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The Mass Retrofitting of an Energy Efficient—Low Carbon Zone

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Chapter 1
Introduction

demonstrating how urban morphology matters by reaching beyond the geometry of building design, construction systems and occupational behaviours and towards broader context-specific transformations

Recent studies of urban morphology suggest the planning, development and design of district centres have as much a bearing on levels of energy consumption and rates of carbon emission as either the layout of neighbourhoods, construction of "blocks", or use and occupation of buildings. In short, they suggest urban morphology matters. This book aims to reiterate this message by demonstrating how urban morphology matters. Not only with respect to either the geometry of design and construction systems, or occupational behaviours, that such studies draw particular attention to, but also with regard to a matter which they have hitherto overlooked. That is with regards to the potential which the planning, (re)development, design, construction, use and occupation of buildings, has to not only lower levels of energy consumption and rates of carbon emission, but global warming associated with climate change.

In meeting this aim and demonstrating how urban morphology does matter, the book shall build on a brief critique of the state-of-the-art on urban morphology, the geometry of design typologies, construction systems and occupational behaviours. Armed with the critical insights this offers, it shall go on to reground the subject via a case study analysis of recent attempts made by cities to reduce energy consumption and associated levels of carbon emissions, both by way of and through what has been termed: an active and integrated institutional arrangement. This institutional, integrated and active regrounding of urban morphology shall draw upon the experiences of a transformation taking place in the London Borough of Sutton known as the Hackbridge project: a mass retrofit proposal designed as a sustainable suburb with district centres, neighbourhoods and buildings, laid out and contextualised as an energy-efficient, low-carbon zone. That is by the institutionalisation of a mass retrofit proposal, which is actively integrated in an urban regeneration strategy, whose vision, district-wide master plan, programme of neighbourhood renewal and redevelopment of suburban housing estates, is in turn

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capable of sustaining the ongoing transformation of Hackbridge into an energy-efficient, low-carbon zone.

Offering a context-specific analysis of how institutions can begin to actively plan for, integrate and sustain the development of energy-efficient, low-carbon zones, the case study draws particular attention to the type of baseline assessments needed to legitimate not only the strategic value of such arrangements, but their practical worth as measures able to meet the standards of environmental sustainability set out in the 2008 UK Climate Bill.

Urban Morphology

The article by Ratti et al. (2005) offers an account of why urban morphology, design, layout, texture and fabric matters via what might be best described as a coded critique of how the "building scientist" approaches the matter of energy performance, that is to say by way of and through a coded critique of the approach which assigns buildings a set of values to be read off by type of design, system of construction and occupant behaviour independent of their environment. For Ratti et al. (2005), it appears that such a scientific reading of the subject offers too narrow a perspective on the determinants of energy performance and for this simple reason, such a framework for analysis fails to explain the high degree of variance between the values assigned to them and those experienced.

Putting this right, i.e. explaining this variance in energy performance in terms of the gap between theory and practice, according to Ratti et al. (2005), means that we need to transcend the all too narrow perspective of energy performance which the building scientist offers and broaden it out so as to begin accounting for the complex environmental processes at play in such determinations. Ultimately, this means understanding the relationship that buildings have to their environment both by way of urban morphology and through the context-specific form which the design, construction, use and occupation of buildings take on. This is because for Ratti et al. (2005), urban morphology provides a critical insight into the context-specific form of the designs, construction, use and occupation of buildings that is currently missing and which limits what is known about energy performance. Focussing on the design, construction, use and occupation of buildings within the cities of Berlin, Toulouse and London, Ratti et al. (2005) find that variation in the consumption of energy by system and behaviour is something which cannot be explained by way of surface-to-volume ratios (STVR) alone, but through the relationship the passive to non-passive areas of their district centres, neighbourhoods, blocks and buildings also have to one another.

The Thesis

The background research to the study of urban morphology by Ratti et al. (2005) is based on March's (1972) analysis of building heat loss, Owens' (1986) extension of this study across house types and augmentation of the analysis by Steadman et al. (2003) to include the non-domestic sectors. All of this is in turn captured in Steemer's (2003) study of energy consumption within cities and relation this has to the density of buildings alongside their associated mobility and transportation networks.

Against this backdrop, Ratti et al. (2005) explore the effects of urban texture on energy consumption. This work is based on the analysis of digital elevation models (DEMs) in London, Toulouse and Berlin. In these studies, DEMs are stored in a 2D-Matrix with height values and processing tasks constructed by means of MATLAB software. Highlighting urban geometry, design, construction systems and occupants' behaviour as the "four parameters of energy performance", Ratti et al. (2005) loosen the grip buildings have on energy performance by way of and through an analysis of the form they take. In loosing this grip and highlighting all four parameters of energy performance, Ratti et al. (2005) draw particular attention to two urban morphology ratios whose geometric form set the parameters for the other three (buildings, construction systems and occupational behaviour).

The first ratio draws on the earlier research of March (1972) which arose from the question: "which shape should a building have to minimise heat loss?" For this model of building design, March (1972) assumes that its shape is perfectly rectangular, thermal transmittance is equal through all external walls and there is no heat transfer from the building to the ground. This is referred to as the STVR and value which is calculated by dividing the overall building envelope area (without ground area) by the volume. However, Ratti et al. (2005) suggest the STVR is not a very good indicator of energy performance, because only heat lost through the exposed building envelope is measured, while any gains from the use of natural ventilation and sunlight for heating and lighting purposes are ignored.

Taking the limitations of the STVR into account, Ratti et al. (2005) advance a second ratio that subdivides buildings into passive and non-passive areas. Here, passive areas measure the parameters of buildings lying within 6 m of the façade or within twice the ceiling height. These passive areas gain from natural ventilation and sunlight, whereas non-passive areas do not. The ability of buildings to use natural ventilation and sunlight is referred to as the *passive-volume-to-total-volume ratio* (PVTVR). This ratio offers another attempt to analyse the geometry of a building's energy performance, and its limitations are also drawn attention to. This is because passive areas can still be wasteful; for example, being mechanically lit their ventilation and glazing ratios may be very low, allowing heat loss through external walls and roof spaces to be greater than gains from sunlight.

Seeing that only an integrated energy model can overcome such limitations in the measurement of energy performance, Ratti et al. (2005) make use of the lighting and thermal method (LT-method) to calculate the annual lighting, heating,

Table 1.1 Data for London, Toulouse and Berlin (Ratti et al. 2005)

	London	Toulouse	Berlin
Ground floor area (m^2)	89,663	64,368	55,978
Unbuilt area (m^2)	70,377	95,632	104,022
Built volume (m^2)	1,221,499	966,768	1,042,199
Vertical surface (m^2)	174,757	174,888	119,698
Surface to built volume ratio (m^{-1})	0.216	0.248	0.169
Average energy consumption in passive and non-passive zones (kWh m/p.a.)	0.0683	0.0668	0.0731
Average energy consumption in passive zones (kWh m/p.a.)	0.0590	0.0599	0.0585
Average energy consumption in passive zones with optimum glazing ratio (kWh m/p.a.)	0.0554	0.0568	0.0550

ventilating and cooling values of buildings in terms of use/m^2. This model considers a variety of factors, including solar gains, shading of a neighbour's house (indicated by the obstruction sky view) and the degree of daylight that is either reflected from opposite facades (information about the orientation of facades is needed to calculate this) or which is directly received from the sun. The LT-method is applied by Ratti et al. (2005) to analyse the energy performance of blocks, neighbourhoods and districts in the cities of London, Toulouse and Berlin. The findings of these studies are held up as examples of how urban morphology has a bearing on energy performance when analysed in terms of both the STVR and PVTVR ratios for the "blocks, neighbourhoods and districts" of the building designs, construction systems and occupational behaviours under investigation. The STVR and PVTVR ratios for these case studies are set out in Table 1.1.

In another case study, Salat (2009) compares the urban morphology of Paris with the energy consumption of building designs. This analysis captures the impacts which the types of urban morphology factors listed below have on building designs, construction systems and occupier behaviours in terms of energy consumption and CO_2 emission.

- Mean and standard deviation of building height
- Mean and standard deviation of vegetation height
- Building height histograms
- Area-weighted mean building height
- Area-weighted mean vegetation height
- Surface area of walls
- Plan area fraction as a function of height above the ground surface
- Frontal area index also as a function of height above the ground surface
- Height-to-width ratio
- Sky view factor
- Roughness length
- Displacement height

- Surface fraction of vegetation, roads and rooftops
- Mean orientation of streets

In this case study, 96,000 residential buildings are analysed and four key components of energy consumption are calculated in accordance with the contribution they make to levels of CO_2 emission. The key components, derived from this case study, along with their factor contributions are set out below:

• Efficiency of urban morphology (e.g. density)	(1.8)
• Building design performance (e.g. shape, envelope area)	(2.5)
• Efficiency of construction systems (e.g. age of boiler)	(1.8)
• Occupants behaviour	(2.6)

Under this factor-component model, the city is represented as a homogenous entity where urban morphologic values, such as density, mobility networks and accessibility, are related to one another. Like Ratti et al. (2005), Salat (2009) sees the ultimate value of this model as lying in the ability it has to isolate the contribution urban morphology makes to energy performance when measured in terms of either the STVR or the PVTVR. In the case of Paris, the ratios calculated and drawn upon as measures of energy performance suggest the traditional, densely-built courtyards of this city have a good STVR and PVTVR. Good in the sense that unlike their modern counterparts, which are characterised as dispersed low-density developments and found in the suburbs of Paris, these designs, construction systems and occupational behaviours illustrate poor STVR and PVTVRs.

In view of the potential which exists for such large-scale assessments to save energy and reduce carbon emission by as much as 50 %, Bourdic and Salat (2012) stress that in order to capitalise on such virtues, save energy, reduce carbon emissions and sustain development, stakeholders need robust methods capable of assessing such possibilities. As they point out, many tools and assessment methods have been developed to improve energy performance. However, as they also go on to stress, most of these methods are still based on the building envelope and given stakeholders are now convinced the so-called building scientist approach is too narrow, these assessments need to be extended so energy performance analysis can cover the design, construction, use and occupation of both the blocks, neighbourhoods and districts of cities.

The reason why Bourdic and Salat (2012) reiterate this message is important because it throws some much needed light on what the calculation of the STVR and PVTVRs for London, Toulouse and Berlin offers in terms of energy performance. For what they offer is “proof of concept” and evidence as to the significance of urban morphology as a key component of energy performance. That is to say, as a key component of energy performance, which does not just matter, but should also be taken into account *alongside* the design layout, construction systems and