apartment situated at the building corner

In this last case, the roof is not anymore a heat loss surface, on the other hand, the internal wall from the base case (S=18.70m²) is now considered as facing west and therefore it is an outside heat loss surface. With this case we are simulating the energy demand of an apartment situated in the corner of a building.

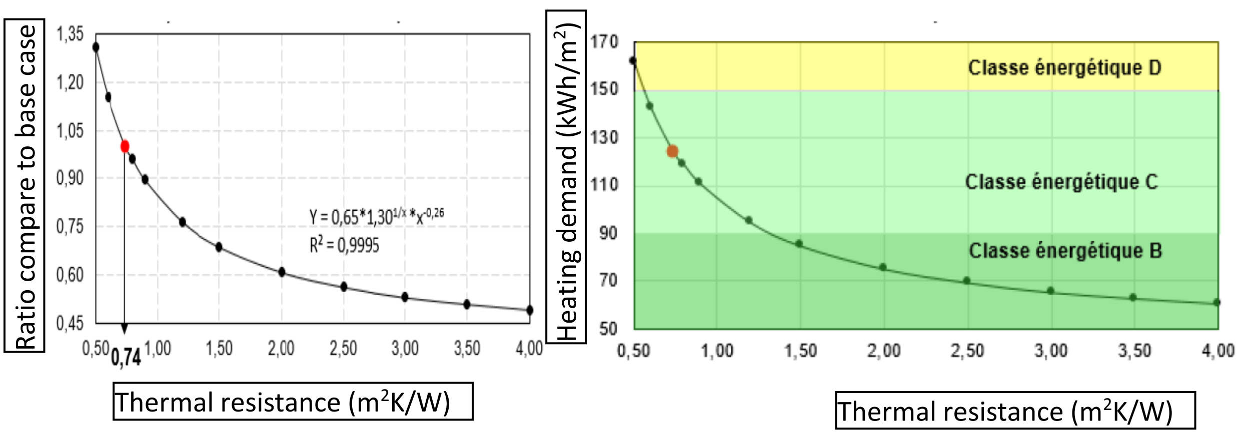

Figure 3. Impact of external walls thermal resistance on the heating demand (S/V=0,44 m^2/m^3)

In this last case, we observe once again the same trend of the curve as for the previous cases. Furthermore, we can also notice that an increase/decrease of the wall thermal resistance has a larger impact on the energy demand more important than the previous 2 cases. For this case the compactness value is 0,44 m^2/m^3. It can be noticed that if we made an error on the Rwall of 0,3 m^2K/W that represents almost 20% (from 125 kWh/m^2 to 100 kWh/m^2 – see Figure 4 b) from the heating energy demand. The errors can be even higher if the external walls area are larger

Study case part 2

A second part of the results consisted of the analysis of the thermal resistance of the floor between the apartment and the basement.

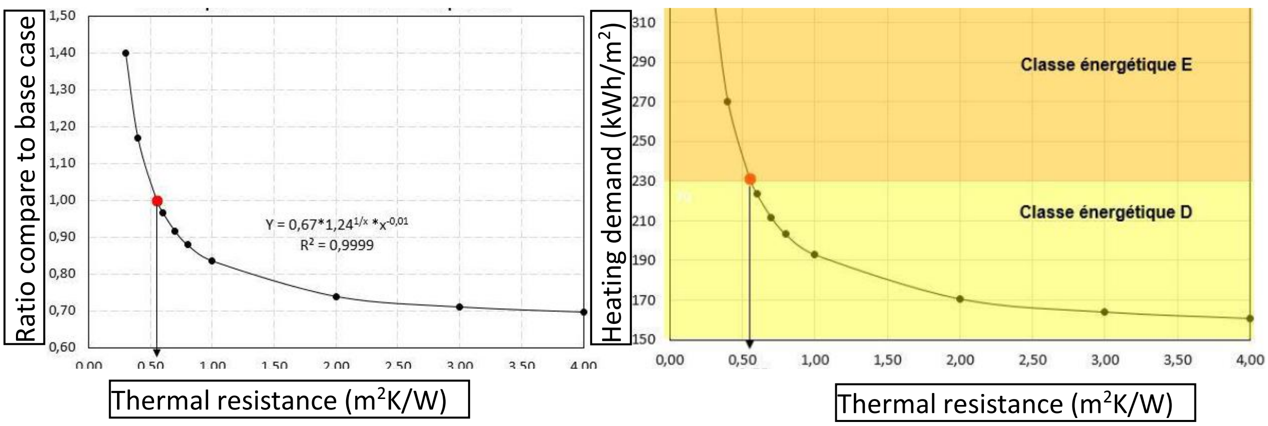

Figure 4. Impact of floor thermal resistance on the heating demand

We can notice the same line trend decrease of the energy demand as previously. We can also observe that the difference between a non-insulated floor and a very good one represents 30% decrease on the energy demand. For the corner apartment the difference was almost 50% while for the middle case apartment was 35%.

Study case part 3

A third part of the study was meant to analyze the impact of the roof thermal resistance on the energy demand of the apartment.

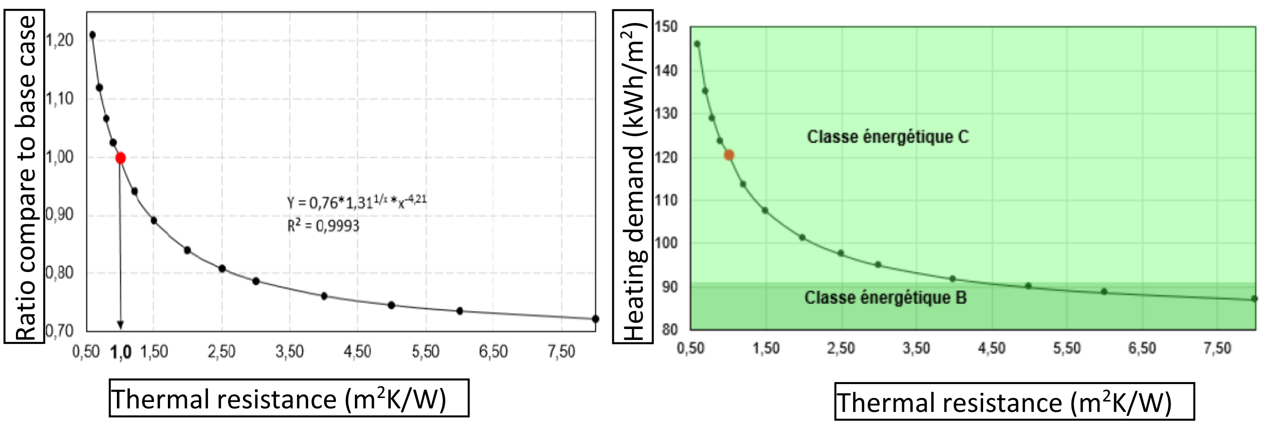

Figure 5. Impact of roof thermal resistance on the heating demand

The third part of the study consisted of the analysis of the roof thermal resistance variation on the energy demand of the apartment. It can be noticed that the difference between a non-insulated roof (R=1 m^2K/W) and an insulated one (R=5 m^2K/W) represents 25% or 120 kWh/m^2

compared to 90 kWh/m^2. A 0,25÷0,3 m^{2}K/W error on the thermal resistance represents no more than 5-7%.

Study case part 4

The last part of the study was dedicated to the analysis of the window thermal resistance and its surface on the energy demand of the apartment. On the two figures below on the x-axis we have the ratio between the glazing area and the apartment surface. The base case corresponds to a 13,3% ratio and a thermal resistance of the window of 0,5 m^{2}K/W.

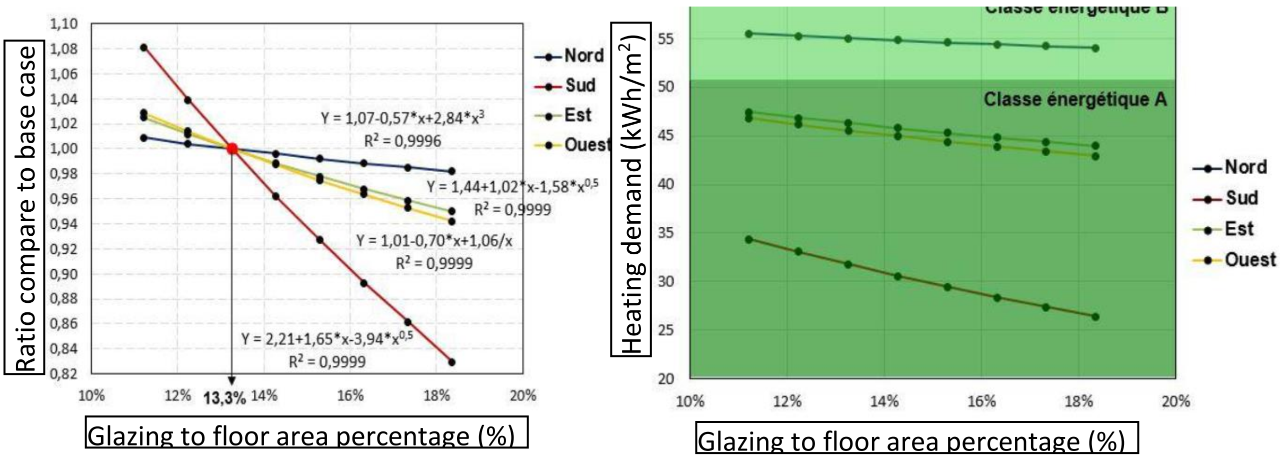

Figure 6. Impact of glazing area and orientation on the heating demand (S/V=0,22 m^2/m^3 and Rwindow =0,5 m^{2}K/W)

4. Conclusions

The energy performance has become an important criterion of choice when buying or renting an apartment. In this article it was shown that even small errors on the building envelope thermal resistances or glazing areas can influence the heating energy demand. For accurate values we have used a well-known dynamic simulations software and we have analyzed more than 50 simulation cases. The article is divided in multiple studies: part 1 – impact of external walls thermal resistance for various positions of the apartment, part 2 – impact of the floor thermal resistance adjacent to the basement, part 3 – impact of the roof thermal resistance and finally part 4 – impact of windows area and orientation on the heating energy demand. The conclusions are as follows:

- For a corner apartment with two external walls a small error (0,25÷0,3 m^{2}K/W) on the thermal resistance can influence by 20% the heating demand,
- For middle apartment with only one external wall a small error (0,25÷0,3 m^{2}K/W) on the thermal resistance can influence by 10% the heating demand,

- For a last floor apartment with only one external wall and a roof a small error (0,25÷0,3 m^2K/W) on the thermal resistance of the roof can influence by 7-9% the heating demand,
- For a ground floor apartment with only one external wall and a floor to the basement a small error (0,25÷0,3 m^2K/W) on the thermal resistance of the floor can influence by 5-6% the heating demand,
- As concerns the glazing area it was noticed that if the orientation is North an error on the glazing area represent less than 5%, however if the orientation is South than the errors can reach even 20%.

In the energy certification of buildings in France, the methodology imposes standard values for the thermal resistances based on the year of the construction. This applies if the walls, roof or floor layers are not known. We believe that such approach should be also used in the Romanian certification methodology to avoid any further errors as we have seen in the article. Using standard values based on the age, structure of the building will avoid large errors.

5. Acknowledgement

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