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Title: An ultra-low energy refurbishment of a 1900 Victorian dwelling in Oxford, UK.

Dionysios Antypas

MSc Sustainable Buildings: Performance and Design, Oxford Brookes University, UK, email: dio.antypas@gmail.com

Abstract

This paper examines the energy performance and the thermal comfort of the occupants of a 1900 Victorian conventional dwelling. The dominant research aim is to investigate to what extents can variable interventions in the building envelope of a dwelling and occupants' comfort contribute to minimising energy consumption as part of a fabric upgrade of an existing Victorian dwelling. The objectives taken into account to this paper to address the desired energy building performance are Code for Sustainable Homes Level 6 standards, evaluation of impact of internal planning options, MVHR system installation instead of natural ventilation, usage of aerogel insulation instead of conventional insulation materials and the embodied energy of the refurbishment. Finally, conclusions and recommendations would be discussed for the energy improvement of the dwelling according to Code for Sustainable Homes Level 6 standards.

Keywords: ultra-low energy, refurbishment, sustainability, embodied energy, carbon emissions

Introduction

Greenhouse gas emissions are already at levels which scientists consider to be significantly risky. Specifically, atmospheric CO_2 concentration has risen by an average 1.4 ppm annually since 1960 and the rate of increase itself is going up 1.9 ppm per year from 1995 to 2005 (Metz, Davidson, Bosch, Dave, & Meyer, 2007). The energy used for electricity, heating, domestic hot water and electric devices in houses in the UK accounts approximately 30% of the national emissions (Department for Business, Enterprise and Regulatory, 2007). Hence, it is necessary to improve the performance of the existing housing to meet the 80% CO_2 reductions target by 2050. There are more than 4 million of Victorian houses in the UK built before 1919 (Yates, 2006) and therefore it represents a common typology that can be analysed to examine the potential of upgrading this typology to help achieve the 80% reduction in carbon emissions and other pollutants. There is a strong belief that refurbishment consumes less energy than construction process (Power, 2008). A dominant question is 'Does a refurbishment offer comfortable and modern living?' People's needs change rapidly and discussions about the integration of modern lifestyle into conventional houses are very common and views differ. A refurbishment needs accurate planning as there are more restrictions than a new development. Additionally, in order to be achieved the desirable energy performance it is necessary to take into account the design, the construction type, materiality and variable demands an old dwelling might have.

Retrofitting a house according to the highest UK standards might be more cost effective compared to a new building. Several problems such as solid brick walls, no mains gas, and old sash windows will raise the cost of the refurbishment. As the UK Government plans to keep the majority of the existing housing stock, it is important for 1900 Victorian houses to be examined in terms of sustainable interventions and their energy performance.

Aim and Objectives

The dominant question that has to be answered to this paper is 'To what extents can variable interventions in the building envelope of a dwelling and the occupants' comfort habits contribute to minimising energy consumption as part of a fabric upgrade of an existing Victorian dwelling?'

Several objectives need to be met so as the dominant aims to be achieved.

1. Examine possible solutions for refurbishing a 1900 Victorian dwelling in terms of energy efficiency and if these solutions address the UK standards
2. Evaluation of the existing energy performance of the building through computer modeling
3. Evaluation of impact of internal planning options on energy performance
4. Calculation of the embodied energy of the materials used for the refurbishment
5. Recommendations for energy improvement according to Level 6 standards

Description of standards and methods used in case study building

There is a great variety of standards to assess a building in terms of its energy performance. The energy performance calculations in new construction are easier than in a refurbishment as the materials used are specific and the architectural design is made from scratch. To improve the energy performance of the case study and in other three scenarios the Code for Sustainable Home Level 6 has been selected as a standard guide. Small interior interventions and a roof extension on the rear side of the building that does not affect the aesthetics principles were made to meet the standards.

Table 2: Code for Susttainable Homes
Source: www.theconstructioncentre.co.uk

Code Level	Current energy standard (Part L)	Regulation changes	2009 consultation proposals (percentage improvement over 2006 Part L)
5	100% regulated emissions		70% onsite + 30% allowable solutions
6	zero carbon onsite -100% onsite + appliances equivalent to around 150% in total	2016	zero carbon home -70% onsite + allowable solutions to reach zero carbon

What is Code 6 for sustainable Homes?

The Code is intended as a single national standard to guide industry in the design and construction of sustainable home. It is a continuous improvement, greater innovation and exemplary achievement in sustainable home building.

The design categories included within the Code are:

Energy/CO2, Water, Materials, Surface water run-off, Waste, Pollution, Health and wellbeing, Management, Ecology

A completely zero carbon home (zero net emissions of carbon dioxide from all energy use in the home). The water consumption (lt/person/day) must not exceed 80 (Government, 2010).

Proposal analysis and results

A typical Victorian house was modeled using IES software, while several factors such as wall, roof, floor and glazing U-values were calculated to estimate the energy demand of the building. Taking into account the design, the passive strategies principles for CfSH and aesthetics, the calculation process can be completed.

Table 1, 2: wall constructions, glazing and U-values of the interventions

	wall thickness (mm)	U-value (W/m2K)
rear facade, exterior insulation 10mm lime-based render on mesh, 145mm glass wool, insulation, 235mm solid wall	490	0,12
front facade, interior insulation 245mm solid wall, 225mm glass wool insulation, 12mm plasterboard with skim coat plaster	482	0,11
roof construction to front slate tiles, breather membrane, 300mm glass wool insulation	285	0,1
flat roof over roof extension and over kitchen EPDM single ply membrane, 100mm PU insulation, 18mm WPB ply,	355	0,1
roof over new bathroom EPDM membrane, 18mm ply, 200*50mm timber rafters, 200mm insulation between rafters, 100mm counterbattens and insulation below, vapour control layer	355	0,1

window type	U-value (W/m2K)
single glazing (case study before refurbishment)	5,6
triple glazing (case study after refurbishment)	0,7

The purpose of the calculations is to examine different interventions on the building envelope of the dwelling to achieve the desirable energy performance, while at the same time to address the dominant case study question, which is whether the internal planning of a dwelling can contribute to energy reduction as part of a fabric upgrade of an existing Victorian house or not. Moreover, the embodied energy of the materials used for the refurbishment was calculated. The energy performance of the building was assessed by IES software, which is used by many of the world's leading building design and consultancy companies, the majority of whom are specialists in sustainable buildings (iesve, 2012).

The aim for the case study building was to achieve an energy performance in compliance with the Code for Sustainable Home Level 6, which means that the house must have zero net emissions of CO_2 from all energy use. This was achieved by improving the thermal efficiency of the walls, floors, roofs and windows, reducing air permeability to the minimum, installing a high efficiency condensing boiler, avoiding thermal bridging between wall and floor intersections and installing renewables such as solar thermal panels, photovoltaic, combined heat and power systems and wind turbines. The principle is that the energy taken from the national grid must be replaced by low or zero carbon generated energy so that over a year the net emissions to be zero. Additionally, the shading factor, A++ rated appliances and occupants satisfaction were taken into account to the calculations.

Altering all the parameters and simulating through IES, is the process followed to succeed the anticipated energy performance of the building.

The following scenarios were tested:

1. Model using mechanical ventilation with heat recovery (MVHR) instead of natural ventilation;
2. Alter the internal planning and compare the results with the case study.
3. Assess different insulation materials. The glass wool and mineral wool insulation will be substituted from aerogel insulation and the results will be compared with the previous scenarios as well.

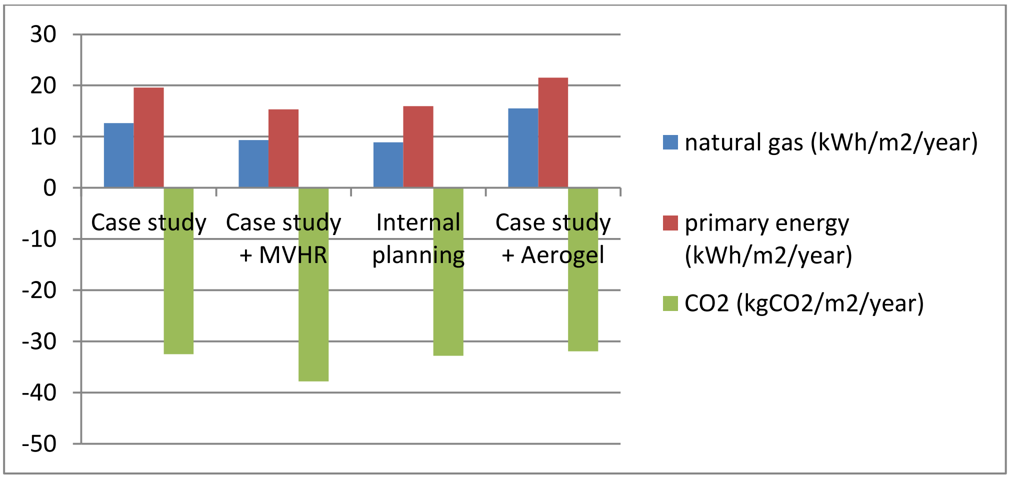

Figure 1: Energy demand and carbon emissions in three different scenarios.
Source: IES software

Embodied Energy calculation

The majority of the materials used for the refurbishment of the dwelling come from the UK with some exceptions such us the windows which come from Norway and the breathable plaster which comes from Germany. The origin of a material is defined by the raw material and the manufacture cycle it does to be converted into a usable building material. The longest distance a material came from is Liverpool (173 miles) and the shortest is Abington, Oxfordshire (5.7 miles) excluding the imported materials. The overall road miles from Germany to the construction site were 837.3, while from Norway were 1,264.05, including 84.2 sea miles journey. The quantity of each material has to be defined from the architectural drawings for the embodied energy calculation. To calculate the embodied energy of a material, the manufacture energy (MJ) is needed, as well as the sea/road energy consumption (MJ). The sum of these two sizes gives us the total embodied energy of a material measured in MJ. The manufacture energy is calculated by multiplying the quantity of a material by its density and its embodied energy (C.Jones & G.Hammond, 2008). The sea/road energy consumption is the product of the density, quantity, road/sea miles and road/sea transport coefficient. When this product is divided by 1000, sea/road energy consumption measured in MJ is calculated. Road transport coefficient is 2.8 MJ/ton/mile, while sea transport coefficient is 0.155 MJ/ton/mile. The latter number is compulsory to multiply it by 1.13 to convert sea miles into road miles. The total embodied energy of the refurbishment is 157,971.64MJ.

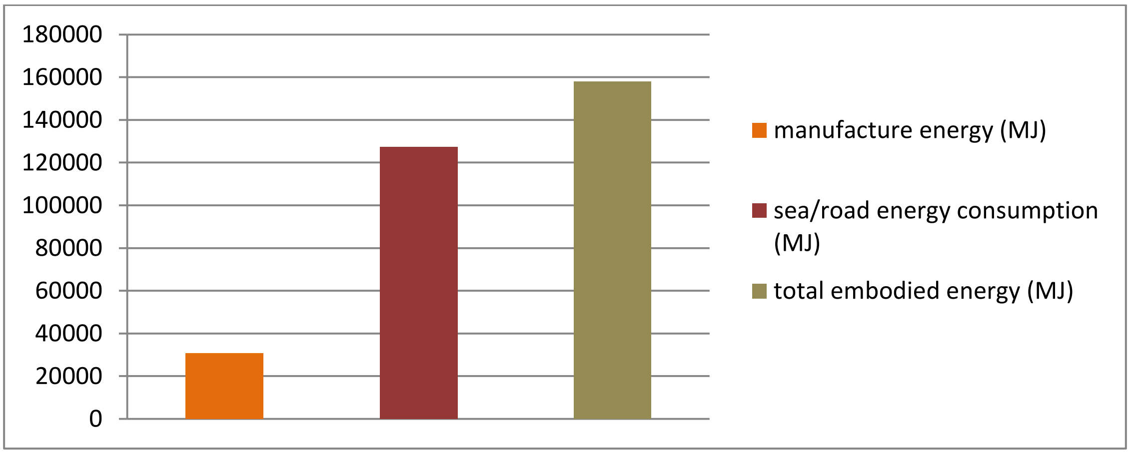

Figure 2: Total energy demand needed for the refurbishment

Recommendations and Conclusion discussion

The key point of this paper is to convert a conventional Victorian dwelling located in Oxford, UK into an ultra-low energy house with zero net carbon emissions and reduced electricity and gas consumption. Theoretically, the aim was successfully achieved with several interventions in the building envelope and the installation of renewable energy sources to cover the whole needs of the household. The scope of the research is to find alternative solutions for better energy performance of the building. An experiment took place through IES software and an Excel sheet for the exact calculations of the renewable energy supplies. The internal planning of the building was redesigned. The two bedrooms were transferred in the ground floor, while the living and dining room moved in the first floor. The internal alterations were targeting to the improvement of the building performance changing the over day and overnight stay of the occupants. The test was successful, since the simulation results have shown that the primary energy required for the dwelling was less than the conventional arrangement. The energy performance and the thermal condition of the occupants are examined through three scenarios with different interventions. The results occured through IES software and were very useful to take decisions for potential improvements of the case study. A fundamental finding was that the refurbished house performs better using a MVHR system than natural ventilation. Through IES calculations, a greater level of energy efficiency was achieved. This could be explained by the systematic, balanced and adjusted air flow that a MVHR system offers, while the natural ventilation should be adjusted by the occupants who might not see this process as an advantage of the house but as a liability. This is an important issue, because a potential MVHR system installation will cover enough usable area in the loft and sometimes its installation is not affordable.

Bibliography

Retrieved June 16, 2012, from Department for Business, Enterprise and Regulatory: http://www.hm-treasury.gov.uk/d/mainest08_26_berr.pdf

iesve. (2012). Retrieved July 25, 2012, from What we do: http://www.iesve.com/corporate/about-us/what-we-do

C.Jones, & G.Hammond. (2008). *Inventory of carbon & energy (ICE).* Retrieved July 19, 2012, from www.bath.ac.uk/mech-eng/sert/embodied/: http://perigordvacance.typepad.com/files/inventoryofcarbonandenergy.pdf

Government, C. a. (2010). *Code for Sustainable Homes-2010 .* Retrieved July 23, 2012, from http://www.communities.gov.uk/documents/planningandbuilding/pdf/1766436.pdf

Metz, B., Davidson, O., Bosch, P., Dave, R., & Meyer, L. (2007). *IPCC Fourth Assessment Report: Climate Change 2007.* Retrieved June 15, 2012, from http://www.ipcc.ch: http://www.ipcc.ch/publications_and_data/ar4/wg3/en/contents.html

Power, A. (2008). *Energy Policy.* Retrieved August 26, 2012, from Elsevier: http://www.bis.gov.uk/assets/foresight/docs/energy/energy%20final/power%20paper-section%205.pdf

Yates, T. (2006). *BRE.* Retrieved June 15, 2012, from http://www.RefurbVicHousing.pdf