Proceedings of 2nd Conference: ***People and Buildings*** held at Graduate Centre,
London Metropolitan University, London, UK, 18th September 2012.
Network for Comfort and Energy Use in Buildings: http://www.nceub.org.uk

Applicability of Level 6 CSH: Refurbishment of a Grade II Listed building

Aritz Moriones[1]

1 MSc Architecture Energy & Sustainability, Faculty of Architecture & Spatial Design, London Metropolitan University, UK, amorion10@gmail.com

Abstract

The constant increase in energy demand plays against drastically needed reductions in CO_2 emissions. Considering that more than a quarter of UK carbon emissions come from the housing sector and most of the UK's old and heritage-listed housing stock needs to be renovated refurbishment and retrofitting are key subjects for cutting down CO_2 emissions. The objective of this paper is to prove that it is possible to aim for level 6 of the Code for Sustainable Homes in the refurbishment of a Grade II listed building. The research method consists of a review of current regulations and standards relevant to the subject, a summarisation and compilation of relevant precedents that have attained high CSH levels, and analysis of the Case Study tested against key mandatory sections of the CSH.

Key Words: The Code for Sustainable Homes, Energy, CO_2 Emissions, Refurbishment, Listed Buildings.

1. INTRODUCTION

The constant increase in energy demand plays against drastically needed reductions in CO_2 emissions. Considering that more than a quarter of UK carbon emissions come from the housing sector and most of the UK's old and heritage-listed housing stock needs to be renovated refurbishment and retrofitting are key subjects for cutting down CO_2 emissions. The Code for Sustainable Home is a tool to tackle the CO_2 emission issue and to improve living standards (A. Mc Manus) in new plan dwellings.

In standard architectural practices, sustainability is usually addressed after planning permission, once the design is quite developed. This leaves little room for changes in the building shape. The case study will study a grade II listed building which is refurbished and argue the feasibility to balance out the initial poor building energy performance, aiming for level 6 of the CSH.

Listed Buildings: A listed building is a building which, because of its architectural or historic interest, is protected from needless changes or destruction. Changes will be allowed but the possibility of modifying, removal or refurbishment will depend on the Grade of the building and the importance of each one of its features. The buildings are classified into three different grades:

Grade I - Buildings of exceptional interest and national relevance.
Grade II*- Exceptional interest and outstanding importance.
Grade II - Buildings of interest which deserve every effort to protect them(Planning,2011)

Code for Sustainable Homes: Technical Guide 2010 (CSH)

The CSH is an environmental assessment method for rating and certifying new homes against sustainability parameters that are managed by BRE. The CSH covers nine different categories:

1. Energy & CO_2 Emissions
2. Water
3. Materials
4. Surface Water Run-off
5. Waste
6. Pollution
7. Health & Well-being
8. Management
9. Ecology

Depending on the level of accomplishment, the building will be awarded a number of credits and eventually the code awards the dwelling from 1 to 6 stars. In order to achieve a greater number of stars, not only has the building to comply with more restrictive minimum requirements in some of the different categories, but it has also to obtain more credits as a whole.

Zero Carbon (CSH): In the current definition, just regulated emissions (i.e. energy consumed for water heating, lighting, pumps and fans) from the dwelling needs to be zero or better.

SAP: SAP is the Government's Standard Assessment Procedure for assessing the performance of dwellings in the UK. SAP2009 is the software selected to assess the energy efficiency of the case study. The software takes into account: Materials, thermal insulation, ventilation type and equipment, heating systems, solar gains, fuel and renewable energy technologies (BRE,2011).

2. CASE STUDY: Beltwood Gate House

Climate Conditions: London has a temperate marine climate and receives an average of only 1468 hours of sunshine every year. Warm weather can usually be expected from May to September. The prevailing winds come from WSW during most of the year varying during February (SW) March (NNE) and April(E) (Wikipedia,2011).

Context: The Gate House is a Grade II listed building located in the London Borough of Southwark (51.4327°N 0.0720°W). The building dates from early c.20th. It is of traditional construction with rendered load bearing masonry elevations and a natural slate covered multi-pitched roof. There are painted metal framed Crittal style windows and timbered doors. Internally, the walls and ceilings are generally finished with a plaster on masonry or lath and plaster finish. Floors are predominantly suspended timber with floorboards.

For the refurbishment, the English Heritage allowed the team to replace all the interiors, just keeping the outer shell. Furthermore, the windows and doors could be replaced as long as new ones are put in place with the same formal language as the old ones. Therefore, the refurbishment is considered as if a new building was being built inside an outer layer, easing the task of achieving level 6 of CSH.

Methodology:

The case study analysed the dwelling before and after the refurbishment against two mandatory sections of the CSH:

A. Fabric Energy Efficiency (FEE)
B. Dwelling Emission Rate (DER)

They are the mandatory points of the category 'Energy and CO2 emissions' which is weighted 36.4% out of the nine categories. In order to attain level 6CSH, the building needs to meet the requirements of those two points. By these means, its chances of obtaining level 6 status are considerably raised.

A. Fabric Energy Efficiency: The FEE assesses the performance of the building fabric in terms of space heating and space cooling energy demand, throughout the year and covers only passive measures. The unit for this concept is kWh/m²/yr and its benchmark comes from a notional dwelling with natural ventilation and without considering internal gains from domestic hot water (BRE,2011). FEE is intrinsically related to the carbon emission rating but is independent of the type of fuel. The Zero Carbon Hub sets the target for Zero carbon Homes in 2016 for Semi detached, end of terrace and detached houses in a maximum energy demand of 46kWh/m²/yr. Therefore, this is the theoretical maximum value for the FEE for the case study of this thesis. The FEE is based on: The Building Fabric U-value, thermal bridging, air-permeability, thermal mass and thermal gains.

B.Dwelling CO_2 Emission Rate (DER)

The DER is based on the annual CO_2 emissions associated with space and water heating, ventilation and lighting, less the emissions saved by energy generation technologies. It is adjusted by floor area and its unit is kg/m²/year.

1st SCENARIO | Existing building:

The energy performance of the existing building was assessed using the following data.

Building Features:

Shape factor: the shape factor is a numerical quantity representing the degree to which a shape is compact. The footprint of the house is almost a square, hence, it has a very good shape factor = 0.6. Consequently, it loses less heat per unit of internal floor area than another building with the same building features and floor area but with a greater perimeter.

The building envelope works as thermal barriers between the interior and exterior. The **U-value** of the openings fluctuates from 3.5W/m^{2}K for the entrance door to 4.8W/m^{2}K for the single glazed windows. Whereas, the U-value of the building fabric varies from 3.2 W/m^{2}K for the roof to a minimum U-value of 0.6W/m^{2}K with an U-value of 1.47W/m^2 for all the external walls.

Thermal Bridging: Thermal bridging can cause great amounts of energy loss and condensation in inner layers of the building fabric. A notional value is adopted. Y= 0.15W/K

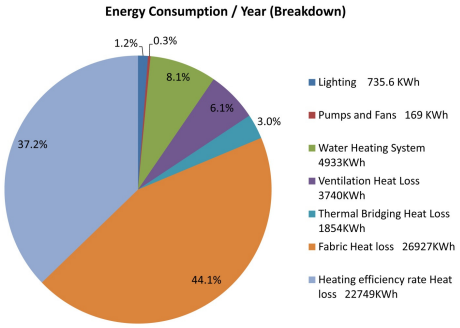
Thermal Mass: In this case a high value of thermal mass will be adopted, because of the high levels of thermal inertia in the masonry walls of the dwelling. TMP= 450 j/m2.K

Air Permeability$_{@50pa}$: No pressure test, hence a default value is adopted. Air perm. = 15 m^3/m^{2}h

Space & Water Heating Systems: The primary system is a gas boiler with radiators (Efficiency Factor = 69%). It supplies 90% of the space heating demand and 100% of Domestic hot water demand. The secondary system is an open fire place fuelled by wood logs (E.F. = 32%) 10% space heating demand. The Cylinder volume is 200L and is insulated with a10mm-thick layer.

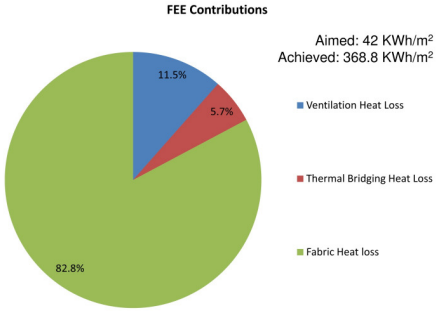
There are not **renewable energy sources** installed or **low energy lighting outlets.**

Results: 1. Energy Consumption Breakdown



Whilst, the total energy consumption is 61108KWh, it is much more important to know the percentage of energy consumption of each element. Knowing the refurbishment scope of works and the Energy consumption ratio it is possible to assess the relative importance of each heat loss source and determine the order of intervention.

The largest energy consumption is related to the fabric heat loss, with 44.1% of the total. The heating system efficiency rate accounts for 37.2% and 8.1% for the water heating system. Therefore, the first priority would be to upgrade the building fabric. In many listed buildings improving the building fabric U-value could be complicated, because there could be some of its features protected. Hence, knowing the fabric heat loss ratios would be very helpful to decide which the first exposed elements to act on are. The next measure would be to improve the efficiency of the heating system. The existing heating systems are very inefficient (69% for the gas boiler and 32% for the fire place) so replacing them for high efficient systems, ca.85-90% efficient, would drastically reduce the energy consumption.

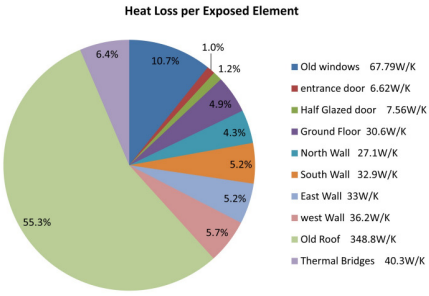


2. Fabric Energy Efficiency (FEE)

The total fabric heat loss is divided into three main factors:

Fabric heat loss 82.8%
Thermal bridges 5.7%
Ventilation heat loss 11.5%

There are others which are of marginal relevance (BRE,2011) for this case study. Therefore, in order to improve the FEE, the building fabric U-values have to be improved first. Chart 3, shows the heat loss on each exposed element. The roof accounts for more than half of the energy losses. Thus, this would be the first element to be thermally insulated to improve the FEE.



3.Dwelling CO_2 Emission Rate (DER)

The DER obtained in this first analysis is **120 kg/m²/year,** when the target for Level6 is 0 kg/m²/year. To improve the DER, reducing energy consumption and decreasing the CO_2 emissions is fundamental. As mentioned before, the first step would be improving the building fabric U-value because this would simultaneously reduce heat loss, and thereby energy consumption and CO_2 emissions. Changing the type of fuel would be critical because the current main fuel, (i.e. gas) presents an emission factor = 0.198 $KgCO_2$/KWh that is worse than the emission factor of other types, e.g. wood pellets (EF=0.028 $KgCO_2$/KWh) .Therefore, Changing the boiler for a highly efficient one with a better type of fuel, in terms of CO_2 emissions, would also help to improve the DER acting on both of the key factors too.

2nd SCENARIO| Refurbishment

Economical Viability: Net Saleable Area (NSA)

It is fundamental to establish a compromise between energy efficiency and economical viability and the NSA plays an important role for this purpose. NSA is the Gross Internal Area of a dwelling with headroom taller than 1.5m. There are zones in the under roof space of the dwelling with less than 1.5m headroom. Ergo, that space could be used to attach thermal insulation to the inner layer of the pre-existing building fabric without losing market value or NSA.

It is recommended that the building envelope keeps a consistent U-value throughout for a better thermal performance. Hence, the same amount of thermal insulation will be added to the ground floor walls. The ground floor in the refurbishment part has more than 1.5m throughout. Therefore, any layer of thermal insulation attached to the wall would reduce the total NSA, thereby decreasing, its potential market price. The compromise found for the designer is that the level of thermal insulation can increase as long as the headroom on the first floor is less than 1.5m. As a result, the thickness of the thermal insulation is 210mm.

Building features: The building footprint stays exactly the same as before the refurbishment.

Building Fabric: the first step in order to improve the FEE and DEA is acting on the thermal performance of the building fabric. This reduces the level of energy transfer through the building envelope which improves the FEE and decreases the CO_2 emissions emitted to maintain levels of comfort within the dwelling, improving the DER.

Opening Types: As explained before in the first Scenario input data, the openings are a significant source of heat loss; therefore, it is very important to act on them. The entrance door is replaced with a timber door of outward appearance, but with an embedded layer of thermal insulation. The chosen door's U-value is 1 W/m^2K. The single glazed windows are replaced with double glazed timber framed windows, maintaining the same aesthetic character as the originals but with a U-value of just 1.2 W/m^2K as opposed to 4.8 W/m^2K.

Exposed Elements: The external appearance of the exposed elements cannot be altered; therefore, new inner layers with thermal insulation have been added to the exposed elements to improve their thermal performance.

Even though the U-values have greatly improved they are still worse than the typical CSH level6 U-value: 0.1-0.12 W/m^2K (Communities.gov.uk,2011) due to the NSA compromise. In the roof it was possible to achieve **0.1 W/m^2K**, specifying thermal insulation on top of the rafters without compromising the NSA of the property. Moreover, this helps to avoid thermal bridges in the roof without any difficult construction solution.

EXPOSED ELEMENTS	TYPE (COMPOSITION)	GROSS AREA	OPENINGS	NET AREA	U-VALUE
GROUND FLOOR	20mm wood flooring/30mm timber batten/100mm cast	51m^2	-	85.4m^2	0.16W/m^2K
1ST FLOOR	internal floor: no relevant	36 m2	-	133 m2	0.9W/m^2K
ROOF	10mm slate tiles/ 50mm timber batten/ 200mm rafter roll in-between 300mm timber joist/ 25mm plasterboard	109 m^2	-	109 m^2	0.16W/m^2K
NORTH WALL	30mm Lime render/215mm Brick/ 25mm well ventilated air layer/ 215mm rocksilk dritherm/ 25mm plasterboard	26.25 m^2	7.81 m^2	18.44 m^2	0.16 W/m^2K
SOUTH WALL		26.25 m^2	3.86 m^2	22.39 m^2	
EAST WALL		28 m^2	5.57 m^2	22.43 m^2	
WEST WALL		28 m^2	3.38 m^2	24.63 m^2	

Thermal Bridging: The refurbishment is approached as if a new building was being built inside the outer existing shell. Therefore, it is possible to drastically improve the thermal bridging. By default, some possible errors in construction are considered. **Y = 0.48 W/K.**

Thermal Mass: Despite the new thermal insulation on the inner wall layers of the perimeter walls, the inner masonry walls still benefit from a high level of thermal mass THM= 450 j/m^2.K

Air Permeability: Decreasing the air permeability rate, improves the building fabric performance, requiring less energy to keep the comfort levels.Due to the higher technical demand of the refurbishment, the expected air permeability rate will be higher than the typical levels for level6 (i.e. 3-1.48 m^3/m^2h) (Communities.gov.uk,2011) . **AirP.@50pa= 6.5 $m3/m^2h$**

Heating Systems: Primary: The Old gas boiler has been replaced by the TDA Thermodual biomass boiler. Efficiency Factor= 93%. 100% space heating demand. Secondary: None

Water Heating: It uses the biomass boiler for domestic hot water and solar panels for water heating. Cylinder: 200L | 75mm factory insulated |Primary pipework insulated

Waste Water Heat Recovery Systems (WWHRS): A WWHRS uses a heat exchanger to recover heat from waste warm water as it flows through the waste plumbing system (BRE,2011). The **Shower-Save Recoh-vert RV3 System A** has been selected for all the bathtubs and showers.

Fixed Lighting Outlets: Total fixed Low energy lighting outlets: 12 (100% of total outlets).

Renewable Energy Sources: To offset some of the dwelling's CO_2 emissions and reduce some of the net energy consumption. At the moment the CSH only allows onsite energy production.

PV panels and Solar Thermal panels are the systems adopted. South orientation collects the maximum amount of solar energy but the only problem is the space constraint. The south facing part of the roof has ca. 18 $m^{2,}$ confined within a triangular shape, such that the real usable area, when considering the rectangular shape of the panels, is reduced down to 12 m^2.

An inclination similar to the latitude is optimal for an annual maximum production(W Thermal,2011)*;*Therefore, considering that the site latitude is 51^o, the existing 46 ^{o}-roof angle is close to the ideal inclination.

Solar Thermal Panels: As a rule of thumb, it is needed between 1 and 2 m^2 of collector/person(Yougen,2011). SAP2009 considers an avg. occupation of 2.58people, therefore: 2.58p x 1.5m^2/p = 3.87 *(4m^2)*

The collector type is a glazed flat plate, south orientated and with and 45^o angle. The dedicated solar store volume is 100litres (combined cylinder).

PV panels: The type of PV panel chosen is: **BP 4180T.** Its maximum power per panel is 180W (1000w/m^2 irrandiance). Considering the space left for the thermal solar panels and its dimensions (790mm x 1587mm) there is enough room for 6 units, therefore:

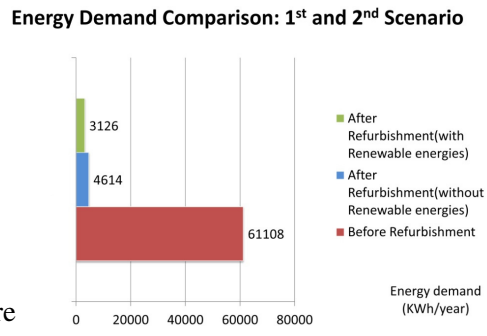
6panel x 180W/panel = 1,08KW = Peak KW | Tilt: 45 °| Orientation: South

The electricity produced by the PV module in kWh/year is:**910.66 KW/year**

RESULTS: **Summary|** DER = -1.73 | TER = 20.64 | FEE = 45.98

1. Energy consumption: Before & After

Prior to refurbishment the energy consumption was 61108 KWh/year, whereas after refurbishment it has reduced to 3126 KWh/year, almost 20 times smaller. It can be seen that renewable energies account for 1488 KWh/year. Thus, the renewable energies, contribute roughly a third of the dwelling's energy needs.



2. FEE

Table 1 shows the energy features of the building before and after the refurbishment and the resulting FEEs.

All the Building fabric elements have been improved but the most notorious is the roof which after the refurbishment its U-value is 32 times better than before. The FEE after the refurbishment is 45.97 KWh/m^2; before the refurbishment, it was 368.8KWh/m^2, so roughly an

eight-fold improvement. The new figure meets the CSH level 6 requirements of 46 KWh/m^2, a fact that supports the hypothesis that level 6 of CSH is achievable in a refurbishment of this kind.

Building Fabric U-values: The main reason behind the U-value improvement is the thermal insulation. Before the refurbishment, there was no thermal insulation in any exposed element but after, all exposed elements have as an average a 210mm-thick layer.

The windows have been upgraded to double glazed windows, and the entrance door has been replaced with one with thermal insulation. The initial thermal insulation for the refurbished roof value was the same as the rest of the walls, 210mm thick. However, the resulting FEE was 48.8 KWh/m^2, so to achieve 46 KWh/m^2, the insulation was increased to a 300mm layer.

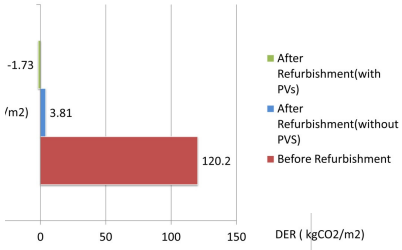
Table 1: Building Features and FEE. Before & After

	After Refurbish.	Before Refurbish.
BUILDING FABRIC ELEMENTS	VALUES	VALUES
GROUND FLOOR	0.13W/m^2K	0.6W/m^2K
1ST FLOOR	0.9W/m^2K	1W/m^2K
ROOF	0.1W/m^2K	3.2W/m^2K
NORTH WALL	0.1 W/m^2K	1.47 W/m^2K
SOUTH WALL		
EAST WALL		
WEST WALL		
Air Permeability@50pa	6.5m^3/m^2h	15m^3/m^2h
Thermal Bridging	0.48W/m2.K	0.15W/m2.K
windows	1.2W/m^2K	4.8W/m^2K
entrance door	1W/m^2K	3.5W/m^2K
FEE	45.97 kWh/m^2	368.8 kWh/m^2

DER: Diverse strategies to decrease CO_2 emissions have been implemented; reducing energy consumption, improving the emission factor and self producing energy, thereby offsetting some energy demands. Before the refurbishment, the DER was 120.19kgCO_2/m^2year, whereas after it, DER is -1.73kgCO_2/m^2year. Again, this figure exceeds CSH level6 requirements (i.e. 0kgCO_2/m^2year).

Chart 9 compares CO_2 emissions from dwelling before and after refurbishment, as well as with and without PVs. It can be seen that PVs can play an important role in offsetting the CO_2 emissions. The same building without the PVs would emit 3.81 kgCO_2/m^2year whereas with the PVs the net CO_2 emissions are -1.73 kgCO_2/m^2year. The amount of CO_2 emission that the Photovoltaics offset is: 910.66KWh/year x 0.52981 KgCO_2/KWh = 481.74 KgCO_2/year

DER Comparison: 1st and 2nd Scenario



FINDINGS & CONCLUSIONS

The good level of compactness (0.6) makes the building more suitable for being energy efficient.

In order to comply with the two mandatory sections of the CSH the refurbishment needs to follow a holistic approach. For that purpose, the following strategies have been used:

1-Highly thermally insulated building fabric
2-A passive solar design approach
3-Low energy lighting
4-Environmentally-friendly materials
5-Water-efficient sanitary fittings
6-Rainwater harvesting
7-Renewable energy systems such as: Photovoltaic cells, biomass boilers and thermal water heating.

The results obtained after the refurbishment are 45.98 KWh/m^2 and -1.73 kgCO_2/m^2/year respectively; meeting their targets for CSH level6; 46 KWh/m^2 and 0 kgCO_2/m^2/year. The energy demand of the Case Study improves, from 739.7 KWh/m^2/year before refurbishment to 37.51 KWh/m^2/year after. In addition, the results for FEE (41.89 KWh/m^2) and DER (-1.15 kgCO_2/m^2/yr) meet their respective targets for CSH level6; 46 KWh/m^2 and 0 kgCO_2/m^2/year. Therefore, this proves that it is reasonable to aim for level6 of the Code in refurbishment projects; even within the context of a Grade II listed building.

References

Planning,20011. http://www.onlineplanningoffices.co.uk/html/additional_advice/listed_buildings.php
ZeroCarbonHub, Nov2009. *Defining a Fabric Energy EfficiencyStandard forZeroCarbonHomes.* ZeroCarbonHub.Nov2009.
BRE,2011. *The Government's Standard Assessment Procedure for Energy Rating of Dwellings,2009edition*, Watford, BRE
Wikipedia,2011. http://en.wikipedia.org/wiki/London
Communities.gov.uk,2011. *CSH Case Studies,* London
W Solar,2011. http://en.wikipedia.org/wiki/Sustainable_architecture#Solar_panels
Yougen,2011. http:// http://www.yougen.co.uk/renewable-energy/Solar+Thermal