The Carbon Value of the U.K.'s Historic Housing Stock

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Abstract – The need to reduce carbon emissions and lower the energy consumption of the historic built environment is now recognized as a critical factor in helping the U.K.'s government's aim to reach net-zero carbon emissions by the year 2050. This paper proposes rather than encourage historic homeowners to sustainably refurbish their properties, it proposes that the most sustainable option is to adopt a building conservation-focused strategy to maintain and apply small benign changes to the property. The primary data is from testing a range of different sustainable improvement interventions on 20 different historic houses using computer modelling and live data. The paper will show that significant energy and carbon savings can be made without affecting the visual or fabric heritage of the property. The study will go on to show that this strategy is also the most economically effective method for sustainably refurbishing historic dwellings. The paper concludes by defining the balance of the competing priorities of economic capacity, the preservation of the heritage of the historic housing stock and environmental performance improvements happens at a key 'tipping point' which is used to define the 'carbon value' of our historic housing stock.

Keywords – Sustainable Refurbishment; Carbon Value; Economic value; Historic Dwellings; Sustainable strategy.

1. INTRODUCTION

The reduction of carbon emissions is now regarded as one of societies' most important challenges in the 21st century. With the UK's Existing housing stock contributes 27% of national CO_2 emissions,[1] and it is predicted that two-thirds of the dwellings that will be standing in 2050 are already in existence [2]. Improving the performance of existing dwellings is therefore vital in helping to reduce the ecological footprint of the UK as a whole. This paper sets out to define the heritage difficulties and the economic barriers that need to be overcome with the historic housing stock in England if these sustainable refurbishment targets are to be met. The UK has one of the oldest building stocks in the developed world, and there are currently around 4.7 million historic dwellings [3]. So, with the challenge to refurbish this large number of properties to reduce their carbon emissions while at the same time, preserve their heritage and value requires a different approach. This paper proposes that the most suitable method of sustainable refurbishing a historic UK home is to focus on small benign changes and maintenance methodologies rather than an invasive environmentally-focused refurbishment strategy for each dwelling. This large number of refurbishments needed also has enormous economic implications and therefore for the consideration has to be taken to balance the different priorities of the reduction of carbon emissions, the preservation of the historic housing stocks inherent heritage and economic capacity has to be considered if such a refurbishment methodology is to be successful.

2. CONTEXT

The U.K. has one of the oldest building stocks in the developed world. This group of buildings are defined as hard to treat, and strategies for their sustainable refurbishment remain ambiguous at best and at worst damaging to the fabric of the building. The U.K.'s carbon reduction target is net-zero carbon by the year 2050. As part of this strategy, the target of all dwellings in England and Wales to have an equivalent environmental performance of an energy performance certificate (EPC) grade C or higher by 2035. The pre-1919 housing stock in the U.K. has, on average, the worst SAP score and the highest carbon emission of any house age group, and typically, over twice the maintenance costs compared with modern housing for basic repairs [4]. There are over 4.7 million of these dwellings in England alone [5] which equates to over 420 home refurbishments every single day from now until 2050 if the net-zero carbon emissions goal is to be met. More drastic is if the target of refurbishing all dwellings by 2035 to be reached this would mean that 850 refurbishments every day need to be completed between now and 2035.

3. PROJECT AIMS

The project hypothesis is 'The most sustainable strategy for owners of historic dwelling does not lie in sustainable focused refurbishment of their dwellings but in historic building maintenance and benign improvements.' The overall aim of the project is to show that building maintenance and carefully selected interventions, could significantly improve the environmental performance of historic dwellings and at the same time be economically viable and culturally beneficial to the preservation of the historic asset.

3.1 METHODOLOGY

The primary data for this study comes from analysis of 20 different historic dwellings in England. The dwellings came from a range of sources; 4 dwellings from The Reading case-study project [6], 12 dwellings from the Redbridge project [7][8], A further 4 dwelling were tested to complete a range of historic urban/suburban dwelling typologies found in England. The dwellings were tested using a range of techniques; the computer modelled buildings were tested using the Government's Standard Assessment Procedure (SAP) calculation for domestic energy consumption and carbon emissions. The NHER Plan Assessor [9] was used to simulate existing environmental performance of the dwellings and then range of improvements. Data from other dwellings included live and actual energy consumption and carbon emission results collected from the dwelling following refurbishment. In each case, a variety of environmental performance improvement interventions were tested. These included conservation-based maintenance and benign environmental improvements which have little or no effect on either; the visual heritage of the dwelling or damage to the historic fabric of the dwelling or impacted the building's physical properties (such as moisture transfer) (see section 3.3). For comparison also tested were other common sustainable interventions such as replacing the single glazed windows with double glazing (to compare these changes with the benign conservation changes). Each intervention was tested against the following criteria: cost of the intervention, the amount of reduction is CO_2 (eqiv.) emissions and reduction in energy consumption. From these results cost to benefit calculations were derived.

3.2 HISTORIC BUILDING MAINTENANCE AND BENIGN CHANGES

It is important to understand that the fabric and the appearance of a historic dwelling have cultural significance - the building itself is an artefact and historical asset. The idea of approaching work from a minimum intervention methodology is best summarised by the Burra Charter [10] "as much as necessary, as little as possible". The methodology for this study is the improvement in energy saving and carbon emissions reduction with as little damage or change to the inherent heritage of the historic dwelling. The Historic Town Forum [11] supports this methodology stating that "One of the most energy efficient ways to preserve historic buildings is to ensure that continued, regular maintenance is carried out to safeguard its historic fabric." Both the Historic Town Forum and English Heritage encourage the use of small/benign changes to improve the environmental performance of a historic dwelling. Benign changes are defined as changes to the building that either have little or no effect on the heritage of the dwelling or do not damage the dwelling fabric either to the fabric itself or the way it needs to perform or react. Typical benign interventions include installing of loft insulation, draught proofing the building, insulating the hot water cylinder (if applicable), replacing a non-condensing boiler with a high efficiency condensing boiler, improving the heating controls, installing energy-saving lightbulbs & installing floor insulation in raised timber floors. Maintenance tasks such and servicing of heating systems were also included as well as Periodical renewal of elements with a set lifespan, be they sacrificial elements such as paint or appliances as long as their replacements meet the requirements of a benign intervention were also included in the study.

4. THE RESULTS OF THE STUDY AND TIPPING POINT & CARBON VALUE

The aim of this study was to investigate if maintenance and benign changes could be seen as the most sustainable approach for the refurbishment of historic suburban dwellings.

Table 1 overall energy savings of the benign interventions from the study

Action	Percentage Energy Saved %			Capital Cost Used in Study (£)	Impact on Fabric Heritage	Impact on Visual Heritage
Upgrading the loft insulation to 300mm	4.0%	to	31.1%	£273.00	LOW	LOW
Draft proofing and window repair	2.0%	to	10.0%	£50–£2000	LOW	LOW
Hot water cylinder insulation to >75mm	3.6%	to	8.7%	£20.00	LOW	LOW
Fitting of a condensing boiler	16.0%	to	46.0%	£1,750.00	LOW	LOW
Improved heating controls	12.0%	to	14.1%	£250.00	LOW	LOW
Energy saving light bulbs	0.1%	to	0.2%	£200.00	LOW	LOW
Floor insulation fitted in raised timber floor	8.3%	to	14.0%	£1,000.00	LOW	LOW

First overall finding is that this study found that benign maintenance (conservation focus) refurbishment as the potential to save between 30% and 50% of carbon emissions along with this up to around 40% savings in energy consumption. To be considered sustainable cultural, economic and environmental factors have to be considered and ideally in balance. There is a point at which these factors become in equilibrium. This point is defined as the tipping point.

All of the primary results when mapped against carbon reduction and cost of intervention from the primary research showed the same pattern showed in figure 1. Figure 1 compares the cost savings of the building intervention (set of interventions) against the CO_2 Saving Incurred.

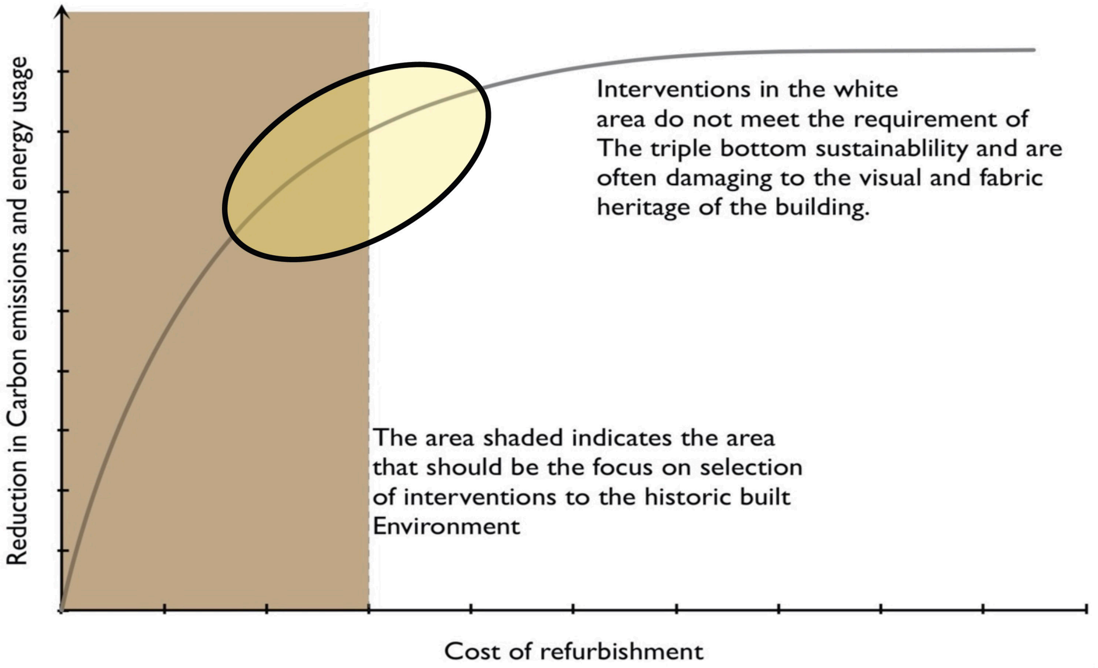

Figure 1 Comparing the cost savings of the building intervention against the CO_2 Saving Incurred tipping point highted in yellow

The point circled on figure 1 is the point in which the gradient changes significantly this can be seen as a tipping point or the turning point in which the rate of the cost to benefit (carbon saving/energy savings) changes in relation to the amount of financial costs of the sustainable interventions applied to the dwelling. This cost benefit analysis (CBD) starts to put real-world numbers on the findings and the hypothesis of this study. In the cost benefit analysis, the value unit is the financial cost of the intervention and the benefit is the reduction in CO_2 emissions from that intervention. The units are defined as: £ per KG CO_2 reduced or £ per %CO_2 reduced. Steeper the gradient shown in the chart the more CO_2 is saved per pound spent, in other words, greater the cost benefit ratio. Smaller the cost benefit ratio and lesser the amount of CO_2 saved per pounds spent on the intervention. For the best balance between the economic and environmental values of an intervention should be calculated. All of the primary results follow a similar trend. While the individual buildings follow slightly different result gradients, the trend remains constant. In the Redbridge study the ratio for the benign changes £6.71 per kg CO_2 which then rose to £42.90 per kg CO_2 past the tipping point. In the Reading study ratio for the benign changes £2.54 per kg CO_2 which then rose to £27.02 per kg CO_2 past the tipping point. This ratio changes but the tipping point remain within a consistent tipping point. This Tipping point occurs around the £3000-£7000 mark and show a carbon emission savings of between 30% and 50%.

If the triple bottom-line criteria are taken into account this is the point where environmental and economic values could be seen to be in balance or at least to be in the most efficient. This would be the case if all of the interventions are seen as benign, little to no damage to either the visual or fabric heritage. This is the point in which the graph gradient turns from a steep slope to a gradual incline, this tipping point is a key part of the discovery of this study as it shows the balance point between the economic and the environmental values.

4.1 CARBON VALUE

From the tipping point it is possible to begin to define what is possible in reducing the carbon emissions from historic dwelling within the financial capabilities of the owner and without damaging the heritage (visual and fabric) of the dwelling. This number when compared to the overall target of reduction in CO_2 emissions is labelled the carbon value of the heritage of the dwelling. This is the differential between what is economically and culturally possible calculated against the perceived target of the reduction in CO_2 emissions. It is possible to define the carbon value in a simple equation and this could be translated as

Carbon value of heritage	=	Target Carbon emission Reduction	–	Total Carbon emission saving that can be achieved without damaging the heritage of the building

As defined earlier in the study the benign changes are interventions that do not have a negative impact on either visual or fabric heritage so therefore the question can be written as

Carbon value of heritage	=	Target Carbon emission reduction	–	Total Carbon emission saving from the benign changes

This can be further rewritten as to bring in the third value of economic limitations equation has to be further defined to bring in the economic limitations

The triple bottom line carbon value of heritage	=	Target Carbon emission Reduction	–	Total Carbon emission reduction of the benign changes which are financially viable

At this point, the tipping point, results can be used to provide the owner with the best value, this is the best cost to benefit in the case of historic suburban housing. The results show that the tip point occurs in the range of £2000 to £7000 which provides a carbon emission saving of between 30% and 50%. When these numbers are put into the final equation the results show that the triple bottom-line carbon value of Historic dwellings is between 30% and 50% of carbon emissions target.

4.2 COST DIFFERENTIAL

While the carbon value shows the gap between the proposed target and what the study finds is optimal in terms of carbon emissions reduction in Historic suburban dwellings (in England). This could be seen as a failure to achieve the desired target. However, the tipping point and the cost benefit analysis highlights the economic reality of trying to reduce the historic housing stocks carbon emissions by the UK government's target of 80% to 100% reduction in carbon emissions by using refurbishment methodology.

Table 2 Overall Refurbishment costs compared for total Pre-1919 housing stock

Type of interventions	cost	number of dwellings	total cost
Upper full refurbishment	£80,000.00	4,700,000.00	£376,000,000,000.00
Mid full refurbishment	£40,000.00	4,700,000.00	£188,000,000,000.00
Lower full refurbishment	£20,000.00	4,700,000.00	£94,000,000,000.00
Upper benign changes	£7,000.00	4,700,000.00	£32,900,000,000.00
Mid benign changes	£3,000.00	4,700,000.00	£14,100,000,000.00
Lower Benign changes	£2,000.00	4,700,000.00	£9,400,000,000.00

It would cost between £9 billion and £32 billion to reduce their historic housing stock in the U.K.'s carbon emissions to around 30% to 50%. To reduce the same stock by an additional 30% to 50% (to meet the government target) and additional £61 billion-£373 billion will be needed. This additional cost needs to be seen within the context of the overall cost to benefit for the country as a whole. There is a tenfold increase in financial cost to increase the saving from 30%-50% CO_2 emissions to 80%-100% reduction in CO_2 emissions. This large jump in cost raises the question whether the cost of the further intervention (above the benign intervention) can be better spent elsewhere in policy such as greening the electricity grid which would benefit the whole of the built environment rather than a small group of buildings.

The building is industry capacity also needs to be taken into account with 4.7 million pre-1919 dwellings in England this would equate to over 420 refurbishments to be completed every day from now until 2050. If the target of refurbishing old dwellings by 2035 is to be reached this would mean that 850 dwellings every day need to be completed between now and 2035.

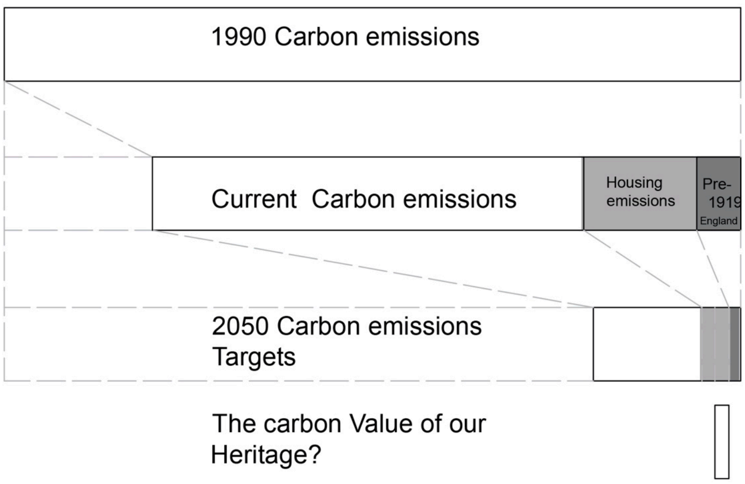

Figure 2 Carbon Value of heritage 80% emission target

The figure 2 show the carbon value of the heritage. That show the size of the Triple Bottom line Carbon Value of our historic housing. The small size of the carbon value can be seen against the other savings required.

4.3 OTHER USES FOR THE CARBON VALUE

As much as the carbon value was intended to be used as a decision-making tool it could however be used for other purposes. The carbon value could be used in further scenarios: it could be used as a measure for carbon taxation applied to historic dwellings or for the use of offsetting to help meet the target of net reduction in carbon emissions. It is the net target that is important as part of the government's carbon reduction strategy.

5. CONCLUSION

While it is accepted that the historic built environment must reduce its energy consumption and lower their carbon emissions but at the same time the need to preserve inherent heritage. This defines the need for change. If we take the definition of building conservation as the management of change [12] and the basis of sustainability is the balance of the triple bottom line. The study has shown that benign changes and maintenance do offer a triple bottom line sustainable strategy for lowering carbon emissions and increased energy efficiency of historic suburban homes.

The study has shown that benign changes and maintenance are cost-effective with a high cost to benefit ratio benign changes help preserve the cultural value and historic fabric of the dwelling and finally the study shows that the Tipping point occurs around the £3000-£7000 mark and show a carbon emission savings of between 30% and 50%. The study clearly shows that the optimal balance between economic measures and environmental improvements can be found at the tipping point. After the tipping point the cost benefit ratio decreases and becomes increasingly more expensive to lower carbon emissions and reduce energy consumption. It must also be noted that as the interventions to the property are either benign or maintenance based there is little or no impact to the visual heritage, furthermore, maintenance is critical to the survival of the historic fabric of the building. Historic building maintenance, periodical renewal and benign improvements methodology can be expected to get most pre-1919 dwellings up to an EPC level C rating. Real-life limitations have to be taken into account such as the amount of financial capital, the capacity of the built environment to be able to refurbish a large number of properties *et cetera*. The vast scale of the number of interventions and refurbishments needs to be understood. While it has been shown that it is technically possible to refurbish a dwelling beyond the tipping point, the time and resources needed to do such a refurbishment provide their own limitations: with 4.5 million of these dwellings in England alone, this equates to at least 425 refurbishment every single day from now until 2050 so any policy/strategy for encompassing all of the historic built environment dwellings needs to able to be scaled up simply to meet the huge number of refurbishments that have to be completed. Another key point to support the hypothesis is that benign changes and maintenance is **not** a set, restrictive strategy. Benign changes and maintenance do **not** restrict other sustainable improvements to take place on the dwelling, if correctly applied, actually they should support them. The strategy does not rely on a single large refurbishment completed at a single point, but in a collection of small interventions done over a period of time.

In final conclusion then, if all historic dwelling sustainably refurbished to their tipping point and those interventions are benign, then the balance between the need to lower carbon emissions and energy consumption, then need to preserve the heritage of the building and the need for the intervention to offer the best values and be affordable will be met and be at the optimal balance of the triple bottom line sustainability requirements. After the tipping point, the question is which of the triple bottom line has to give way to the other criteria or does it require the use of other models such as carbon off-setting or carbon taxation.

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