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Low Carbon Urban retrofit. The case study of Neath

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ABSTRACT

The present study was designed to determine the impact of urban form on the CO_2 emissions when a retrofitting procedure is carried out. The focus was mainly on two factors responsible for carbon emissions at this scale; building stock emissions and transportation emissions by investigating urban density and walkability factors. Neath in Wales was selected for the case study.

Five steps were followed: a) analysis of the current carbon emissions; b) building retrofit; c) alteration in urban density; d) improving the walkability; and e) calculating the overall impact of the proposal.

Contributing to current similar researches, the results confirmed the initial hypothesis that the urban form has a significant impact on CO_2 emissions during the retrofit procedure. It also established the already-there impact of urban form on the existing building stock.

As for the relationship between building and urban retrofit, the first has been proved to be the dominant factor leading to significant CO_2 emissions reductions. Secondly, significant variations have been identified among neighbourhoods, which proves that such an approach might be useful for policy-making.

Finally, crucial issues remain to be solved regarding the Low Carbon Urban Retrofit assessment criteria.

KEYWORDS: Low Carbon, Urban Retrofit, CO_2 reduction, BREEAM, SAP ratings.

INTRODUCTION

Effective strategies for mitigating the increased Green House Gas (GHG) emissions seem necessary when moving towards a low carbon future. According to the UK Government's Climate Change Act in 2008, enforced by international accords, 80% of carbon emissions is planned to be reduced by 2050 from 1990 levels. Taking into consideration that "*71% of global energy-related greenhouse gas emissions can be attributed to urban areas* (IEA, 2008 cited in Keirstead and Calderon, 2012)", the current challenge is "*how to manage the decarbonisation transition of the nation's urban built environment"* as stated in the same article (Keirstead and Calderon, 2012).

A challenge to be met by planners is the impact of urban form on energy consumption of buildings (Ratti et al., 2005, Keirstead and Calderon, 2012, Liu and Sweeney, 2012, Chan et al., Bulkeley, 2011, Scott and Ben-Joseph, 2012, Christen et al., 2011, Mitchell et al., 2011). As such, "*are there opportunities to seek overall carbon reduction through new urban forms?*" (Crawford and French, 2008).

According to Ratti et al. (2005), the impact of urban geometry on energy consumption "*still remains understudied and controversial*" (Ratti et al., 2005). This research aims to

contribute to such investigations, since further studies are required for "*more conclusive judgements*" (Liu and Sweeney, 2012).

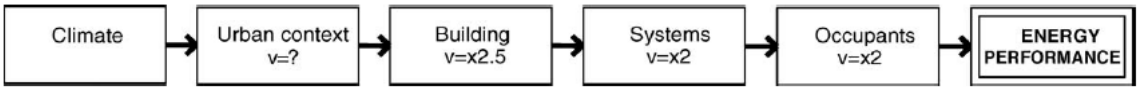

Figure 1. Factors that affect energy consumption in buildings; urban context is not quantified. (Baker and Steemers, 2000)

First and foremost, urban form could be specified as the spatial structure and character of a metropolitan area, city, town or village. In detail, its attributes are: the physical structure (street pattern, plot pattern and building pattern); "*intensity, diversity, distribution and proximity of land uses, buildings, streets and mobility functions and their associated energy sources and infrastructure*" (Christen et al., 2010).

LITERATURE REVIEW

There are various arguments suggesting that, compared to a new development, retrofit is associated with lower carbon emissions (Smith, 2010; Jerkins cited in Smith, 2010). During retrofit one adds a component or accessory to something that did not have it when manufactured (University, 2012). According Scott and Ben-Joseph (2012), house energy retrofit might include fabric or energy systems improvements. These improvements can perceived differently at a larger scale (Bourdic and Salat, 2012).

Compared to a sustainable retrofit, a low carbon retrofit takes additionally into consideration the GHG emissions. The two ways of measuring the effectiveness of carbon indicators (the per capita and per hectare basis) differ in the way the carbon emissions are calculated (Prince's Foundation of Built Environment, 2010) and in the final outcome of measurements.

In terms of proposal assessment, BREEAM for Communities in UK and LEED for Neighbourhood Developments in USA are the most internationally recognised sustainability assessment tools in larger scale than this of buildings (Beattie, 2011). In this context, BREEAM for Communities' limitations are the underestimation of low carbon criteria in favour of sustainability and its sole focus on new developments and not retrofits.

METHODOLOGY

Neath Port Talbot was selected as the place with the highest carbon emissions in UK according to the data released by the Department for Energy and Climate Change in 2012. In the beginning, an analysis of Neath's urban characteristics, existing building stock's characteristics, land-use characteristics, transportation and energy systems - renewables is carried out and relevant maps are produced.

Firstly, the residential sector's carbon footprint, which forms the boundary of the project's environmental profile, is assembled and analysed. The proposal was composed sequentially by five steps: a) analysis of the current carbon emissions(1^{st} step); b) building retrofit (2^{nd} step); c) alteration in urban density (3^{rd} step); d) improving the walkability (4^{th} step); and e) calculating the overall impact of the proposal (5^{th} step). In order to achieve this, the analysis was based on CO_2 emissions calculations for six representative neighbourhoods, three for each building type: terraced and semi-detached.

Following this, a bottom-up typology approach was used to estimate the carbon emissions. This was achieved by combining SAP rating model (DEFRA, 2005) and ENERGY PLUS software (2012, U.S. Department of Energy, 2012). In this way, the overshadowing of the surroundings was considered and daylight calculations led to more accurate lighting loads calculations.

Figure 2 (below) illustrates the workflow for this combined methodology.

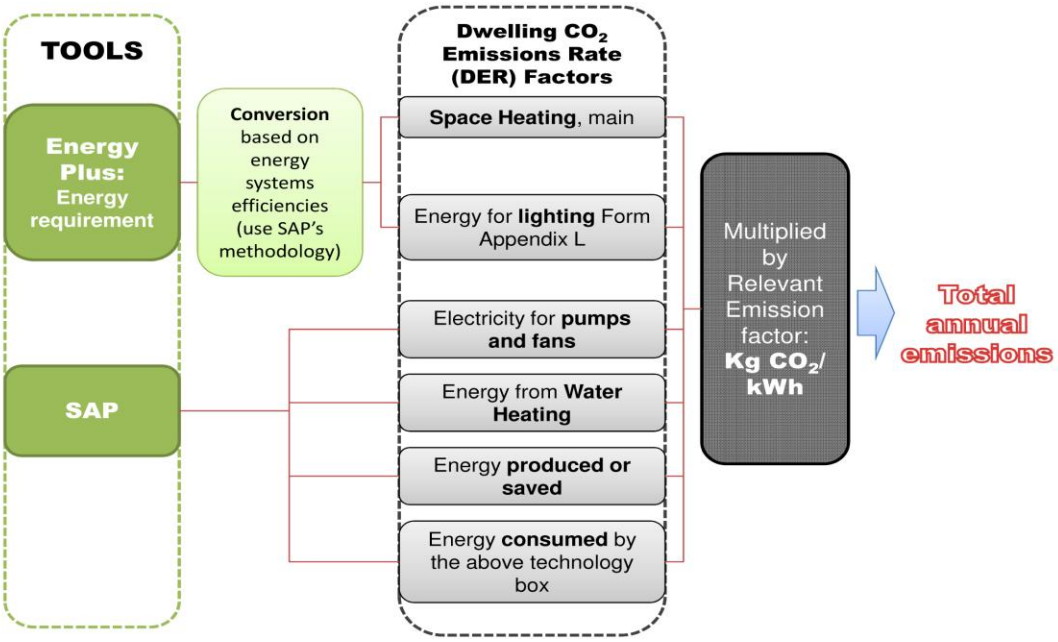

Figure 2. Analysis of Methodology on how energy consumption and its carbon emissions has been modelled in current research.

Current Transport Emission: According to Christen et al. (2010), to convert measured data of travel routes into carbon emissions, it is necessary to know "*how many trips, of what type (to, from or through) and length, by how many vehicles, of what type, using how much of which fuel*" (Christen et al., 2010). Network Management Map (Environment Directorate, 2011), provided by the local council authorities, is used to calculate the number of trips.

Carbon conversion: following to the previous step, the conversion factors used by the author were 241 gCO_2e/litre for gasoline and 276 gCO_2e/litre for diesel fuel (NRCan,2007 cited in (Christen et al., 2010).

CO_2 emissions reduction via building retrofit (Step 2) includes improvements to the building envelope. Options like the thermal insulation of external walls and roofs and window replacement are the best techniques currently available in EU-25 (Dall'O' et al., 2012). In step 3, alterations in population density, like households division and vertical extension, were applied in order to reduce the carbon emissions. It has been described as the amount of people occupying a specific area and it was usually measured in people per hectare (pph) or households per hectare (hph), based on LDP (2011).

Following these steps, improving walkability was based on BREEAM for Communities (2012) assessment list of criteria (step 4). Then they were categorised in two main sectors of walkability improvement: via transportation and via mixture of land-use.

The final aim of this analysis could be to identify whether there is a further potential carbon reduction by mass-implementation of renewable sources in each sub-divided area or the potential for a more centralised-to-the-town solution. BREEAM for Communities was adjusted to the needs of the current study, even though there are many limitations.

RESULT ANALYSIS AND DISCUSSION

Results were obtained for two representative buildings of Neath's existing urban pattern: House A and House B. Figure 3 represents the models for terraced houses created in Google Sketch Up and then, used as inputs in ENERGY PLUS tool. Semi-detached houses were modelled respectively.

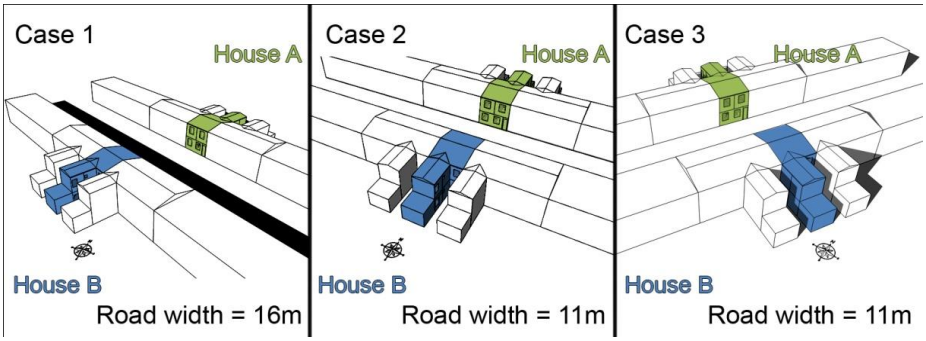

Figure 3. The three neighbourhoods of Terraced houses examined in this project.

Three maps for each stage are presented in order to clarify the carbon reduction for each step included in this part. Both ways of evaluating the CO_2 emissions (per capita and per hectare) are analysed below. Figure 4 show the carbon reduction due to building retrofit. Although the outcome seems to be different in terms of carbon emissions, the reduction in both maps is the same value.

The great controversy of this analysis exists in the last column of **Figure 4** (below), which indicates the carbon emissions following an increase in population density. On the one hand, a per capita basis shows major reductions in CO_2 emissions, when looking on a per hectare basis a completely opposite outcome is illustrated.

CONCLUSIONS

Summing up, the results confirmed the initial hypothesis that the urban form has a significant impact on CO_2 emissions during the retrofit procedure. More specific, variations in CO_2 emissions attributed to urban form alterations can reach up to 12,5%. Similar results have been reported by other researchers as well (Ratti et al., 2005). However, the already-there impact of urban form (road patterns, building orientation, etc) restricts alterations.

As far as the relationship between building retrofit and urban form is concerned, it has been proved that the first is the dominant factor leading to significant CO_2 emissions reductions. More specific, the overall carbon cut reaches more than 45% in most neigh-

bourhoods. According to the initial scenario definition, building retrofit, as a 'stand-alone' measure, is capable of achieving the CO_2 emissions target reduction by 20% until 2020.

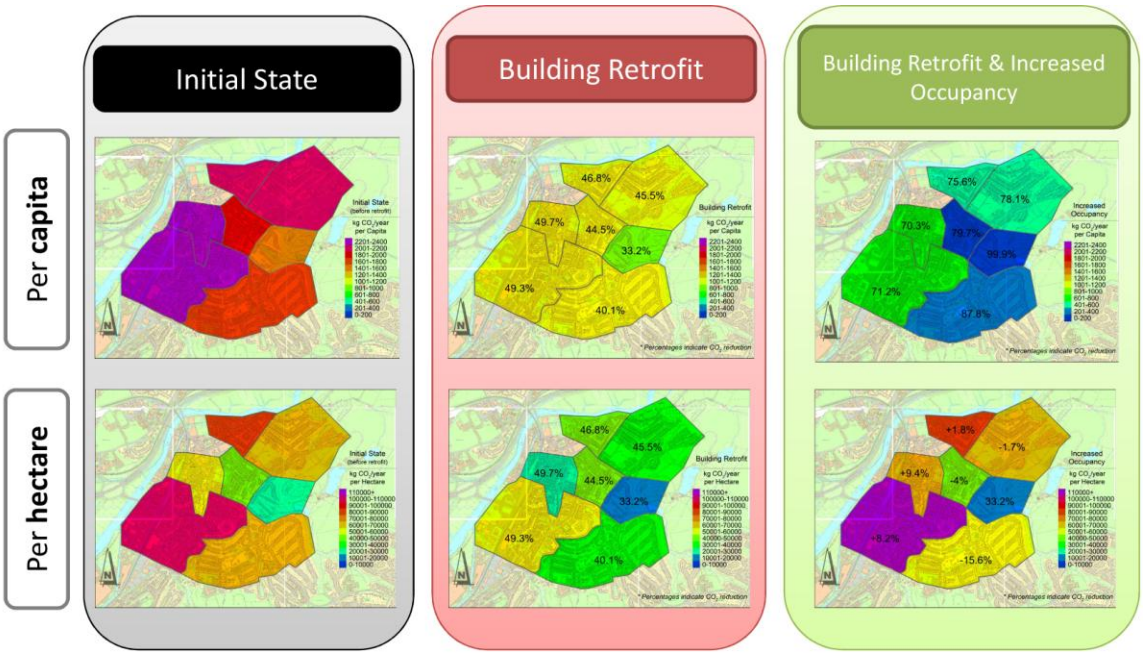

Figure 4. Comparison of carbon emission measurement methods.

Among neighbourhoods, significant variations have been identified. On the one hand this stresses the necessity for integrated approaches on the matter able to trace such variations. On the other hand this calls for site specific proposals. Such an approach could also prove useful for policy-making regarding the allocation of energy systems or the specification of energy requirements and consumption.

In detail, for the case of Neath it came out that during an increased occupancy scenario, community heating using CHP and boilers, and PVs can lead to reasonable carbon cuts as compared to other community systems. However, the upgrade of individual heating (building retrofit) still remains a more efficient solution.

As far as the transportation and current emissions are concerned, the results have brought to surface that simple measurements of traffic density on a road might be insufficient to accurately identify the actual causes for this density. The main focus when considering the reduction in CO_2 caused by transportation should be on reducing the need to travel. This could mean various parameters such as the work, shop and school proximity.

The limitations of such a survey are that, no matter what decisions a planner would take in order to improve an existing urban form, people's behaviour on that remains the dominant factor (Bourdic and Salat, 2012, Crane, 2000).

All in all, the field of Low Carbon Urban Retrofit is relatively new. As a result, there are various unclarified issues to be solved as research progresses. In the context of the current study, such issues had to be confronted when assessing the proposal using BREEAM for Communities, the only tool available at the moment in the UK, which yet remains restricted when considering retrofit. Although many assumptions were necessary

for the current assessment, the final proposal gained a rating of VERY GOOD (16.55 /29.1 equals to 56.9%).

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