Conference Paper

Analysis of Heat Balance in a Light Steel Frame Residence with Different Insulating Thickness

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Abstract

Sustainability and efficiency in buildings are concepts that have been recently growing and developing. Its application in several buildings has become mandatory in many countries around the world. One of the major challenges faced by sustainable buildings is the achievement of satisfactory levels in efficiency terms, without negatively impacting the economics. The residential construction sector has great potential for energy savings and is also where building strategies need to be carefully planned, as they seek to meet the needs of residents not only in the present, but also over time. Residential design must be done thoroughly and must include the analysis of all climate variables involved. In order to verify a residential building envelope behaviour regarding energy and thermal efficiency, this paper intended to evaluate through software Design Builder®, walls and roofs with a rock wool layer, placed in a Light Steel Frame (LSF) house.

Keywords: Insulating materials, Light steel frame, Heat gains, Heat losses

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1. Introduction

Sustainability and efficiency in buildings are concepts that have been recently growing and developing. Its application in several buildings has become mandatory in many countries around the world. One of the major challenges faced by sustainable buildings is the achievement of satisfactory levels in efficiency terms, without negatively impacting the economics. Therefore, in-depth and reality-driven studies should be developed in building designs, seeking a comparison between solutions based on environmental principles, which perform efficiently, meet user needs, promotes financial savings and reduces material consumption.

The residential construction sector has great potential for energy savings and is also where building strategies need to be carefully planned, as they seek to meet the needs of residents not only in the present, but also over time. Residential design must be done thoroughly and must include the analysis of all climate variables involved, such as solar

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path, predominant direction of air masses, as well as the surrounding buildings. On the other hand, indoor spaces should be designed to use the most of natural elements while avoiding excessive energy consumption for heating or cooling. Heat gains from the sun should be arranged during winter, while during summer, some strategies should be studied to avoid excessive heat gains [1].

One of the factors that has the greatest influence on the thermal and energy performance of a building is the choice of building materials. Elements that separate the interior and exterior environments of the building, such as walls, roof, glazing and others, must have suitable thermal conductivity characteristics to prevent unwanted energy gains or losses. Often the envelope can be designed with numerous layers, with structural and insulating materials, further improving its thermal properties. Likewise, other sustainable strategies can be ensured, such as natural lighting, the use of natural surroundings to create an appropriate microclimate, along with energy-generating devices from renewable sources, such as solar panels [2].

In order to verify a residential building envelope behaviour regarding energy and thermal efficiency, this paper intended to evaluate through software Design Builder®, walls and roofs with a rock wool layer, placed in a Light Steel Frame (LSF) house.

2. Case Study House: A Light Steel Frame Residence in Bragança

Bragança is a city located in northeast Portugal. As stated by IPMA (Portuguese Institute of Sea and Atmosphere), the city has a Csb climate, according to Koppen Geiger. Figure 1 exemplifies the temperature profile presented by the city throughout the year [3].

This Figure 1 shows that summer and winter temperatures can reach extreme values. Consequently, in order to achieve indoor thermal comfort, passive constructive strategies need to be proposed for the residence. It is also of great importance that the internal temperature remains at a satisfactory level for users all over the seasons.

The case study house is a single-family residence, which has three bedrooms, closet, toilets, home office, an integrated kitchen and dining area, laundry, garage and an outdoor recreation space, totalling 180,00 square meters [m^2]. The residence schematic floor plan can be seen in Figure 2.

It is important to note that this building was designed in accordance with the Portuguese law- decree 118/2013 (transposition of the European Directive 2010/31/UE), which concerns the energy performance requirements of buildings.

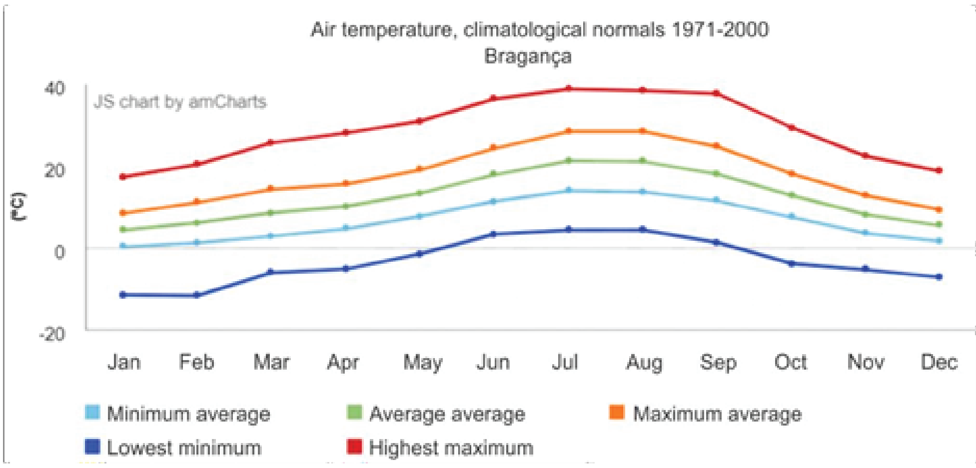

Figure 1: Annual temperature profile in Bragança Source: [3]

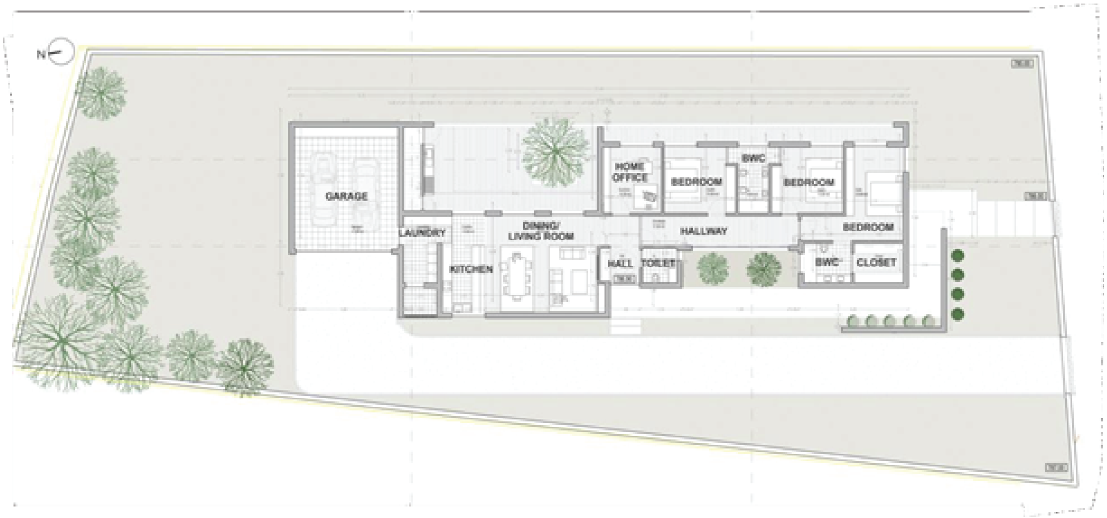

Figure 2: Light Steel Frame residence – floor plan Source: Architect file

Some additional information about the case study house that will impact directly on model efficiency are:

- Will be used LED lighting;
- Heating will be attained by a pellet fireplace (biomass) located in the dining/living room;
- Domestic Hot Water (DHW) will be heated by a heat pump;
- Natural ventilation provided by window openings will be the main cooling device;
- Garage and the laundry room were purposely positioned in North direction, since they represent less significant spaces regarding the direct sunlight.

All the windows in the residence have been positioned to maximizing the natural heat and lighting gains from the sun. Following this principle, the house has no openings directed to the North. Although they represent a large percentage in the building energy efficiency, this paper will not discuss architectural elements, position of the rooms or passive construction strategies applied. The materials of the envelope will be analyzed, considering the floor plan presented in the Figure 2.

3. Thermal Insulation of Building Envelope and Energy Consumption

Elements that directly control heat gains and losses in a building, such as the roof, external walls, floors and windows, are considered building envelope elements. The theory of heat transfer says that heat flows from warmer to cooler zones until there a thermal balance is achieved. Applying this concept in building designs, there are different situations in winter and summer. During the hottest season, heat transfer occurs from the outer spaces to the interior of the building. In winter, heat is transferred from indoor heated spaces to those at a different and lower temperature (outside or unheated environments such as garages) through the envelope elements [4].

In order to decrease thermal gains and losses, along with reducing energy consumption with heating and cooling devices, walls, roofs, windows and floors must be good thermal insulators. There is also the possibility of using layered material compositions, to further improve insulating features. Well-designed buildings with insulated materials must provide comfort and low energy costs all year round [1].

In light steel frame residences, the steel structure that supports the walls has sealing layers in both sides and insulating elements between them. The insulation can be done in different ways and using different materials and compositions. Same is true for the roof.

For the case study residence, the following compositions will be used:

- All the floor plans are composed, from the innermost layer, of 15 mm of timber, 40mm of concrete floating block, 5mm of electric foil heating system, 40mm of extruded polystyrene (XPS) with equivalent thickness in the surroundings, 200mm concrete slab, the lower space is a ventilated clearance (Figure 3a).
- Internal partition walls are composed of two gypsum plasterboard with 12mm each, filled with 90mm of rock wool (mineral wool) (Figure 3b).
- Windows and glazed elements are made up of double glazing with a 16mm air layer between, with PVC frames. Glazed elements are designed with a Heat Transfer Coefficient (U) of 1,5 [W/m^2°C].

- In the simulations the box shutters were disregarded, and it was considered the minimum amount of air changes established by the Portuguese law.
- External doors are made of wood with a Heat Transfer Coefficient (U) of 2,995 [W/m^2°C].
- External walls layers are, from innermost one, a 12mm of gypsum plasterboard, 150mm of insulating material, a 12mm oriented strand board, 100mm extruded polystyrene and 6mm of external rendering. In order to establish a relationship between the consumption of insulating material and its efficiency, two different arrangements of external walls were simulated. The first with 150mm of rock wool and the second with 100mm of rock wool plus a 50 mm air gap, as shown in the Figure 3c and Figure 3d.
- The roof is composed of a light-coloured polyvinyl chloride (PVC) layer (outermost), followed by 100mm of extruded polystyrene (XPS), an 18mm oriented strand board (OSB), insulating material, a variable air gap (it is variable due to the roofing slope), and the 12mm gypsum plasterboard. As well as done in the walls, the roof insulating layer were simulated with two different arrangements. The first with 100mm of rock wool and an average air gap with 300mm, and the second with 200mm of rock wool plus 200mm air gap (Figure 3e and Figure 3f).

Table 1 contains properties of the materials used in each layer of elements compositions.

Table 1: Material properties Source: [6].

Material / Layer	**Density ρ [kg/m^3]**	**Thermal resistance R [m^2°C/W]**
Air	1,23	0,18
Material / Layer	**Density ρ [kg/m^3]**	**Thermal Conductivity λ [W/m°C]**
Concrete Slab	2000 - 2300	1,650
Expanded Polystyrene (EPS)	20	0,037
External render	1800 - 2000	1,300
Extruded Polystyrene (XPS)	25 - 40	0,037
Gypsum Plasterboard	1000	0,400
Oriented Strand Board (OSB)	650	0,130
Polyvinyl Chloride (PVC)	1200	0,140
Rock Wool (mineral wool)	20 – 35	0,045

Values of density, thickness of the material layers and their respective thermal conductivity, which were obtained by ITE 50 [6], are relevant to obtain the thermal resistance

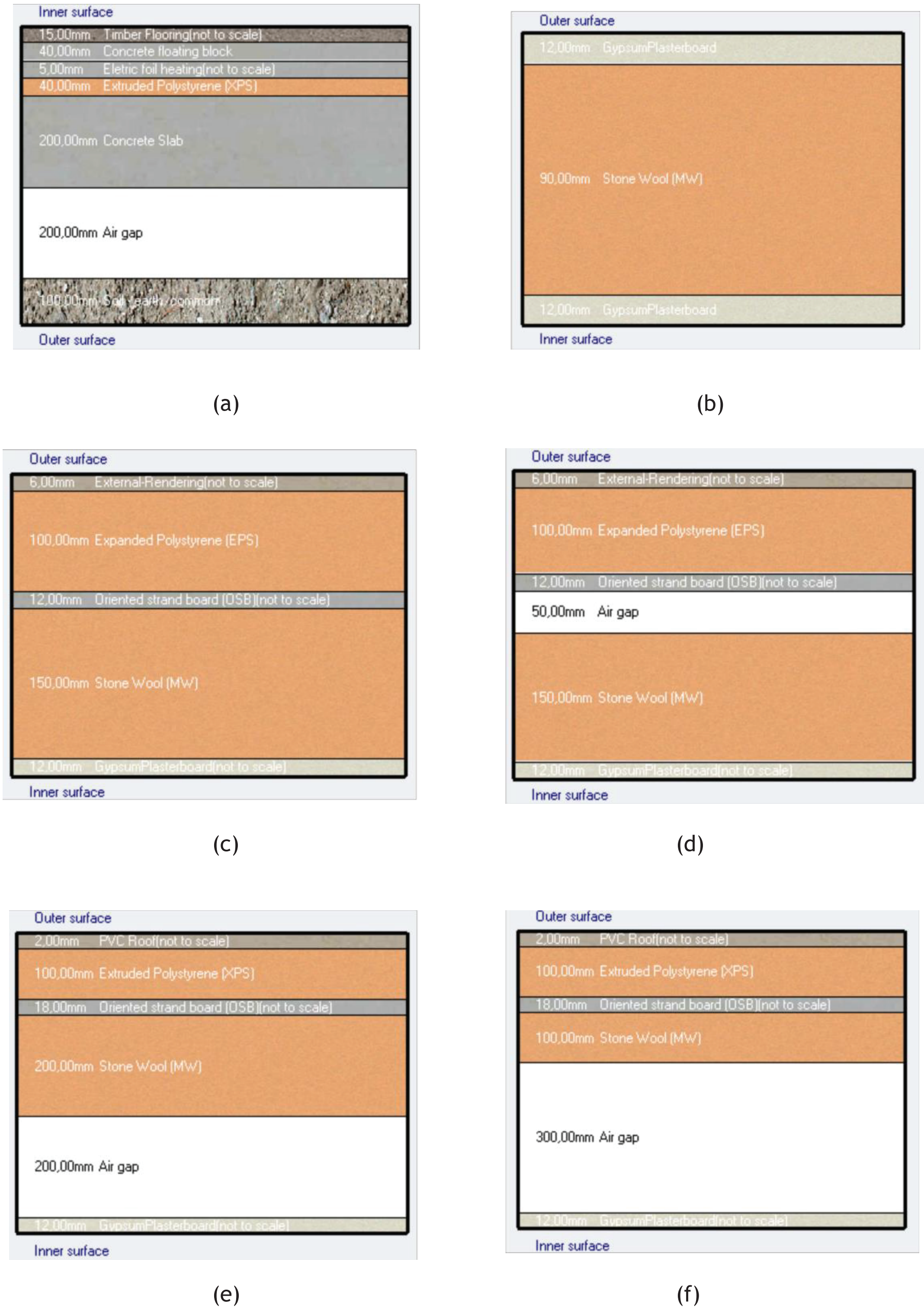

Figure 3: Envelope element layers (a) floor (b) internal partitions (c) external wall 01 (d) external wall 02 (e) roof 01 (f) roof 02. Source: Design Builder® files [5].

of the materials. In turn, thermal resistance together with the indoor and outdoor air temperatures are determining values for obtaining the heat transfer coefficient and verify the behaviour of the material when exposed to different thermal situations [6].

4. Thermal Balance Simulations

In order to find the thermal gains and losses for the case study house, simulations were performed through the software Design Builder®, seeking to compare extreme summer and winter temperatures.

Heat gain simulations were performed (by software settings) considering hourly intervals on July 15. During time intervals the temperature is considered constant. With this information it is possible to observe the heating pattern of the residence through the envelope elements throughout the day.

Heat loss simulations were made considering an external winter temperature, which for the Bragança was defined as -3.8°C.

Considering the elements described in Figure 3, four simulations were performed combining different envelope configurations. In the simulations, the same floor (Fig. 3a), internal partitions (Fig. 3b) and glazing elements were maintained, altering the external walls and roof as follows:

- Simulation 01 - External wall 01 (Fig. 3c) + Roof 01 (Fig 3e);
- Simulation 02 - External wall 01 (Fig. 3c) + Roof 02 (Fig. 3f);
- Simulation 03 - External wall 02 (Fig. 3d) + roof 01 (Fig. 3e);
- Simulation 04 - External wall 02 (Fig. 3d) + roof 02 (Fig. 3f).

5. Results and Discussion

Initially it was possible to calculate the heat transfer coefficient of each element by entering material data in Design Builder®. These values are shown in Table 2:

Regarding the heat transfer coefficient, the higher is the value, the greater is the heat flow through the surface, in other words, lower is the insulating capacity of the material.

Initially, heat loss simulations were done. The corresponding values are presented in Table 3 below:

In the thermal balance for heat losses, some important points can be observed and will influence the materials layers choice. Losses that occur through windows and glazing does not change significantly, being slightly lower when it comes to the roof 02. Walls

Table 2: Construction elements properties Source: [5].

Envelope element	Heat Transfer Coefficient U [W/m²°C]
Floor	0.544
Windows	1,5
Doors	2,995
Wall 01 (Fig. 3c)	0,158
Wall 02 (Fig. 3d)	0,154
Roof 01 (Fig. 3e)	0,131
Roof 02 (Fig. 3f)	0,184

Table 3: Temperatures and heat loss thermal balance Source: Design Builder® simulation [5].

	Simulation 01	Simulation 02	Simulation 03	Simulation 04
Air temp. (°C)	19,20	19,19	19,21	19,19
Radiant temp. (°C)	17,02	16,9	17,04	16,91
Operative temp. (°C)	18,11	18,05	18,12	18,05
Outside dry-bulb temp. (°C)	-3,80	-3,80	-3,80	-3,80
Glazing (kW)	-2,50	-2,49	-2,50	-2,49
Wall (kW)	-0,80	-0,80	-0,78	-0,78
Ground floors (kW)	0,09	0,11	0,09	0,11
Partitions (int.) (kW)	-0,01	-0,01	-0,01	-0,01
Roofs (kW)	-0,69	-0,97	-0,69	-0,97
External Infiltration (kW)	-3,26	-3,26	-3,26	-3,26
External ventilation (kW)	-1,07	-1,07	-1,06	-1,07
Zone sensible heating (kW)	8,24	8,49	8,22	8,48

also suffer little variation when it comes to heat losses, being -0.80 kW for wall 01 and -0.78 for wall 02. This shows that the walls do not need to be filled with 150mm of insulating material to be efficient. Walls with 100mm insulation with an air gap, further then presenting satisfactory results, will also generate financial and material savings. Heat gains from the ground also have their performance related to the roof. Roof 01 provides slightly lower thermal gains than the 02. The roofing subsystems is where most significant differences appear. Roof 01, which has 200mm of rockwool, presents a significantly lower energy loss, proving that the use of insulating materials in the roof is as important as the insulation of the walls.

The results obtained for zone sensible heating show that the heating energy does not vary significantly according to the layers combinations. Thus, when the analysis involves heat losses, it is worth considering the savings of materials and financial resources, since the efficiency is quite similar. Among the simulations, the most efficient combination (which has the lowest losses) is Simulation 03.

For the simulations considering thermal gains during summer, the following results were obtained, as shown in Figure 4.

Temperature and Heat Gains - RESIDENCIA

EnergyPlus Output — 15 Jul, Sub-hourly — Student

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Air Temperature (°C)	25,18	24,50	24,55	25,09	29,57	31,23	32,55	30,93	28,22	25,27	25,59
Radiant Temperature (°C)	25,68	25,03	25,29	28,07	29,88	31,13	32,30	33,31	31,42	29,05	27,13
Operative Temperature (°C)	25,43	24,76	24,92	26,58	29,72	31,18	32,43	32,12	29,82	27,16	26,36
Outside Dry-Bulb Temperature (°C)	20,69	19,72	19,72	23,59	29,38	33,41	35,50	34,53	31,64	27,45	24,55
Glazing (kW)	-0,68	-0,71	1,09	3,06	2,43	1,43	1,88	2,01	1,37	-0,33	-0,44
Walls (kW)	0,37	0,32	-0,21	-0,64	-0,99	-0,41	-0,37	0,60	0,87	1,71	0,69
Ground Floors (kW)	-0,52	-0,41	-2,35	-3,00	-2,85	-2,05	-2,83	-1,93	-0,84	0,91	-0,26
Partitions (int) (kW)	0,41	0,46	-0,57	-1,10	-1,51	-0,86	-0,98	-0,61	0,83	3,02	0,97
Roofs (kW)	0,68	0,60	-0,31	-0,87	-1,17	-0,49	-0,49	0,60	1,14	2,13	1,13
External Infiltration (kW)	-0,59	-0,62	-0,63	-0,19	-0,02	0,27	0,37	0,45	0,43	0,28	-0,13
External Vent. (kW)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,03	0,00
General Lighting (kW)	0,00	0,00	0,02	0,09	0,00	0,00	0,00	0,00	0,02	0,64	0,40
Computer + Equip (kW)	0,07	0,07	0,10	0,96	0,07	0,07	0,07	0,07	0,28	0,59	0,37
Occupancy (kW)	0,11	0,11	0,13	0,16	0,00	0,00	0,00	0,00	0,03	0,07	0,04
Solar Gains Exterior Windows (kW)	0,00	0,00	3,83	8,16	5,36	2,67	3,22	4,34	3,31	0,00	0,00
Zone Sensible Cooling (kW)	-0,08	-0,09	-0,19	-6,13	-0,03	-0,09	-0,10	-5,47	-7,52	-8,22	-2,88
Sensible Cooling (kW)	0,00	-0,00	-0,09	-6,09	-0,03	-0,09	-0,10	-5,47	-7,55	-8,25	-2,88
Total Cooling (kW)	0,00	-0,00	-0,09	-6,09	-0,03	-0,09	-0,10	-5,47	-7,55	-8,25	-2,88
Relative Humidity (%)	41,34	43,02	42,86	42,19	32,57	29,47	27,12	30,15	35,22	41,19	40,39
Mech Vent + Nat Vent + Infiltration (ac/h)	0,82	0,82	0,83	0,86	0,70	0,70	0,69	0,69	0,72	0,76	0,75

(a)

Temperature and Heat Gains - RESIDENCE

EnergyPlus Output — 15 Jul, Sub-hourly — Student

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Air Temperature (°C)	25,29	24,59	24,60	25,09	29,55	31,23	32,60	31,04	28,31	25,28	25,62
Radiant Temperature (°C)	25,80	25,12	25,34	28,06	29,85	31,13	32,38	33,48	31,61	29,24	27,27
Operative Temperature (°C)	25,55	24,85	24,97	26,57	29,70	31,18	32,49	32,26	29,96	27,26	26,45
Outside Dry-Bulb Temperature (°C)	20,69	19,72	19,72	23,59	29,38	33,41	35,50	34,53	31,64	27,45	24,55
Glazing (kW)	-0,70	-0,72	1,09	3,06	2,43	1,44	1,87	1,99	1,36	-0,34	-0,45
Walls (kW)	0,37	0,33	-0,20	-0,63	-0,98	-0,42	-0,40	0,57	0,86	1,73	0,69
Ground Floors (kW)	-0,53	-0,41	-2,34	-2,97	-2,83	-2,06	-2,88	-1,99	-0,88	0,93	-0,27
Partitions (int) (kW)	0,42	0,48	-0,55	-1,07	-1,50	-0,89	-1,03	-0,67	0,81	3,12	0,98
Roofs (kW)	0,73	0,59	-0,37	-0,96	-1,21	-0,43	-0,31	0,86	1,44	2,46	1,34
External Infiltration (kW)	-0,60	-0,64	-0,64	-0,19	-0,02	0,27	0,36	0,44	0,42	0,28	-0,14
External Vent. (kW)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,03	0,00
General Lighting (kW)	0,00	0,00	0,02	0,09	0,00	0,00	0,00	0,00	0,02	0,64	0,40
Computer + Equip (kW)	0,07	0,07	0,10	0,96	0,07	0,07	0,07	0,07	0,28	0,59	0,37
Occupancy (kW)	0,11	0,11	0,13	0,16	0,00	0,00	0,00	0,00	0,03	0,07	0,04
Solar Gains Exterior Windows (kW)	0,00	0,00	3,83	8,16	5,36	2,67	3,22	4,34	3,31	0,00	0,00
Zone Sensible Cooling (kW)	-0,08	-0,10	-0,21	-6,12	-0,03	-0,09	-0,11	-5,50	-7,71	-8,65	-3,08
Sensible Cooling (kW)	0,00	-0,00	-0,10	-6,08	-0,03	-0,09	-0,11	-5,50	-7,74	-8,68	-3,07
Total Cooling (kW)	0,00	-0,00	-0,10	-6,08	-0,03	-0,09	-0,11	-5,50	-7,74	-8,68	-3,07
Relative Humidity (%)	41,07	42,80	42,75	42,19	32,61	29,47	27,03	29,99	35,08	41,18	40,32
Mech Vent + Nat Vent + Infiltration (ac/h)	0,82	0,82	0,83	0,86	0,70	0,70	0,69	0,69	0,72	0,76	0,75

(b)

Temperature and Heat Gains - RESIDENCE

EnergyPlus Output — 15 Jul, Sub-hourly — Student

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Air Temperature (°C)	25,18	24,49	24,55	25,09	29,57	31,23	32,55	30,92	28,21	25,26	25,59
Radiant Temperature (°C)	25,67	25,02	25,28	28,06	29,87	31,13	32,30	33,31	31,42	29,05	27,12
Operative Temperature (°C)	25,42	24,76	24,91	26,58	29,72	31,18	32,42	32,11	29,82	27,16	26,35
Outside Dry-Bulb Temperature (°C)	20,69	19,72	19,72	23,59	29,38	33,41	35,50	34,53	31,64	27,45	24,55
Glazing (kW)	-0,68	-0,71	1,09	3,06	2,42	1,43	1,88	2,01	1,37	-0,33	-0,44
Walls (kW)	0,37	0,32	-0,21	-0,64	-0,98	-0,41	-0,37	0,59	0,87	1,70	0,69
Ground Floors (kW)	-0,52	-0,41	-2,35	-3,00	-2,85	-2,05	-2,83	-1,93	-0,84	0,91	-0,26
Partitions (int) (kW)	0,41	0,46	-0,57	-1,10	-1,50	-0,86	-0,98	-0,61	0,83	3,02	0,97
Roofs (kW)	0,68	0,60	-0,31	-0,87	-1,17	-0,49	-0,48	0,60	1,14	2,13	1,13
External Infiltration (kW)	-0,58	-0,62	-0,63	-0,19	-0,02	0,27	0,37	0,45	0,43	0,28	-0,13
External Vent. (kW)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,03	0,00
General Lighting (kW)	0,00	0,00	0,02	0,09	0,00	0,00	0,00	0,00	0,02	0,64	0,40
Computer + Equip (kW)	0,07	0,07	0,10	0,96	0,07	0,07	0,07	0,07	0,28	0,59	0,37
Occupancy (kW)	0,11	0,11	0,13	0,16	0,00	0,00	0,00	0,00	0,03	0,07	0,04
Solar Gains Exterior Windows (kW)	0,00	0,00	3,83	8,16	5,36	2,67	3,22	4,34	3,30	0,00	0,00
Zone Sensible Cooling (kW)	-0,08	-0,09	-0,19	-6,13	-0,03	-0,08	-0,10	-5,46	-7,51	-8,20	-2,88
Sensible Cooling (kW)	0,00	0,00	-0,09	-6,09	-0,03	-0,08	-0,10	-5,46	-7,54	-8,23	-2,87
Total Cooling (kW)	0,00	0,00	-0,09	-6,09	-0,03	-0,08	-0,10	-5,46	-7,54	-8,23	-2,87
Relative Humidity (%)	41,35	43,03	42,87	42,19	32,58	29,48	27,12	30,16	35,22	41,20	40,40
Mech Vent + Nat Vent + Infiltration (ac/h)	0,82	0,82	0,83	0,86	0,70	0,70	0,69	0,69	0,72	0,76	0,75

(c)

Temperature and Heat Gains - RESIDENCE

EnergyPlus Output — 15 Jul, Sub-hourly — Student

Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Air Temperature (°C)	25,28	24,58	24,59	25,09	29,55	31,22	32,60	31,03	28,31	25,28	25,62
Radiant Temperature (°C)	25,80	25,12	25,33	28,05	29,85	31,13	32,38	33,47	31,61	29,23	27,26
Operative Temperature (°C)	25,54	24,85	24,96	26,57	29,70	31,18	32,49	32,25	29,96	27,25	26,44
Outside Dry-Bulb Temperature (°C)	20,69	19,72	19,72	23,59	29,38	33,41	35,50	34,53	31,64	27,45	24,55
Glazing (kW)	-0,70	-0,72	1,09	3,06	2,43	1,44	1,87	1,99	1,36	-0,34	-0,45
Walls (kW)	0,37	0,33	-0,20	-0,63	-0,98	-0,42	-0,40	0,57	0,85	1,72	0,68
Ground Floors (kW)	-0,53	-0,41	-2,34	-2,97	-2,83	-2,06	-2,88	-1,99	-0,88	0,93	-0,27
Partitions (int) (kW)	0,42	0,48	-0,55	-1,07	-1,50	-0,89	-1,03	-0,67	0,81	3,12	0,98
Roofs (kW)	0,73	0,59	-0,37	-0,96	-1,21	-0,43	-0,31	0,86	1,44	2,46	1,34
External Infiltration (kW)	-0,60	-0,63	-0,64	-0,19	-0,02	0,27	0,36	0,44	0,42	0,28	-0,14
External Vent. (kW)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,03	0,00
General Lighting (kW)	0,00	0,00	0,02	0,09	0,00	0,00	0,00	0,00	0,02	0,64	0,40
Computer + Equip (kW)	0,07	0,07	0,10	0,96	0,07	0,07	0,07	0,07	0,28	0,59	0,37
Occupancy (kW)	0,11	0,11	0,13	0,16	0,00	0,00	0,00	0,00	0,03	0,07	0,04
Solar Gains Exterior Windows (kW)	0,00	0,00	3,83	8,16	5,36	2,67	3,22	4,34	3,31	0,00	0,00
Zone Sensible Cooling (kW)	-0,08	-0,10	-0,21	-6,12	-0,03	-0,09	-0,11	-5,55	-7,71	-8,64	-3,07
Sensible Cooling (kW)	0,00	-0,00	-0,10	-6,08	-0,03	-0,09	-0,11	-5,55	-7,74	-8,67	-3,07
Total Cooling (kW)	0,00	-0,00	-0,10	-6,08	-0,03	-0,09	-0,11	-5,55	-7,74	-8,67	-3,07
Relative Humidity (%)	41,09	42,81	42,76	42,19	32,61	29,47	27,03	30,00	35,08	41,18	40,32
Mech Vent + Nat Vent + Infiltration (ac/h)	0,82	0,82	0,83	0,86	0,70	0,70	0,69	0,69	0,72	0,76	0,75

(d)

Figure 4: Heat gains simulations (a) Simulation 01 (b) Simulation 02 (c) Simulation 03 (d) Simulation 04. Source: Design Builder simulation [5].

To better understand the behaviour of envelope elements during summer, it is important to evaluate variations at hourly time intervals, as the behaviour may vary among day and night. The external temperature profile is the first factor to be considered, since thermal gains of all elements will vary according to this parameter.

Among the simulations presented, the glazed elements suffer few variations, regardless of the material composition used. Throughout the day, the glasses behaviour has negative gains (losses) during the early hours of the day, and this value increases as these elements receive sun's irradiation. This value decreases again after sunset, when the residence (heated during the day) loses heat to the outside.

The walls together with the roof, have an interesting performance throughout the day, because depending on the outside temperature they may have positive or negative gains. In the early hours of the day the elements will have positive gains, while during the hours of intense sun heat, gains will be negative, avoiding overheat in the indoor environments.

According to the simulations, walls suffer minimal variations regardless the insulation configuration, the same happened in previously case of heat losses. Also, the roofs have greater ranges of energy gains, as in the previous analysis. The case where energy variations are smaller according to the simulations, are those that the roof 01 was used.

It can be considered that the configuration used for floors presents significant variation independent of the simulation. The interior partitions behave similarly to the outer walls, as during the day the interiors will be heated, and the partitions will play a role in preventing unwanted heat from spreading.

Overall, the energy required for home cooling has the lowest values in Simulation 03, as shown in Figure 4c.

6. Conclusion

Performing the analyses with the insulation configurations presented in this article, it can be concluded that it is not always suitable to use large amounts of insulating material in the sealing elements. Performing simulations is important to ensure that nearly real data is obtained. It avoids waste of materials and prevents building owners from wasting unnecessary financial resources. In the presented residence, the configuration with better efficiency was Simulation 03, with 100mm rock wool inside walls and 200mm rock wool inside roof layers.

Further analysis should be performed using different insulation materials available on the construction sector, varying their thickness and comparing each other to verify their respective efficiencies and cost-effectiveness.

For this paper a Light Steel Frame residence was used because it is a versatile, sustainable material, with great recycling potential when it reaches the end of its useful life, reinforcing the existing interconnection between energy efficiency, resource saving and sustainability.

It is important to notice that in typical masonry constructions in Portugal it is not common to find insulation materials with this thickness (higher than the most used), due to the constraints of the building system itself. Even references such as ITE 50 [6] have maximum thicknesses of 80mm for calculations of thermal transmission coefficients (U). As a result, conventional masonry buildings are considered less energy efficient than the solution presented in Light Steel Frame.

For further research, it is suggested that studies with other insulation materials with high thicknesses (of 100mm and 150mm, for example) be developed, seeking to verify their effectiveness. It is also interesting to elaborate a comparative study between the material efficiency and the costs involved for its implementation.

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