Student Modelling Competition

Design and simulation of a near-zero energy building

Building Simulation 2013, Chambery, France

Halla Huws

PhD Candidate, Birmingham City University

Birmingham Institute of Art and Design, Birmingham City University
The Parkside Building, 5 Cardigan Street, Birmingham B4 7BD, UK

1.Introduction

This study is based on a three bedroom house located in Chambery,France. The house has been modelled, with an aim to achieve high standards of energy performance while maintaining thermal comfort. Fabric improvements and passive design strategies were implemented to achieve those targets. On-site low/zero carbon technologies were applied to the model to test the possibility of reducing the overall impact of the building on the environment.

The software used is *Integrated Environmental Solutions (IES) Virtual Environment (VE)*. IES has passed the BESTEST validation test, and was chosen due to its accuracy and versatility.

The competition organisers provided the exact geometry of the house, along with the internal gains in bedrooms, kitchen, bathroom and living area. All of which were applied to the model in IES. The brief specified a minimum temperature during occupied heated period of 19°C, allowing a reduction of the heating temperature to 16°C during unoccupied hours of the weekdays.

The operative temperature was specified not to exceed 27°C for more than 50 hours throughout the year and 3 consecutive hours. At all times, the maximum operative temperature should not exceed 30°C. And the minimal ventilation rate to ensure at all time is 0.6 ACH.

The model went through a process of improvements which were based on the following three steps:

1. Fabric enhancement
2. Passive strategies
3. Low/ Zero carbon technologies

This study focused on highlighting the importance of building fabric in reducing energy demands, as well as various passive design strategies such as shading and vegetation. Indoor light quality was also looked at to ensure a healthy pleasant environment for the occupants, as well as the potential decrease in artificial lighting.

2. Modelling Methods & Assumptions

Using the house dimensions provided, a model was built in ModelIt. The building thermal conditions and construction were all specified using the building templates and variation profiles. Macroflo was used to take into account natural ventilation during summer months. Finally the simulation was run by ApacheSim to obtain the thermal and energy results from the model. Furthermore, Radiance-IES and FlucDL were utilised for testing indoor natural daylight quality.

Occupancy profiles and internal gains were all obtained from the brief, which indicated the energy related to lights and appliances. The roof area and storage room were the only two spaces set as unheated spaces.

No mechanical cooling was applied to the model, assuming that natural ventilation is applied between June and September by opening windows. Window templates were linked to a formula where windows only open when indoor temperatures were greater than 23°C and higher than outdoor temperature((*ta>23) & (ta>to*)). The windows were divided into two groups, the ground floor windows and the first floor windows; first floor windows open only during occupancy hours of the day time, and closed at night for maintaining security. The first floor windows open during occupancy hours of all rooms. Keeping in mind that in each group there are different types of windows, where the base model had both centre-hung and side hung windows.

The base model's construction was not set to optimum standards, to highlight the importance of fabric within the overall energy consumption of a building. The U-values and fabric layers are listed in Table 1.The base model will go through several steps to achieve the desired energy efficiency along with the thermal comfort, in each step the various related assumptions will be clarified.

Table 1 Building fabric in model

	Base Model Fabric			Enhanced Fabric		
		Total Thickness (m)	**Total U-value (W/m².k)**		**Total Thickness (m)**	**Total U-value (W/m².k)**
Glazing	Double Glazing	0.024	1.977	Triple Glazing	0.042	0.69
External wall	Brickwork Dense EPS Slab Insulation Concrete Block Gypsum Plasetring	0.273	0.35	External Render Neopor Insulation Brickwork Granolithic Render	0.524	0.107
Ground Floor	Clay Brickwork Cast Concrete Dense EPS Slab Insulation Chipboard	1.19	0.249	Sand Polystyrene Cast Concrete Timber Flooring	0.54	0.128
Roof	Tiles Cavity Mineral Wool Quilt Plasterboard	1.08	0.4995	Tiles Roofing Felt Particle Board Insulation Board Warmcell Airtight Membrane Plasterboard	0.5375	0.0787

3. Fabric Enhancement

The building Fabric is the most important aspect in achieving energy efficiency. It has the ability to reduce the heating and cooling requirements, or even eliminating them completely.
Building fabric refers to both opaque and glazed building elements. The fabric enhancement will follow three steps:

- Glazing
- Insulation
- Thermal Mass

The base model was assumed to be constructed of basic construction of minimum insulation, as shown in Table 1, which resulted in a total heating energy of 5.9823 MWh.

Glazing

The base model had double glazing applied for all windows, in this step the glazing was upgraded into triple glazing with a U-value of (0.69 W/m².k), this resulted in reducing the heating demand by 18% as shown Figure 1 ,

Fabric

The opaque elements; external walls, ground floor and roof, were modified into highly insulated construction as described in Table 1 . The whole fabric enhancement resulted in a 46% reduction of the total yearly heating demand, nearly eliminating any heating requirement for the months of April and October as shown in Figure 1.

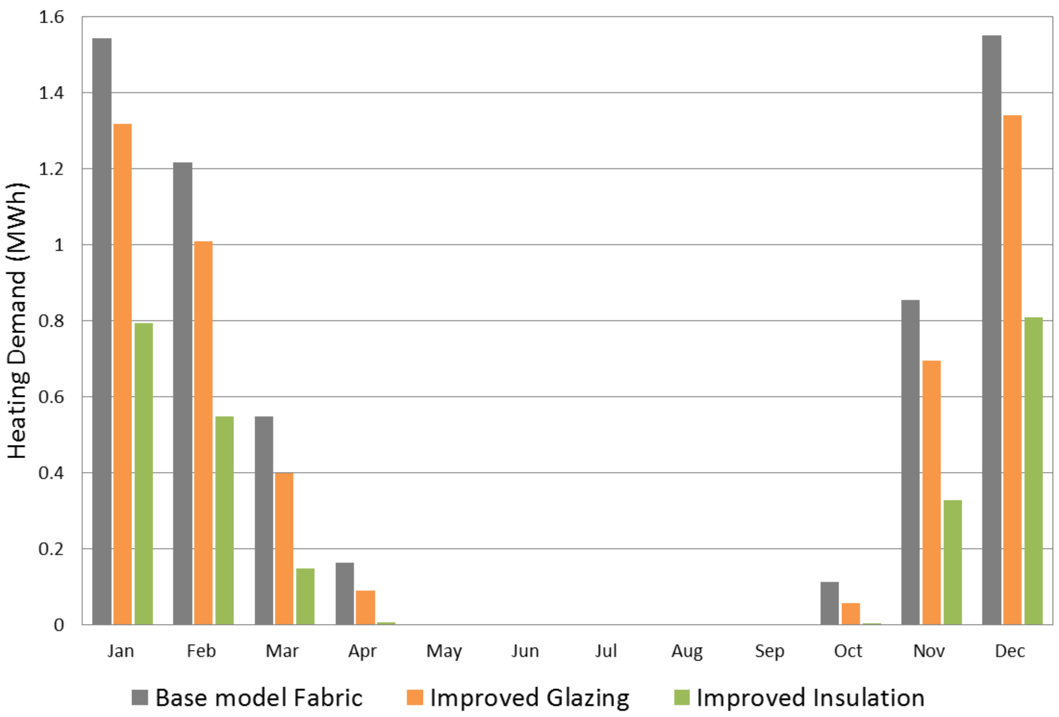

Figure 1: Fabric enhancement and heating demand

Thermal mass

Internal temperatures during summer time were high, indicating required passive measures to reduce those peaks. Thermal mass is one of the effective ways for reducing building heating and cooling loads and temperature swings, it reduces the speed at which the internal temperatures will rise when subjected to solar or internal gains.

Thermal mass was added in stages, first stage was removing the wooden floor int eh ground floor and adding a 75mm of rammed earth instead, a change in the internal temperature was noticed and the temperatures exceeding 27°C reduced by 13% in the Living room and 9% in the kitchen (Table 2). This did not have a negative effect on the heating demand as Figure 7.

The second stage was increasing thermal mass by changing the internal partitions, from plastered brick wall into exposed brick wall, this change did not have a significant effect on the internal temperature, However it resulted in increasing the total heating demand. Therefore, the internal walls were kept as plastered brick leaf.

The total heating energy demand after the fabric enhancement was 2.6262 MWh, achieving a 56% reduction from the base model as shown in Figure 7.

3. Passive Strategies

The main aims were to reduce the heating demand in winter and eliminate any cooling requirements in summer, to achieve that the following was tested:

- Shading (Louvre)
- Increasing glazing area
- Vegetation

Shading

The base model had a balcony projection with a width of 1m, this is a good strategy for eliminating the southern summer sun, while still allowing it in during winter. Therefore this balcony was kept as it is after running a shading analysis in Suncast.

Due to the overheating occurring in the building as shown in Table 2 and Table 3, there was a need to add external shading, louvres were selected as they are flexible, allowing occupants to use them when solar gains reached an uncomfortable level, also they could be protecting the indoor environment from overheating outside occupancy hours.
Louvres were applied within the construction templates, adding it to the triple glazed windows. It was connected to a variation profile that specifies that louvres will operate when solar radiation exceeds 150 W/m^2, during summer months (June to September). Which resulted in reducing overheating significantly as shown in Table 2.

Increasing glazing

The natural lighting levels in the rooms were studied using Radiance-IES, and FlucsDL, which indicated that there was not enough natural light penetrating the building fabric. This would have a negative effect on the internal environment and occupant's satisfaction, as well as a high demand in artificial lighting and electrical consumption. In this study the lighting consumption was fixed, according to the brief. Nevertheless the increase of the natural light would reduce this demand, and the model could take that into account by using room solar sensors. This study mainly focused on the daylight factor and the heating demands disregarding the electrical consumption.

The first change was increasing the ground floor south glazing, in both the living room and the dinning kitchen area. And changing the opening types from side hung into sliding door to allow more natural ventilation. The glazing was increased from 10% of the wall area to 35%, This resulted in Increasing the solar gains significantly which resulted in reducing the energy demand as shown in Figure 2 and improving the day light quality as shown in Figure 3 and Figure 4.

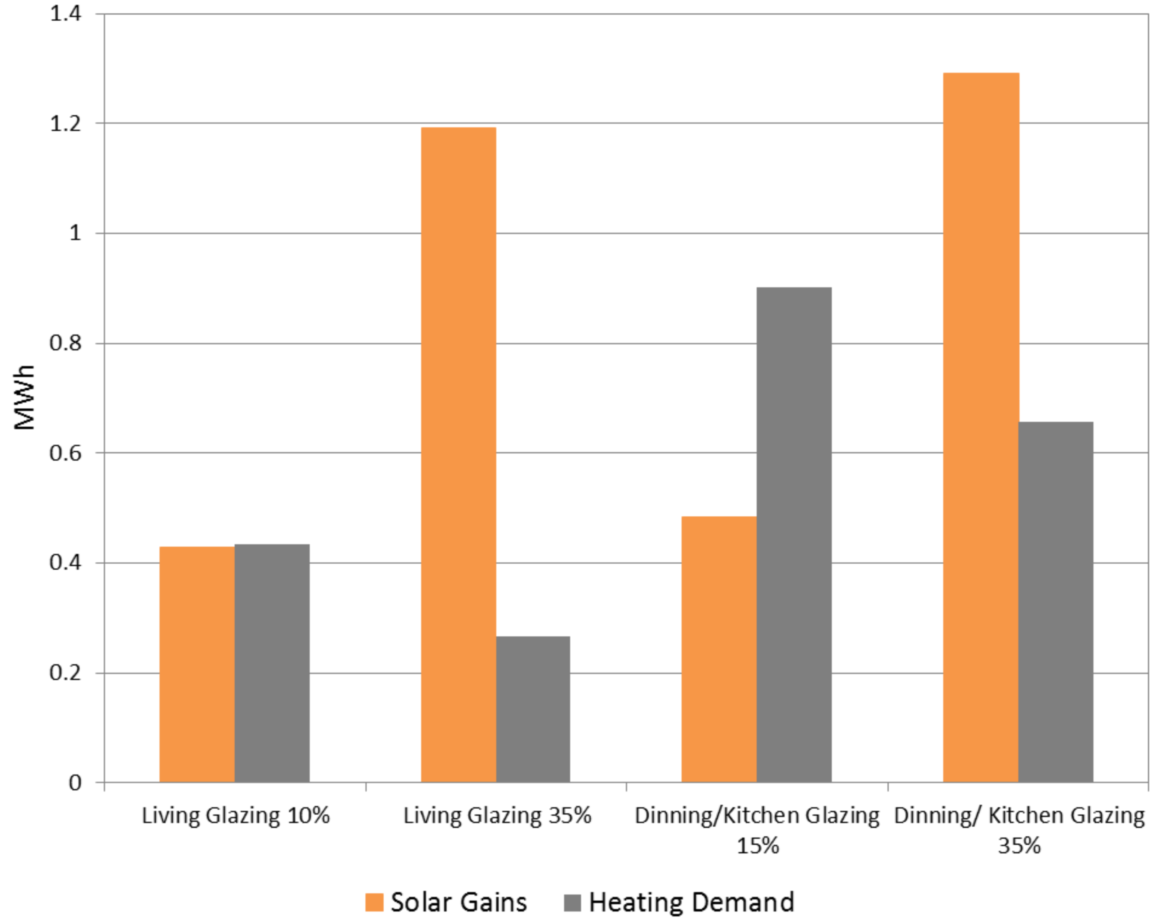

Figure 2 Increase of Ground floor southern glazing

The western façade had an opaque door, this door was changed into a semi glazed door to allow improving the light quality, without allowing much western low angle sun as shown in Figure 5.

Finally, the upper floor rooms had sufficient day light factor levels, except the northern bedroom. a small window of an area of 1.2 m² was added to the northern façade as shown in Figure 6. The window did not increase the heating demand hugely as shown in Figure 7.

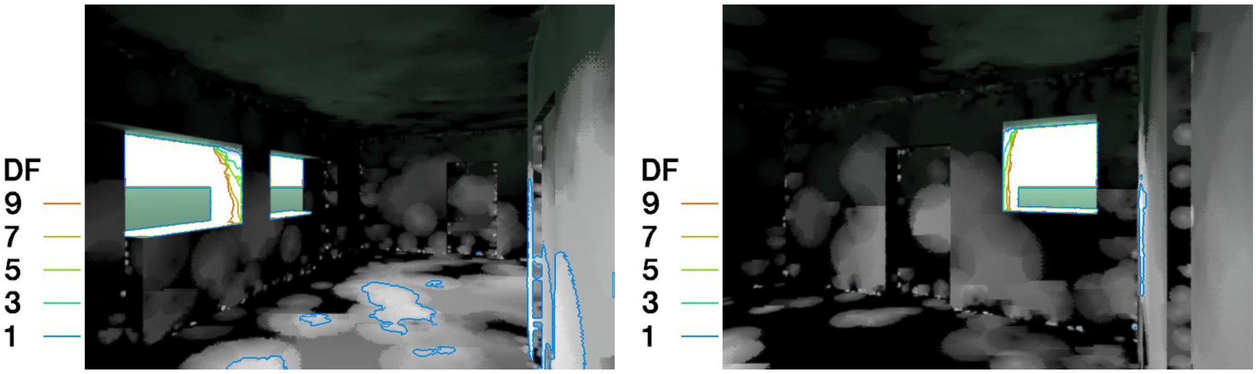

Figure 3 Living, kitchen and dining with 10% southern glazing

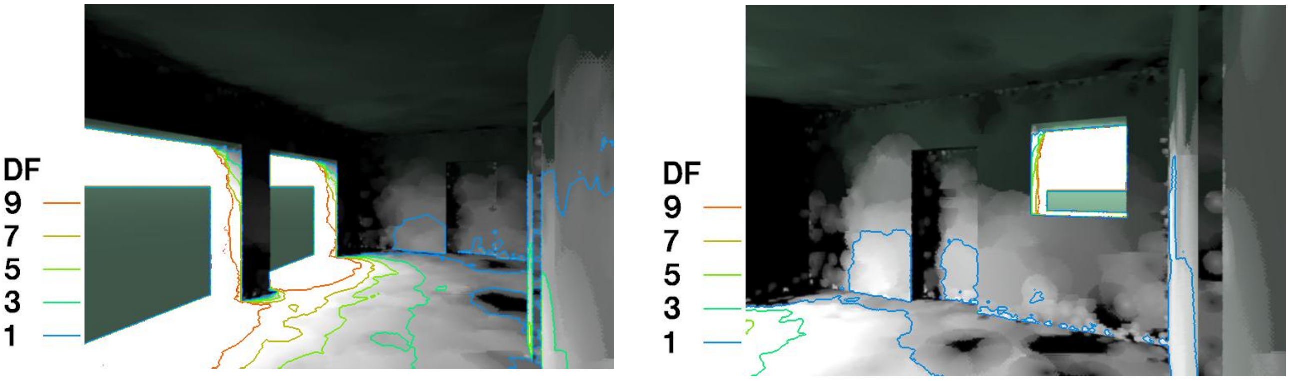

Figure 4 Living, kitchen and dining area with 35% southern glazing

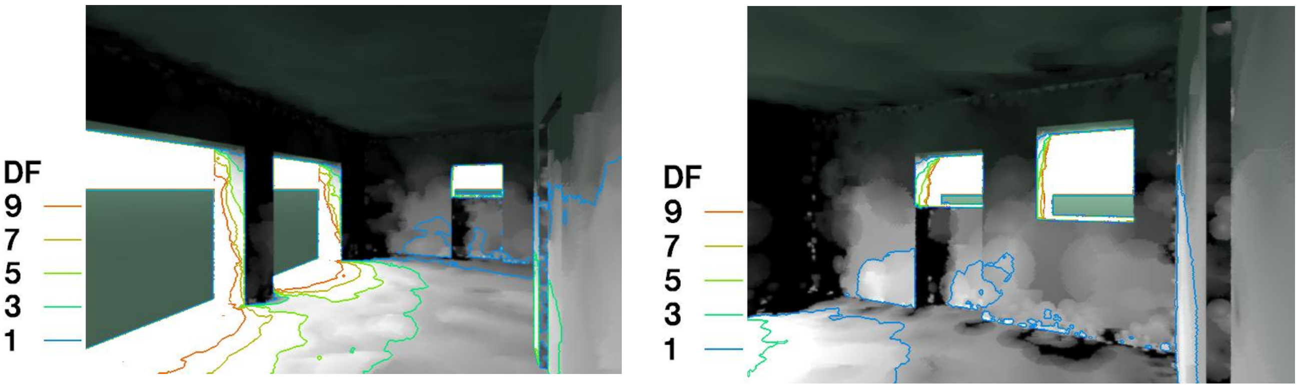

Figure 5: Living, kitchen and dining with additional 6% western glazing

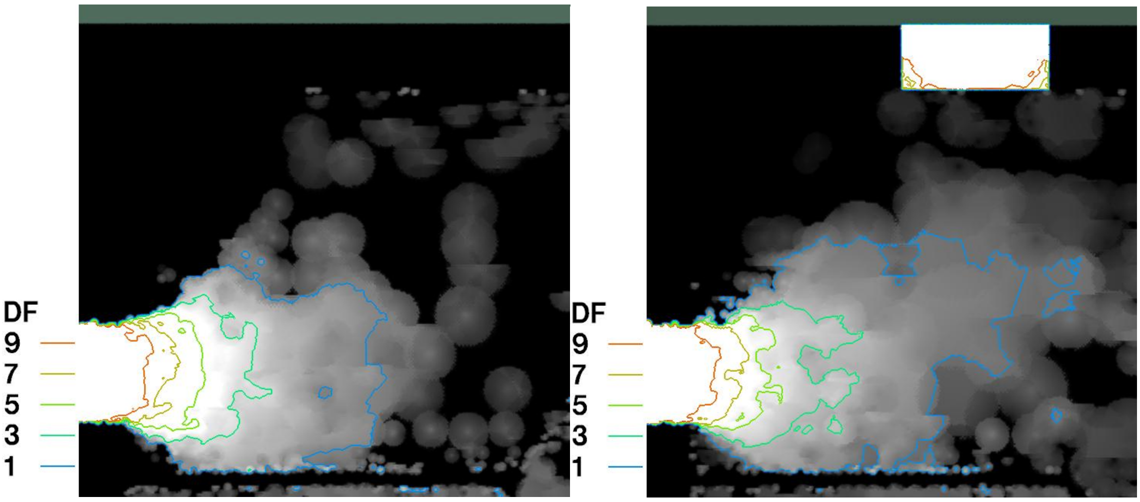

Figure 6 Room 1 light improvement with adding Northern window

Vegetation

Adding vegetation is a well-known and widely used method to improve thermal conditions, Deciduous plants are a very suitable option for this location, as it will provide sufficient shading in summer, without blocking the winter sun.

Trees were added to the model, and thermal comfort targets were achieved as shown in Table 2 and Table 3.

Table 2 Overheating in the ground floor

	Number of Total Hours exceeding 27°C		Number of Occupied Hours exceeding 27°C	
	Living Room	**Kitchen/Dinning**	**Living Room**	**Kitchen/Dinning**
Ehnaced Insulation	119	114	49	30
Rammed earth	103	103	44	25
Louvres and 10% southern glazing	16	15	12	13
Louvres and 35% southern glazing	64	64	32	23
Trees	26	29	18	19

Table 3 Overheating in the first floor

	Number of Total Hours exceeding 27°C		Number of Occupied Hours exceeding 27°C	
	Bedroom South	**Bedroom North**	**Bedroom South**	**Bedroom North**
Ehnaced Insulation	304	51	0	0
Louvres	80	0	0	0
Trees	32	0	0	0

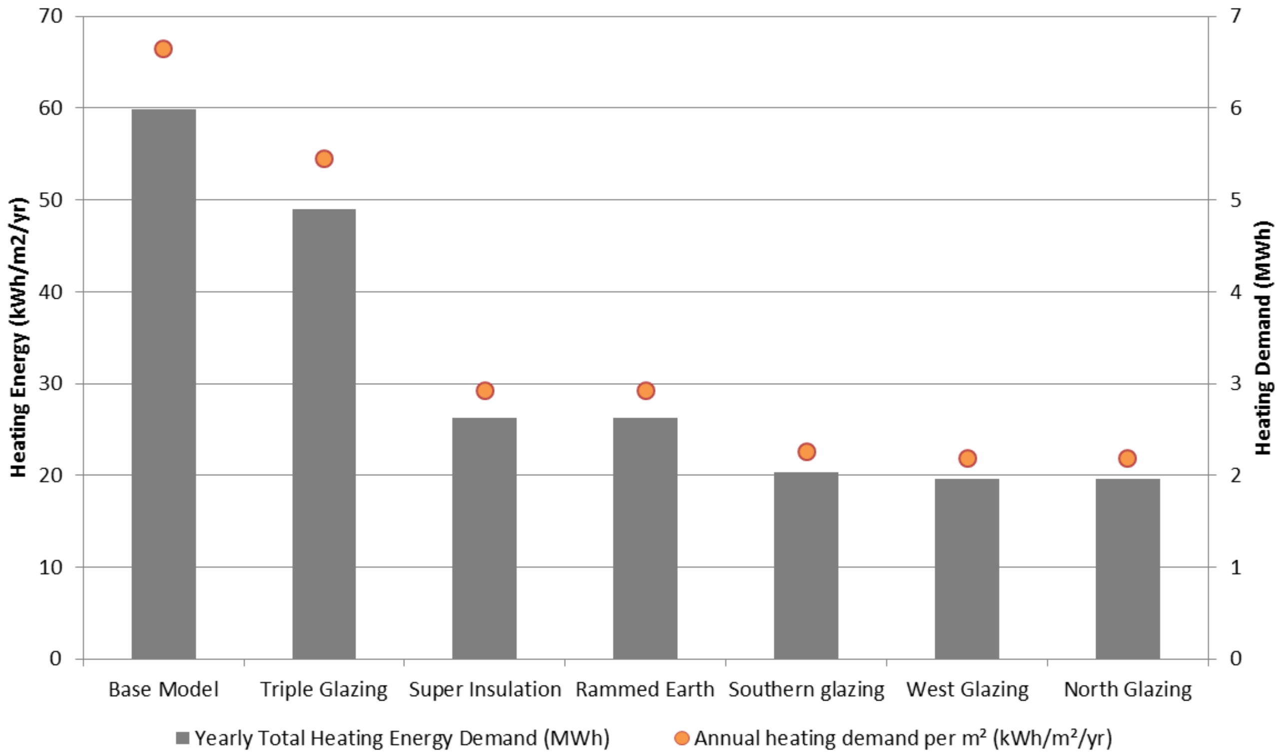

Figure 7 Heating Energy Demand

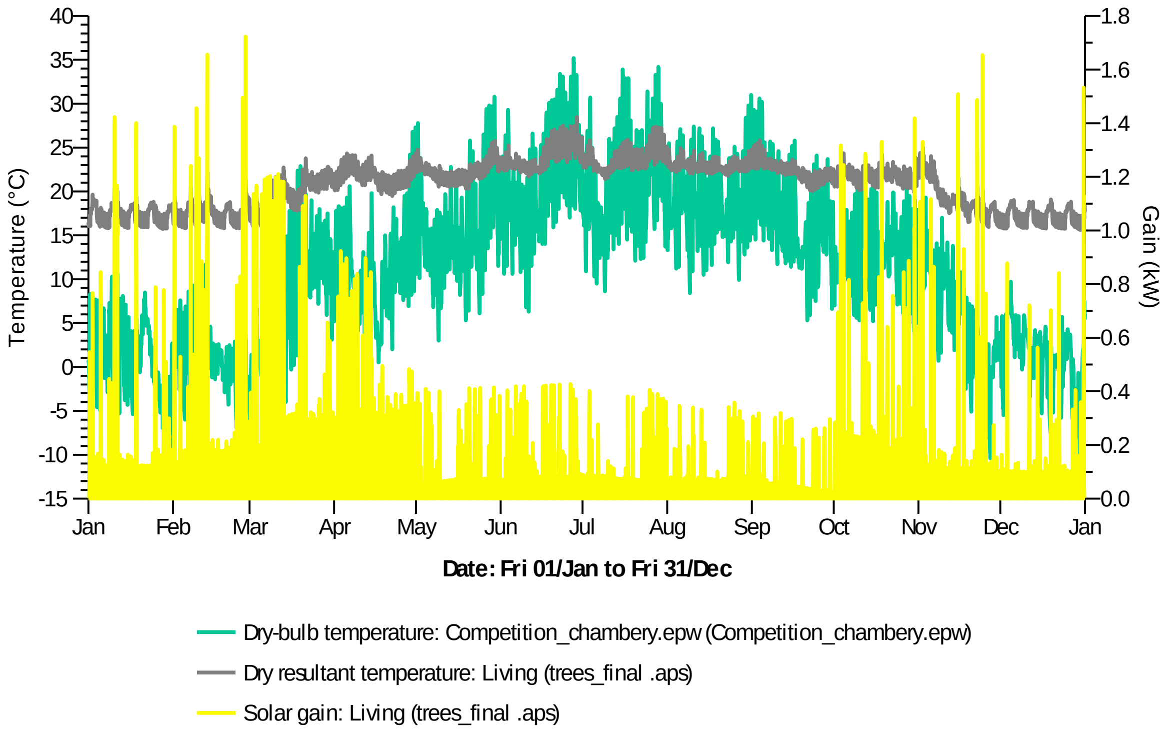

Figure 8 Living room annual performance

4. Low/ Zero Carbon Technologies .

The base model was using electricity as main source of energy, this decision was based on the low carbon intensity of electricity in France, which has a high emphasis on nuclear power, the conversion factor of 61 g/kWh was applied into the model. The total carbon emissions, based on that was 920 kg of CO2.

The heating system was then changed into a biomass boiler, With an efficiency of 96%. which connects to under-floor heating system, With an efficiency of 96%. Which resulted in reducing the total carbon into 263 kg of CO2. Adding a Solar Heating System resulted in reducing the carbon emissions to 200 kg of CO2. Finally to produce on site electricity 30 m2 of PV panels were adding to the southern roof, which resulted in a negative emission of -1886 kg CO2 as shown in Figure 9.

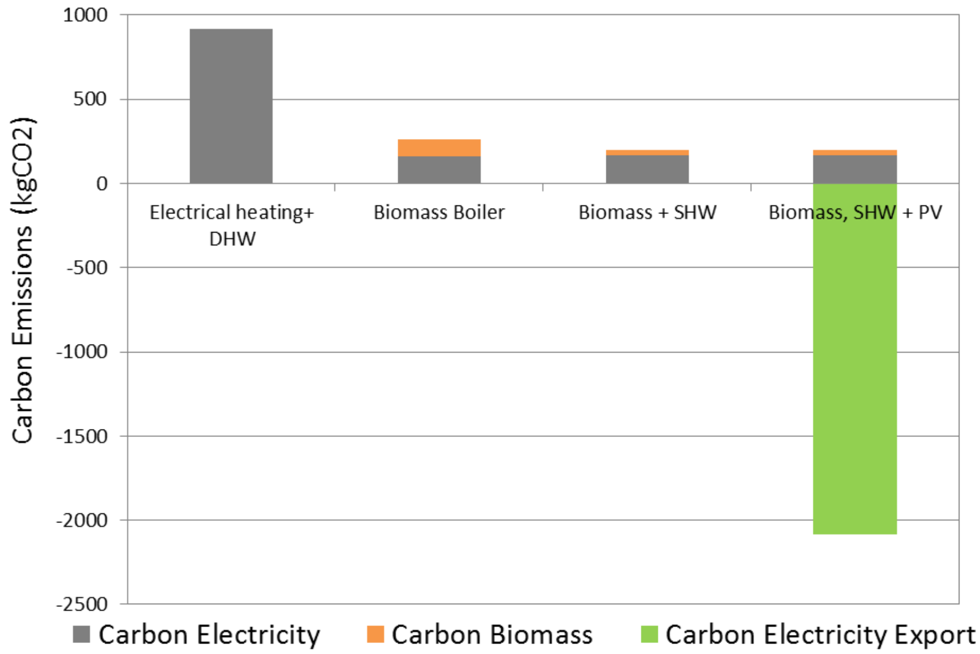

Figure 9 CO2 emissions