The Costs & Benefits of Accommodating Growth in Different Forms of Settlement Pattern – a Literature Review

Final Report

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1 Executive Summary

1.1 The Bottom Line

Since Michael Breheny, Tim Gent and David Lock wrote *Alternative Development Patterns: New Settlements* in 1993 (Breheny *et al.*, 1993), the problems faced by spatial planning and housing in the UK have not changed a great deal in substance, although they have got worse. Fundamentally the issue concerning climate change is resource use and how to reduce it.

The evidence suggests that while urban infill can provide some of the answers, new settlements and urban extensions supported by an efficient public transport network must remain a key part of any serious initiative to combat climate change through the planning system.

1.2 Many issues are 'Wicked Problems'

Many of the issues raised and explored in the course of this literature review are 'wicked problems', described thus by Wikipedia.

- The problem is not understood until after formulation of a solution.
- Stakeholders have radically different world views and different frames for understanding the problem.
- Constraints and resources to solve the problem change over time.
- The problem is never solved [solutions are better, worse or good enough].

The issues raised herein should therefore be considered as interdependent parts of a greater whole.

1.3 Urban Infill – Key Points

- Much of the literature alludes to urban infill through reference to the compact city;
- In the UK, there remains a strong preference for suburban living;
- Development costs tend to be high, but infrastructure costs tend to be low;
- The evidence for improvements to the local economy through urban infill is mixed;
- Access to social facilities is potentially good;
- Local residents will perceive the value of urban infill schemes in terms of how they are directly affected by such schemes;
- Urban infill schemes can make the local community feel threatened – the case for an improved breadth of social mix is not proven;
- Urban infill schemes do not result in loss of greenfield land, and loss of primary habitats is likely to be low;

- Urban infill schemes may however threaten 'derelict' land that has developed its own local ecosystem and social value;
- There is a risk of town cramming and loss of urban green space;
- The multi-functional benefits of urban green space are gaining emphasis, especially for the moderation of climate change impacts.

1.4 Urban Extensions – Key Points

- Cost of the end product is likely to be among the cheapest for the five options;
- Urban extensions are among the cheapest in terms of infrastructure costs;
- Access to employment opportunities is likely to be quite good;
- Access to social facilities is heavily context dependent;
- The likelihood of the development of a sense of community is heavily context dependent;
- Larger developments will tend to take on their own identity, whereas smaller developments will more likely be subsumed into the locality;
- Urban extensions do require greenfield land, but may be able to 'plug in' to existing amenities if they are relatively small;
- Loss of natural habitat is likely, even on previously developed sites such as quarries or railway yards;
- There is no risk from town cramming or loss of urban green space;
- Combined heat and power (CHP) systems may be suitable for use in urban extensions.

1.5 Key Villages – Key Points

- Key villages per se have received minimal coverage in the literature, since they are a category effectively defined by Breheny et al (Breheny *et al.*, 1993);
- May possess a variety of employment opportunities, though not in large quantity (this may have become more pronounced since 1993);
- Key village extensions can leverage existing infrastructure;
- Access to social facilities will depend on the size of the key village;
- Existing residents may resent the incoming residents in the extension;
- Additional land is unlikely to be required, since much of the extension will take the form of infill;

- The quantity of land available within the village curtilage will tend to limit the amount of infill possible;
- Loss of natural habitat is unlikely;
- Loss of green space interior to the village is a risk;
- Breheny and colleagues described key village extensions as 'the worst of both worlds' (Breheny *et al.*, 1993, p80).

1.6 Balanced Growth – Key Points

- Balanced growth is really an issue of spatial, strategic and/or regional planning, rather than a distinctive settlement type;
- There is some consensus that some form of polycentric development of the type implicit in the notion of balanced growth can be a sustainable solution.

1.7 New Settlements – Key Points

- New settlements are likely to have the lowest cost of end product;
- New settlements are likely to be the most expensive in terms of provision of infrastructure;
- A new settlement that is developed around an existing one may have the potential to contribute to its regeneration;
- A sense of community will require many years to build up;
- Loss of land and natural habitats is inevitable;
- Town cramming is not a risk;
- New settlements are particularly conducive to energy-saving initiatives such as CHP.
- New settlements need to be properly self-contained to be sustainable – a 'dormitory settlement' is likely to result in more travel.

1.8 Key Messages for Policy Makers

- There are no easy answers.
- Urban infill is a question of balance: if overdone, it may make cities less pleasant places to live, exacerbating the problem it is intended to solve.
- New settlements and large urban extensions have the potential to be sustainable if:

  a. they are not dormitory settlements, but properly self-contained;

  b. they are built to sufficiently high densities and standards to support initiatives such as CHP;

c. they are properly served by public transport.

d. they are supported by an extensive and well managed green infrastructure.

- Key village extensions may provide 'the worst of both worlds' (Breheny *et al.*, 1993).
- Balanced growth is as much about spatial planning as settlement form.

2 Introduction

2.1 Preamble & Commentary on Project Brief[1]

This literature review comprises stage two of an analysis of the costs and benefits of accommodating growth in different forms of settlement pattern, carried out for Communities and Local Government's (CLG) Planning Research Network (PRN)1 The first stage involved the preparation of an extended bibliography which is included in section 10.

This report has attempted to meet the requirements of the brief as closely as possible in the time available. The brief is drafted to cover an extremely wide array of topics and problematiques, for which simple answers do not exist, and the review itself[2] is correspondingly wide-ranging, occasionally drifting into issues that might reasonably be considered to have more relevance to spatial planning rather than settlement form *per se*.

The question of spatial planning at scales beyond that of the single settlement also crops up, and while alluded to from time to time, this topic is not covered in any detail. The notion of balanced growth, for example, is only partly to do with settlement types; it is also very much to do with the multiple ways in which collections of settlements interact to create a functional whole; this is the very essence of functional polycentricity (Green, 2005), and in planning for climate change, issues of settlement form need to be placed in a much broader spatial context.

This echoes a far-sighted contribution by Owens (Owens, 1992) who reviewed the case for an energy dimension in the land use planning process. She concluded that:

> While not refined in detail, the basic principles for energy-efficient land-use planning already exist. There are some hopeful signs that they will be more widely adopted as success stories stimulate interest elsewhere and as energy efficiency is increasingly identified as a positive asset for any location. Perhaps the only real stimulus, however, can come from crises and, as we enter the 1990s, the increasing urgency to deal with global environmental problems may become the incentive for energy-conscious land-use planning, which unfulfilled threats of physical scarcity have hitherto failed to provide (Owens, 1992).

Since that time the role of anthropogenic greenhouse gas emissions in forcing climate change has become increasingly well recognised (IPCC, 2001) and the implications for the UK better understood (Hulme *et al.*, 2002). In this context, it is important to consider both the relationship between urban form and energy use (*ie* the potential to mitigate climate change by reducing greenhouse gas emissions) and the need to improve the resilience of urban areas to climate change impacts (climate adaptation) (see for example Hunt, 2004; McEvoy *et al.*, 2006). The nature of

1 The brief is at Appendix 1.

2 The references cited in this literature review are listed in Section 9.

climate change impacts on the urban environment was reviewed by the Centre for Urban and Regional Ecology (Gill *et al.*, 2004)[3] and the potential consequences for a large city like London were explored in a wide ranging review (LCCP, 2002)[4]. This provides a new impetus to debates about urban sustainability and widens the context of the long-running debate about urban form and settlement patterns.

2.2 The Context

As the population of Britain continues to spread itself more evenly, a trend described as consistent more than a decade and half ago (Champion, 1989; Owens, 1992), and that has shown few signs of abating in the intervening years (Hall & Ward, 1998; Rogers & Power, 2000; Hall *et al.*, 2006), the question of how best to accommodate increasing numbers of households becomes ever more pressing. This question, which might be put most crudely as how to build cities that meet the needs of sustainability's 'three pillars' – society, economy, environment – is hardly a new one. Its modern origins lie in the 19th century slum 'city of dreadful night' (Hall, 1988) but if overly high densities were one of the problems then, the lower densities that come as a result of the modern trend to counter-urbanisation are surely of crucial importance now. However, as Ravetz (Ravetz, 2000, p.67) has pointed out, 'a "sustainable" urban form for any city is a complex balance of many needs and goals, at larger and smaller scales.'

Hall provided a thorough historical overview of some of the key issues to do with the various debates on urban form entitled *The Future of the Metropolis and its Form* in 1997, and his conclusions, broadly, were that Howard's model of the social city, updated, still had validity. Hall, with Colin Ward, further pursued this position in *Sociable Cities* (Hall, 1997; Hall & Ward, 1998).

2.3 A Note on Wicked Problems

Many of the issues raised and explored in the course of this literature review are 'wicked problems', described thus by Wikipedia.

> According to Conklin in ["Dialog Mapping: An Approach for Wicked Problems," (CogNexus Institute, 2003)], the four defining characteristics of wicked problems are:

- The problem is not understood until after formulation of a solution.
- Stakeholders have radically different world views and different frames for understanding the problem.
- Constraints and resources to solve the problem change over time.
- The problem is never solved [solutions are better, worse or good enough].

[3] Summarised in Appendix 2

[4] See summary table in Appendix 3

The issues raised herein should therefore be considered as interdependent parts of a greater whole. The question of how the density of settlement affects its sustainability is a good example. Density is typically measured in one of three different ways, using one of three different units, giving a total of nine crude ways of measuring density. If we want, say, to attempt to find an optimum density that will support a viable public transport system, we need to know (amongst other things) where people work, when they work, socio-economic conditions, what type of public transport, what we mean by 'viable' (Adequate profit margins? Using a given level of subsidy?) and so forth. The answer to the question "what is the optimum density to support a viable public transport system?" is thus a battery of further, equally complex questions. This is the very essence of a 'wicked problem'.

2.4 Methodology and Structure of this Literature Review

The five settlement forms and the lists of economic, social and environmental criteria set out in the brief reflect those in the 1993 Department of the Environment publication *Alternative Development Patterns: New Settlements* (Breheny *et al.*, 1993). Sections 2.2 and 2.3 (Breheny *et al.*, 1993, pp.7-13) appear to have been particularly closely followed, and then augmented with some new criteria that reflect present day environmental concerns. These criteria (and indeed the first three chapters of *Alternative Development Patterns: New Settlements*) provide a useful starting point, not least because the assessments of the alternative development types are provided by the authors in terms of their own criteria (this table is reproduced as Table 2 in the present document). We can use Breheny et al's initial assessments as a 'control' with which to compare more recent findings in the literature.

Each of the development types has its own chapter, sub-divided into sections in accordance with the criteria set out by Breheny and colleagues. What (if anything) the literature has to say about each of the criteria with regard to a particular development type is then set in the relevant section.

It should be noted at this point that this review is not a statistically significant meta-analysis of the literature, nor can it be. The building and extension of settlements is heavily context dependent, and the fact that there is no 'right answer' that will fit all eventualities cannot be stated strongly enough. The basic aim of this review is therefore to give a general indication as to whether or not there is a general consensus amongst those who study such matters about the positive and negative aspects of each of the different types of development when examined within the context of the criteria and sub-criteria. The three sets of criteria originally developed by Breheny and colleagues (1993) are set out in Table 1 below, with the additions from the project brief added in italics.

Table 1 Original 1993 DOE Assessment Criteria
Source: derived from (Breheny *et al.*, 1993). Criteria added by the current project brief are in *italics*

Economic Criteria	Cost of the end product
	Economy in the provision and use of infrastructure
	Maintenance costs
	Access to employment
	Potential to generate economic growth within the settlement
	Potential to regenerate depressed areas
	Economic viability of public services
	Road congestion
Social Criteria	Access to social facilities
	Potential sense of community
	Breadth of social mix
	Potential affordable housing contribution
	Local acceptability
	Quality of life / local satisfaction with neighbourhood
	Impacts on different social groups
	Car dependency
	Human health
Environmental Criteria	Loss of land
	Loss of natural habitats
	Energy consumption – transport
	Energy consumption – space heating
	Pollution levels
	Contribution to 'greening' the urban environment
	Town cramming effect
	Thermal comfort (heat island effect)
	Impact of environmental hazards (flooding, storms)

At this point, a caveat is in order. Breheny and colleagues note that while it is possible to identify five 'generic forms' of urban growth – urban infill; urban extensions; key villages; multiple villages[5]; new settlements – none is proved superior (Breheny *et al.*, 1993). It is worth quoting their observation at length: '…it depends what weight is given to the differing criteria, either in national or strategic policy, or in local terms, or in any combination of these. In particular it is concluded that the five forms are not real alternatives, but forms of which a changing blend will be required over time' (Breheny *et al.*, 1993, p.80).

In view of the fact this document is intended to assist in developing planning policy for climate change, we would therefore make the point that the complexity of the systems being dealt with is such that there is no 'silver bullet' when it comes to targeting optimal forms of urban development for a particular context.

[5] 'Balanced growth' replaces the 'multiple village extensions' in the original Breheny document. In effect this is a broadening of the meaning of the original term to encompass settlements other than villages that may be extended.

Table 2 Assessment of Alternative Development Forms from (Breheny *et al.*, 1993)

Source: (Breheny *et al.*, 1993, p.35)

	Urban Infill	**Urban Extensions**	**Key Villages**	**Multiple Villages**	**New Settlements**
Economic Criteria					
Cost of the end product	High Development Costs	Medium Values	Medium Values	High: premium on scarcity	Can be cheapest
Infrastructure costs	Low provision & use costs	Low provision & use costs	Lower provision & use costs	Can be high	Will be high
Maintenance costs	Connects to old system	May connect to old system	Relatively low, due to major upgrades	Low due to minimal infrastructure	Low: all new systems
Access to employment	Good	Moderate: can be car dependent	Moderate	Poor	Moderate, dependent on local provision
Social Criteria					
Access to social facilities	Good: existing systems	Moderate: can be car dependent	Moderate: depends on size	Poor local provision	Potentially good
Sense of community	Good: existing networks	Moderate	Moderate, tending to good	Good: existing community base	Good/moderate if planned
Social mix	Usually good	Moderate	Moderate	Poor	Moderate
Affordable housing	Moderate & can be negotiated	Moderate at a large scale	Moderate	Poor/moderate	Good thro' planning gain
Local acceptability	Minimal disruption	Reasonable	Moderate, but poor if over-developed	Can be very severe	Could be severe
Environmental Criteria					
Loss of land	Low, by definition	High	High unless infill	High unless infill	High
Loss of habitats	Moderate, dependent on circumstances	Moderate	Moderate	Low/moderate	Could be high
Energy – transport	Low, dependent on congestion	Moderate	High, car dependent	High: very car dependent	High, dependent on location
Energy – space heating	Poor prospects	Moderate/poor prospects	Prospects poor	Prospects poor	Good prospects
Pollution levels	Good/moderate	Relatively high	High because of car usage	High because of car usage	Potentially high
'Greening' contribution	Poor	Good	Moderate	Moderate	Good
Town cramming effect	Poor	Low	Moderate: some village cramming	Moderate: some village cramming	Good

3 Urban Infill ('Intensification')

3.1 Definition

Breheny et al (Breheny *et al.*, 1993) define urban infill as taking place within the boundaries of existing settlements. Such infill can vary in scale, from the large 'urban village' to the development of large back gardens, or derelict gaps in the urban fabric.

Urban infill has its advantages and disadvantages. Advantages are that:

- those who wish to prioritise urban regeneration find it acceptable;
- those seeking to preserve the countryside find it acceptable;
- seemingly derelict land is put to obvious use.

Disadvantages are that:

- urban areas have a limited capacity to absorb more homes;
- urban green space comes under increasing pressure to be developed;
- seemingly derelict land which may in fact harbour diverse ecosystems comes under threat;
- *town cramming*, and the consequent decline in the quality of urban life is a threat.

While Rogers and Power have claimed that 'people gravitate to compact cities because they like its energy, opportunity, diversity and excitement' (Rogers & Power, 2000, p.281), they offer no evidence to back this up. The trend to counter-urbanisation identified by Champion (Champion, 1989, 2001) suggests that, in Britain at least, the suburbs remain the favoured form of living environment, and that the city centre 'loft living' originally identified by Zukin (Zukin, 1982) remains a preference for a minority, albeit a significant one. Indeed, several authors have observed that many of the merits of urban intensification and the compact city have been based on assertion and theory rather than empirical evidence (see for example Breheny, 1992b, 1992a; Jenks *et al.*, 1996; Williams, 2000; Vallance *et al.*, 2005). Simmonds and Coombe (2000) found in a study comparing a number of compact city scenarios with a 'trend' scenario in the United Kingdom that shifting to a compact city strategy alone will not necessarily change car use, a finding also noted by Banister (Banister, 2005). Simmonds and Coombe also found, however, that a compact city strategy need not worsen travel problems such as congestion unless densities are particularly high (Simmonds & Coombe, 2000). In a recent article, David Lock makes the point that asserting a need to develop at higher densities to make public transport financially 'viable' is, in effect, placing above all other considerations, the profitability of private transport operators (Lock, 2006).

Nonetheless, the merits of the compact city approach are such that Geurs and Wee (2006) conclude that without it, urban sprawl and the concomitant car use in the Netherlands would have been far greater than is currently the case.

3.2 Urban Infill – Economic criteria

Of the three criteria, it is the economic criteria that have received the least coverage in the literature. Breheny et al (Breheny *et al.*, 1993) argue that urban infill has high development costs relative to the four other forms of development that they examine, and that infrastructure costs are relatively low by virtue of the simple fact that much of the infrastructure already exists. Consequently, the *maintenance costs* of urban infill schemes are also likely to be low, since the infill 'plugs in' to existing systems (Breheny, 1992b). Lastly, *access to employment* for urban infill schemes is likely to be good.

Camagni et al carried out a study of the social and environmental costs of different forms of urban expansion in communes in northern Italy (Camagni *et al.*, 2002) in which five forms of urban expansion were identified: infill; extension; linear development; sprawl and large-scale projects. These forms were then combined in pairs and the ten most significant typologies used for statistical analysis (Camagni *et al.*, 2002, p.204). The authors acknowledge that there is a degree of subjectivity in the attribution of different communes to different typologies.

In terms of land use, which has a bearing on the overall *cost of the end product*, Camagni et al found that: large projects and infilling use the least land per residential unit; linear/sprawl uses the most land per residential unit, closely followed by extension/sprawl (Camagni *et al.*, 2002). These findings can be set against, although not compared with, those of Breheny et al, who found that urban infill tends to have high development costs, and that new settlements can be the cheapest of the five urban forms (Breheny *et al.*, 1993). We can hypothesise that the lower cost of agricultural land, and the potentially high costs of cleaning up brownfield sites would account for these findings.

In a study of three London boroughs[6] Williams (Williams, 2000) found that while all three boroughs had undoubtedly seen improvements in the local economy during the study period, and were happy enough to attribute these improvements to their urban intensification policies (unsurprisingly, perhaps), there was in fact little evidence to tie the improvements directly to the policy. Williams concludes on this topic that 'Determining the extent to which these benefits are a direct result of urban intensification, and how much they are the result of broader economic trends

[6] Williams studied the inner London borough of Camden, and the outer London boroughs of Harrow and Bromley.

is almost impossible' (Williams, 2000, p.44). The *potential to regenerate depressed areas* must therefore be seen as heavily dependent on context.

3.3 Urban Infill – Social criteria

While Breheny et al (Breheny *et al.*, 1993) suggest that general *access to social facilities*, and shops in particular, is likely to be good in urban infill schemes, a general assertion supported to an extent in subsequent research by Williams (Williams, 2000), the question of whether or not existing residents actually perceive urban infill as a 'good thing' is not a simple one. Williams (2000) found that the response of local residents to urban infill was highly subjective. If the original residents perceive their *quality of life* to have benefitted directly, they are likely to perceive the urban infill itself as beneficial. Likewise, those who feel that their *quality of life* has suffered as a consequence of urban infill will project that negative perception onto the principle of urban infill in general (Williams, 2000).

The social networks that already exist are judged by Breheny et al (Breheny *et al.*, 1993) to have the potential to contribute to a good sense of community, but more recent work, such as that of Vallance et al (Vallance *et al.*, 2005), suggests that a more circumspect assessment may be necessary in certain cases. Vallance et al focused on Christchurch, New Zealand, a city in which suburban residents guard their privacy closely. What Vallance and colleagues found was that urban infill was often not well received by the local residents; the loss of privacy due to new residential buildings was resented by the local residents, since these new developments sometimes gave a clear view into their houses (Vallance *et al.*, 2005). Local residents also felt that their own community was in danger of being damaged by the incomers (ibid).

Breheny et al (Breheny *et al.*, 1993) were also optimistic with regard to the potential social mix, suggesting that the *breadth of social mix* in urban infill is likely to be good, and that urban infill creates relatively little disruption, so can be expected to have a high level of *local acceptability*. However, as with so much, this turns out to be highly context-dependent. Williams (2000) found that in the suburban and predominantly residential areas that she studied (areas similar to those studied by Vallance (2005)), the social changes wrought by urban infill schemes had a negative effect, being perceived as damaging to the sense of community and local identity, and generally disruptive (Williams, 2000). For the respondents of both Williams and Vallance, the increased *breadth of social mix* was perceived not as a 'good thing', but as a genuine threat to the existing community (Williams, 2000; Vallance *et al.*, 2005). These findings, reports Williams, tend to hold more strongly in the suburban areas, and much less strongly in the less suburban areas that she studied.

Urban infill is not an end in itself but may work effectively if part of a comprehensive programme of socio-economic regeneration (*eg* Housing Market Renewal areas).

Urban infill schemes offer the possibility of only moderate levels of affordable housing, although this can be negotiated, according to Breheny et al (Breheny *et al.*, 1993).

In terms of *car dependency*, Williams (2000), concurs with Breheny (1995) that while intensification has a role to play in reducing car use, it is just one part of the solution; cultural issues play an increasingly strong role too, a situation that does not appear to have changed in recent years, and that does not look like changing in the foreseeable future (Banister, 2005). Taking into account environmental issues too (dealt with in the next section), Williams felt unable to reach a clear conclusion on whether or not urban intensification improves *quality of life* (Williams, 2000). However, it seems clear from the findings of both Williams (Williams, 2000) and Vallance (Vallance *et al.*, 2005), that considerable sensitivity to the local context is required if such urban infill schemes are not to cause resentment and distrust among existing residents.

3.4 Urban Infill – Environmental criteria

As Breheny et al (Breheny *et al.*, 1993) observe, urban infill by definition does not result in *loss of land*, and consequently, the *loss of natural habitats* and the impacts on biodiversity as a result of urban infill schemes might be expected to be low. However, urban areas are surprisingly rich in wildlife habitats (Gilbert, 1989), especially on previously developed land where disturbance followed by neglect initiates natural succession. Research has emphasised the social benefits of contact with nature in urban areas (Harrison *et al.*, 1995) and standards for access to natural green space have been developed and promoted (Pauleit *et al.*, 2003; Pauleit *et al.*, 2005). Urban infill (despite the safeguards in PPG3[7]) can be problematic when it comes to safeguarding urban biodiversity (Frith, 2002).

Williams (Williams, 2000) found that in three London boroughs, intensification had brought some benefits. In the London Borough of Camden, for example, higher density developments had facilitated the use of combined heat and power installations, although the boroughs of Harrow and Bromley, both more suburban in character than Camden, had not realised such benefits (Williams, 2000).

Energy consumption from space heating and lighting can be reduced through the use of combined heat and power (CHP) systems[8]. As Hutchinson (1992) notes, while CHP systems are not 'sustainable' in the sense of using renewable energy sources, by more than doubling efficiency they

[7] The presumption in favour of development on previously developed land excludes 'land where remains of urban structures have blended into the landscape, eg when there are clear reasons that outweigh reuse, eg nature conservation.'

[8] Combined Heat and Power systems aim to capture the heat produced when generating electricity and use it for domestic or industrial heating purposes.

can dramatically reduce energy use. They are most efficient in high density urban areas (ibid). Owens (Owens, 1992) notes that an optimal structure is one that involves relatively compact urban sub-units, although very high densities are not required and may be inimical to energy conservation.

However, in terms of more general *pollution* impacts such as 'air pollution, noise and a generally poor environment for cyclists and pedestrians' (ibid, p.41) Williams found no evidence of improvements due to urban intensification: all of these had in fact got worse during the period studied (ibid).

As we have seen climate change is likely to intensify the urban heat island (Wilby, 2003), with implications for human health and comfort, and increase volume and intensity of surface run-off of rainfall (Ashley *et al.*, 2005) with implications for riverine flooding and surcharging of urban drainage systems. Modelling techniques are now available for quantifying the ecological performance of urban areas (Whitford *et al.*, 2001b) and these have recently been used to explore the potential consequences of climate change for Greater Manchester (Gill, 2006). This work has emphasised the functional importance of urban green space for moderating surface temperatures and run-off (Gill *et al.*, in press). The research emphasises that areas of high environmental functionality such as flood plains, city centre green spaces, low density development on highly permeable soils and even derelict land may have a key role to play in climate management[9]. Urban intensification may reduce this functionality, thus emphasising the importance of counter-measures such as urban forestry (Brown & Gillespie, 1995), sustainable urban drainage systems (SUDS)[10] (Environment Agency & Welsh Government Association, 2003) and green roofs (Mentens *et al.*, 2006). All authors tend to emphasise the multifunctional benefits associated with urban green space in general and these measures in particular.

3.5 Urban Infill – Discussion

Urban infill *per se* has not received a great deal of coverage in the literature, although its close cousin, the compact city, has. In this section, we have therefore not only looked at the literature on urban infill, but also at some of the literature on the compact city form, in particular those articles that analyse the compaction of the city that arises as a consequence of urban infill.

[9] The key recommendations from this research are included in Appendix 4.

[10] Sustainable Urban Drainage Systems aim to reduce the likelihood of flooding in new and existing urban developments, for example by using porous paving surfaces that enable rain water to seep into the ground rather than overloading drainage systems.

Breheny and colleagues (Breheny *et al.*, 1993) found urban infill to be benign for the most part. The two 'weak spots' centred around the possibility that '*town cramming*' becomes a genuine possibility, with negative consequences for the possibility of making a settlement greener. Furthermore, while urban infill has the advantage that it does not encroach on undeveloped land, the increase in suburb to suburb commuting, noted in Breheny (1993), and explored in greater depth by Breheny and Hall (Breheny, 1997; Breheny & Hall, 1999), does raise the possibility that the job-housing location balance may be 'wrong for many households' (Breheny *et al.*, 1993, p.80). In particular, the possibility that urban infill can result in loss of urban green space is noted, as is the possible loss of ecologically rich areas of seemingly derelict land (ibid, p.8).

The multifunctional benefits of urban green space are now being recognised and especially through climate regulation functions, which are so critical for moderating climate change impacts. There is already sufficient evidence to justify strong protection of greenspace resources with high environmental functionality. Urban infill should proceed in a way which results in no net loss of green space and be accompanied by measures to increase functionality, such as SUDS.

However, we also saw from the work of Williams and Vallance (Williams, 1999, 2000; Williams *et al.*, 2000; Vallance *et al.*, 2005) that the potential social impacts of urban infill need to be sensitively handled, and the social, economic and environmental contexts of any proposals carefully understood if urban infill schemes in suburban neighbourhoods are not to do more harm than good.

3.6 Urban Infill – Key Points

- Much of the literature alludes to urban infill through reference to the compact city;
- In the UK, there remains a strong preference for suburban living;
- Development costs tend to be high, but infrastructure costs tend to be low;
- The evidence for improvements to the local economy through urban infill is mixed;
- Access to social facilities is potentially good;
- Local residents will perceive the value of urban infill schemes in terms of how they are directly affected by such schemes;
- Urban infill schemes can make the local community feel threatened – the case for an improved breadth of social mix is not proven;
- Urban infill schemes do not result in loss of greenfield land, and loss of primary habitats is likely to be low;

- Urban infill schemes may however threaten 'derelict' land that has developed its own local ecosystem and social value;
- There is a risk of town cramming and loss of urban green space;
- The multi-functional benefits of urban green space are gaining emphasis, especially for the moderation of climate change impacts.
- Increased densities may make CHP a feasible option;
- Impacts from flooding will need to be mitigated through the use of SUDS.

4 Extension of existing urban areas

4.1 Definition

Urban extensions comprise development which takes place at the edge of an existing settlement, usually on a green field site or other open land (Breheny *et al.*, 1993). Stimulated by improvements in transit systems over the previous century or so, this has been the favoured form of urban growth (ibid). Physically, such growth has usually comprised low-density suburban development, 'a consistently popular residential environment in the UK' (ibid, p.8).

4.2 Urban Extensions – Economic criteria

Perhaps because of the fact that the cost of a particular development is dependent on a large number of context-dependent factors, of which size is the most significant, there is little that has been written about the relative costs of urban extensions. Breheny et al (1993) note that the *cost of the end product* is likely to be lowest for urban extensions, along with new settlements.

Urban extensions are also among the least costly in terms of the *provision and use of infrastructure*, since they are able to make use of the existing infrastructure (Breheny *et al.*, 1993). Urban extensions can also be expected to provide relatively good *access to employment* opportunities, and are likely to be among the least costly options in terms of long term maintenance (ibid).

4.3 Urban Extensions – Social Criteria

While the extent to which urban extensions can offer *access to social facilities* will depend on the location and size of the development (Breheny *et al.*, 1993), there remains the possibility that new residents will have access to existing facilities in the more mature suburbs.

The development of a sense of community is likewise dependent on the size and location of the extension (Breheny *et al.*, 1993). Notions of local identity, in particular, will be tied to the overall scale of the development. A larger development is in a better position to take on its own identity than a smaller extension, which may take its identity from older adjoining development (ibid).

4.4 Urban Extensions – Environmental criteria

Like new settlements, urban extensions inevitably consume greenfield land. Breheny et al argue that if the two types of settlement are assumed to share similar densities, then any differences in the amount of land consumed will come as a consequence of differences in the provision of amenities (Breheny *et al.*, 1993). However, urban extensions can 'plug in' to existing amenities to an extent – schools for example – which means that their requirements for land will be less than those of a new settlement designed for a population of similar size and demographic profile. However, very large urban extensions can be expected to require new amenities, and can therefore be expected to use as much land as a new settlement (ibid). However, the new (off-site) infrastructure required by an

urban extension will be substantially less than that required for a new settlement, according to Breheny et al (Breheny *et al.*, 1993). However, the potential impact on biodiversity is a subset of a wider range of impacts centred on the formerly rural landscape, although sometimes much modified by proximity to the town (Shoard, 2002). Clearly, decisions about peripheral expansion of settlements need to be made in a landscape context and then landscape character assessment is well placed to make an effective contribution (Swanwick & Land Use Consultants, 2002). Interestingly, a study of 'sustainable development of the countryside around the town' found that local authorities were much more confident about the effectiveness of measures to control development (*eg* green belts) than urban extensions (Ravetz & McEvoy, 2002). Inevitably, the success of policies and programmes was found to be strongly context dependent but the key to effectiveness was interactive planning in which cross-sectoral links brought together a cluster or chain of different but complementary initiatives.

Loss of natural habitat due to the development of a new urban extension is possible, even on previously developed sites such as quarries, railway yards or brick pits. This is because such sites may have developed their own, possibly fragile ecosystems in the time since they were abandoned to nature (Breheny *et al.*, 1993).

Breheny et al note that in the case of urban extensions there is no risk from either *town cramming* or loss of urban green space (Breheny *et al.*, 1993). In fact there are positive opportunities here to develop an effective, multifunctional green network (Barker, 1997). This 'green infrastructure' can be seen as a 'interconnected network of green spaces that conserves natural ecosystem values and functions' (Benedict & McMahon, 2002). Design guidance is now emerging about how the green infrastructure can be realised in practice (URBED, 2004) and the concept is now integral to development strategies in the growth areas around London (eg DEFRA and ODPM). A key issue here is to avoid locations, such as flood plains, where environmental hazards may be intensified by climate change (Gwilliam *et al.*, 2006) and to reflect climate change considerations fully in the planning of new development (Land Use Consultants *et al.*, 2006).

Breheny et al found that urban extensions or new settlements that function as 'dormitory' suburbs or towns are not energy efficient, since they encourage rather than discourage travel (Breheny *et al.*, 1993).

*Energy consumption due to space heating and powe*r can also be reduced through the use of CHP systems. While CHP is at its most efficient in high density urban areas, relatively low density suburban housing (including detached housing) is a also a feasible urban form in which to deploy it (Hutchinson, 1992), and thus it may be suitable for use in urban extensions.

4.5 Urban Extensions – Discussion

Urban extensions by definition are on the periphery of existing urban areas. Breheny and colleagues (Breheny *et al.*, 1993) argue that this has consequences both good and bad. The advantages are that the centre is reinforced, and any spare capacity that it might have is utilised. Such peripheral developments also offer the choice of ready access to both urban centre and urban hinterland, although such development is of course closer to that indeterminate area known as the rural-urban fringe (see Gallent *et al.*, 2006 for a discussion of the rural-urban fringe). The disadvantage, suggest the authors, is that any sense of community is not encouraged, and that planning gains in the form of affordable housing, community facilities and so forth were few. Breheny argued, with Peter Hall, that commuting from edge to edge of cities was a growing trend (Breheny, 1997; Breheny & Hall, 1999). A lack of employment provision in such developments does little to discourage long journeys to work (Breheny *et al.*, 1993), and could be expected to to continue this trend of 'edge-to-edge' commuting.

4.6 Urban Extensions – Key Points

- Cost of the end product is likely to be among the cheapest for the five options;
- Urban extensions are among the cheapest in terms of infrastructure costs;
- Access to employment opportunities is likely to be quite good;
- Access to social facilities is heavily context dependent;
- The likelihood of the development of a sense of community is heavily context dependent;
- Larger developments will tend to take on their own identity, whereas smaller developments will more likely be subsumed into the locality;
- Urban extensions do require greenfield land, but may be able to 'plug in' to existing amenities if they are relatively small;
- Loss of natural habitat is likely, even on previously developed sites such as quarries or railway yards;
- There is no risk from town cramming or loss of urban green space;
- CHP systems may be suitable for use in urban extensions.

5 'Key Village Extensions' Approach

5.1 Definition

Key villages were defined by Breheny et al (Breheny *et al.*, 1993) as those villages that were selected within a local development plan for urban expansion. The grounds for making a particular choice of village were that it would be a 'cost-effective focus for investment in new infrastructure and facilities' (ibid). Key villages in fact serve as local service centres for the smaller villages around them. These smaller villages are also relieved of some development pressures by the expansion of the central key village.

The 'key village' – a policy term rather than an analytical one – has its origins in the notion of the key settlement described in particular by Cloke (Cloke, 1979, 1983). Seen in the 1970s as a way of enabling County Councils to select certain settlements for growth, the notion of key settlements *per se* declined as power shifted to the District level in the 1980s. However, the problems that the notions of the key village and key settlement were intended to address (described above in the quote from Breheny et al (Breheny *et al.*, 1993)) remain. This is particularly the case now, as the normative and analytical notion of polycentricity continues to drive the planning agenda both in the UK and elsewhere in Europe (Green, 2005; Hall & Pain, 2006; Hall *et al.*, 2006).

5.2 Key Villages – Economic criteria

Breheny et al noted (albeit nearly well over a decade ago) that key villages can possess a variety of employment opportunities; the problem is that they may not exist in sufficient quantity to meet the needs of those who wish to work locally (Breheny *et al.*, 1993).

Breheny et al (Breheny *et al.*, 1993) note that for 'expansion and village schemes', overall development costs may be lower. Balanced growth approaches also have the advantage that they can leverage existing infrastructure provision, in terms of both use and maintenance. *Access to employment* is likely to be moderately good, again because the existing economic infrastructure may be in place. However, these criteria are all dependent upon the location of the existing settlements.

In earlier work that explored key settlements, Martin and Voorhees (Martin & Vorhees Associates, 1981) argued that the economic reasons for concentrating development since the second World War included the reduction of costs of infrastructure provision and services, and a reduction in cost, but an increase in catchment for services such as schools, health centres, playing fields, village halls and so forth (Martin & Vorhees Associates, 1981).

5.3 Key Villages – Social criteria

While key villages may benefit from the fact that there is a pre-existing community, there is also the risk that this community may resent the intrusion of the incomers: this may be especially the

case when the village in question is relatively small (Breheny *et al.*, 1993). Size will also have a bearing on *access to social facilities* (ibid).

Martin & Voorhees (Martin & Vorhees Associates, 1981) noted that amongst the primary socio-economic reasons for concentration policies between 1945 and 1980 were:

- The maintenance of population numbers in the countryside;
- The prevention of drift from rural areas to urban areas;
- Encouragement of more diverse rural economies;
- Improved quality of rural life;
- The fostering of community spirit.

5.4 Key Villages – Environmental criteria

According to Breheny et al (Breheny *et al.*, 1993), additional land is unlikely to be required for the extension of key villages since new development is most likely to take the form of infill. They add, however, that the relatively small amounts of previously developed land in villages will tend to limit the amount of infill that can take place, especially in comparison with larger settlements such as towns and cities (ibid).

In terms of *loss of natural habitat*, Breheny et al (Breheny *et al.*, 1993) note that since development of key villages tends to be small and dispersed, the impact on natural habitats will be relatively small in comparison, for example, with a new settlement, or an urban extension. However, similar reservations exist here, as with urban infill, particularly for features such as old orchards which have their own distinctive fauna (Webb, 2004).

However, in terms of loss of urban green space, and *town cramming*, key villages are at particular risk for precisely the reasons mentioned above – the relative lack of green space in the village interior (ibid).

Martin & Voorhees (Martin & Vorhees Associates, 1981) note that the concentration of new development in order to safeguard open land for recreation is also a principal reason for concentration policies.

5.5 Key Villages – Discussion

The expansion of key outlying settlements was described by Breheny and colleagues as offering 'the worst of both worlds' (Breheny *et al.*, 1993, p.80). While the character of the village is overwhelmed by the new developments, there are few gains for the local community in terms either of facilities or employment opportunities.

5.6 Key Villages – Key Points

- Key villages per se have received minimal coverage in the literature, since they are a category effectively defined by Breheny et al (Breheny *et al.*, 1993). They do, however, have an approximate counterpart in the notion of the key settlement, but both are policy rather than analytical constructs;
- May possess a variety of employment opportunities, though not in large quantity (this may have become more pronounced since 1993);
- Key village extensions can leverage existing infrastructure;
- Access to social facilities will depend on the size of the key village;
- Existing residents may resent the incoming residents in the extension;
- Additional land is unlikely to be required, since much of the extension will take the form of infill;
- The quantity of land available within the village curtilage will tend to limit the amount of infill possible;
- Loss of natural habitat is unlikely;
- Loss of green space interior to the village is a risk;
- Breheny and colleagues described key village extensions as 'the worst of both worlds' (Breheny *et al.*, 1993, p80).

6 Balanced Growth of Existing Settlements

6.1 Definition

Balanced growth itself is really an issue of spatial, strategic and/or regional planning, rather than a distinctive settlement type, dealing as it does with an over-arching approach that aims to balance social, economic and environmental considerations within the spatial context. It is thus a rather nebulous concept, and likely to mean different things to different people. Breheny and colleagues (Breheny *et al.*, 1993) do not specifically cover general balanced growth of existing settlements, although they do deal with multiple village extensions, which are also discussed in this section. Multiple village extensions are defined as either additions at the village fringe, or as infill development, which may include the conversion of agricultural buildings to residential use (ibid).

6.2 Balanced Growth – Economic criteria

Breheny et al have little to say on the economics of multiple village extensions.

6.3 Balanced Growth – Social criteria

Breheny et al (Breheny *et al.*, 1993) note that new residents in multiple village extensions may have to travel considerable distances to access social facilities, since the scale of development in any single village extension is unlikely to be sufficient to support an increase in local social facilities. There is a sense in which multiple village extensions – each by definition small – simply lack the necessary critical mass.

However, there are advantages to this. Small villages are highly sensitive to sudden relatively large increases in population. A sensitive programme of multiple village extensions will need to be carried through slowly and with a small pace of growth, thus preserving the existing sense of local community (Breheny *et al.*, 1993).

6.4 Balanced Growth – Environmental criteria

As with the economics of multiple village extensions, Breheny et al (Breheny *et al.*, 1993) do not comment at length on the environmental impacts of multiple village extensions. However, it seems reasonable to conclude that as with the expansion of key villages, multiple village extensions will tend to cause little loss of natural habitat, but may cause loss of green space that is internal to the village. The scope for this will of course be limited in the same way that it is for key villages.

6.5 Balanced Growth – Discussion

Balanced growth is not an easy thing to study. In effect, an in-depth study of balanced growth in England would be a study of spatial planning in England: perhaps the closest that anyone has come to this is Peter Hall in *The Containment of Urban England* and, more recently in *The Polycentric Metropolis* (Hall, 1973; Hall & Pain, 2006).

Cervero (Cervero, 1995) has explored the way in which Stockholm developed after the second World War, while Hall and Ward (Hall & Ward, 1998) have set out a blueprint for the balanced growth of England. However, this sort of balanced growth is as much an exercise in regional planning as it is in identifying appropriate urban forms for the mitigation of the effects of climate change.

The TRANUS experiment (Brown, 1998) is interesting because here development is concentrated more or less evenly in villages around the urban centre, whilst restricting car access to the core and facilitating radial transport between the satellites. This produces the largest shift between transport modes but energy use is somewhat higher because trips are on average slightly longer. Banister (Banister, 2002) argues that the only way to move toward sustainable development goals in a car dependent society is through combining planning and transport strategies so as to reduce the need to travel. He says 'this means that people should live in close proximity to services and facilities, and demonstrate a commitment to using them' (Banister, 2002, p.100).

6.6 Balanced Growth – Key Points

- Balanced growth is really an issue of spatial, strategic and/or regional planning, rather than a distinctive settlement type;
- There is some consensus that some form of polycentric development of the type implicit in the notion of balanced growth can be a sustainable solution.

7 New Settlements

7.1 Definition

New settlements are a means of accommodating urban growth through the establishment of a new geographical focus for development (Breheny *et al.*, 1993). Breheny et al make the point that a working definition of a new settlement is not to easy to arrive at, but they offered these approximate guidelines as being appropriate at the time they were writing (Breheny *et al.*, 1993, p.9):

- A new settlement may or may not incorporate a small pre-existing settlement;
- Developers did not typically see a development of less than 350 dwellings as being a 'new settlement';
- A 'new wave' new settlement could be expected to have between 350 and 5,500 dwellings, although there is no reason in principle why it should not be larger;
- The criterion of 'free-standing' must be loosely applied, although some degree of functional separation from other settlements is a requirement.

Having laid down these loose ground rules, Breheny et al defined a new settlement as:

> A free standing settlement, promoted by private or public sector interests, where the completed new development – of whatever size – constitutes 50% or more of the total size of settlement, measured in terms of population or dwellings (Breheny *et al.*, 1993, p.9).

7.2 New Settlements – Economic criteria

Breheny et al found that overall, new settlements, along with urban infill, were likely to have the lowest *cost of the end product*. However, in terms of provision and use of infrastructure, new settlements were likely to be the most expensive (Breheny *et al.*, 1993). Significant provision of *access to employment*, found Breheny et al, had been observed in a minority of new settlements at the time they were writing (1993). They added that none offered the prospect of self-containment (ibid), from which we might reasonably conclude that the potential to generate economic growth was minimal.

By the definition set out by Breheny et al (and given above), it is possible for a new settlement to have the *potential to regenerate depressed areas*, although in practice this would be the pre-existing settlement around which the new settlement is developed. Breheny et al make no comment on this, however.

Banister notes that 'evidence from great Britain shows that large metropolitan settlements tend to be associated with low distance travel and *energy consumption* (Banister, 2005, p.105). This may

be because higher population densities widen the range of opportunities for personal contacts and activities that do not require motorized transport (ibid). Banister also notes, however, that diseconomies of scale may occur with very large settlement sizes, when travel distances between home and the urban centre increase. In short, the relationship between settlement size and travel patterns is complex (ibid).

7.3 New Settlements – Social criteria

While *access to social facilities* can be 'designed in' to a new settlement, the fact remains that a 'sense of community' is built up over the longer term. Thus Breheny *et al* find no evidence that a spontaneous growth of a sense of community will arise until very many years have passed without careful attention to urban design (Breheny *et al.*, 1993). Cervero (1995) notes along similar lines that Sven Markelius designed Stockholm's post-war satellite towns at higher densities, despite surveys showing that Swedes tended to prefer mid- or low-rise housing: Markelius hoped, in effect, to change people's behaviour through design (Cervero, 1995).

7.4 New Settlements – Environmental criteria

New settlements share much in common with urban extensions in terms of environmental criteria, according to Breheny et al (Breheny *et al.*, 1993), particularly in terms of: *loss of land* (inevitable); *loss of natural habitats* (likely); *energy consumption* due to transport (inefficient if a dormitory town); contribution to 'greening' the existing urban environment (no effect, by definition, although does no harm); and *town cramming* (again no effect, but does no harm) (Breheny *et al.*, 1993).

Breheny et al do suggest, however, that new settlements have considerable potential for reduced *energy consumption* in terms of space heating and lighting, since they are being designed from scratch. The difficult question remains, however, of the scales at which it becomes economic to introduce initiatives such as schemes for combined heating and power (CHP). Overall, however, Breheny et al conclude that in the light of the evidence available at the time (1993), new settlements are particularly conducive to CHP schemes (Breheny *et al.*, 1993).

7.5 New Settlements – Discussion

New settlements, according to Breheny and colleagues (Breheny *et al.*, 1993) can, if of sufficient size[11] and in the right location, provide all that is required. However, while they may be able to offer good energy efficiency at larger scales, they require the use of rural land. However, the historical precedents to demonstrate the efficacy of this approach can be found easily enough:

[11] Breheny et al suggest a minimum of 3000–5000 dwellings, with around 10,000 dwellings being preferable BREHENY, M., GENT, T. and LOCK, D. (1993) *Alternative Development Patterns: New Settlements,* London: HMSO..

Markelius's scheme for the post-war expansion of Stockholm is a classic example (Hall, 1988; Cervero, 1995), while Hall and Ward (Hall & Ward, 1998) offer a blueprint for how the balanced regional growth originally advocated by Howard (Howard, 1898) may be updated for the present day.

7.6 New Settlements – Key Points

- New settlements are likely to have the lowest cost of end product;
- New settlements are likely to be the most expensive in terms of provision of infrastructure;
- A new settlement that is developed around an existing one may have the potential to contribute to its regeneration;
- A sense of community will require many years to build up;
- Loss of land and natural habitats is inevitable;
- Town cramming is not a risk;
- New settlements are particularly conducive to energy-saving initiatives such as CHP.
- New settlements need to be properly self-contained to be sustainable – a 'dormitory settlement' is likely to result in more travel.

8 Discussion & Synthesis

8.1 Introduction

'This work was commissioned because of increasing political, public and professional concerns about how best to accommodate new development: its scale, location and consequences.' Thus Breheny, Gent and Lock (Breheny *et al.*, 1993) in the first sentence of *Alternative Development Patterns: New Settlements.* There appears to be little in the literature since the mid-1990s to suggest that much has changed in the decade and a half or so since the publication of this work, which continues to be much-cited in far more recent literature. This is not simply due to a lack of research, although it is certainly the case that in the UK at least, there has been relatively little research into many, although not all of these issues: the compact city in particular has been a topic of considerable debate, and this variance in coverage is very obviously reflected in this review.

The lack of change is also because many of the arguments and issues raised by Breheny, Gent and Lock remain every bit as accurate and relevant in 2006 as they were in 1993: the concerns about housing and settlement type and location remain, and if anything have probably become greater; the phrase 'housing crisis' is no longer decried as unnecessary fear-mongering, but can be heard regularly in the mass media; environmental concerns are now in the political mainstream.

We might therefore have expected a continuing research effort since the mid-1990s on the relative merits of accommodating household growth in different forms of settlement pattern, especially given the imperative of sustainable development. However, as Susan Owens has observed (Owens, 1992), in an era of relatively low fuel costs, it would take an environmental crisis to rekindle serious interest in energy conscious land-use planning. It is clear from our growing understanding of the imminence of climate change, and its likely impacts, that that time is now.

In this review we have seen that many of the questions raised in the original brief have only been partially answered in the available literature (key villages, for example, get barely a mention), and the time constraints within which this review was prepared have not left room for anything except a rather superficial look at what has been written. Even so, it is clear that there are no easy answers.

8.2 Key Criteria for the Evaluation of Settlement Patterns

The framework set out in 1993 by Breheny et al (Breheny *et al.*, 1993), and updated in the brief for this literature review, remains as valid a way of assessing new settlements as any (and no less challenging). To be sure, certain criteria are more mercurial than others, and the fact that settlements do not exist in isolation from one another but are parts of a much larger functional whole makes the development of any list of criteria an invidious exercise.

As Breheny et al point out in their original analysis, the various scores given to different settlement types for different criteria are 'far from sacrosanct.' Instead, 'they are intended to focus discussion,

rather than present a definitive assessment. Readers are invited to produce different scores, weigh criteria, and consider their judgements on the relative merits of the alternatives' (ibid, p.vii). Again, the message is clear: context is crucial – there is no single 'correct' answer.

8.3 Density and Urban Form

The question of density is a vexed one. There is no single agreed way of defining it, although the Town and Country Planning Association's policy statement on residential densities, which draws heavily on the work of the late Michael Breheny, notes that there are typically three ways of measuring density (TCPA, 2003):

- *Net residential densities* include land covered by residential development (including gardens and other spaces), plus half the width of adjacent roads;
- *Gross residential densities* add to net residential densities non-residential development to reflect local amenites and services;
- *Town density measure* the gross residential density over a discrete urban area.

These measures make no reference to which units should be used, and the TCPA note that there are typically three commonly used *units of density* (TCPA, 2003):

- Dwellings per hectare (DPH);
- Habitable rooms per hectare (HRPH);
- Bed-spaces per hectare (BPH).

It can be seen that measuring residential density is no simple matter. None of these three definitions refers to the number of people who actually inhabit a given area, although habitable rooms and bed-spaces suggest potential capacity (indeed, the TCPA suggests people per hectare as their preferred measure). Since a dwelling can be anything from a six-bedroom detached house to a bedsit, the general notion of a dwelling indicates little about the population it houses (TCPA, 2003).

Clearly, then, there is no simple relationship between urban form and density. An urban form comprising residential tower blocks can be given a particular density by the simple expedient of situating it on a suitably-sized piece of undeveloped land. For example, an urban form comprising tower blocks, each having one-hundred dwellings, could be given a density (in DPH) of 25 DPH by situating each block in 4 hectares of undeveloped land, or 100 DPH by situating each block in one hectare of undeveloped land. 25 DPH is a typical density for modern suburban developments, and it can be seen that although the tower block in 4 hectares of land and the modern suburb may have identical densities in terms of dwellings per hectare, they are fundamentally different urban forms.

Even applying such figures is difficult. For example, we may wish to find an optimum density that will support a viable public transport system. To do this, we need to know (amongst other things): where people work; when they work; socio-economic conditions; what type of public transport; what we mean by 'viable' (Adequate profit margins? Using no more than a given level of subsidy? A minimum level of usage?) and so forth. The answer to the question 'what is the optimum density to support a viable public transport system?' is thus a battery of further, equally complex questions.

The SOLUTIONS (Sustainability Of Land Use and Transport In Outer NeighbourhoodS) project (SOLUTIONS, 2007), which aims to explore the ways in which different patterns of development may influence and be influenced by transport, has so far only published interim findings of a case study based around Cambridge.

The safest, and most accurate comment on density is that it is but one part of a complex equation. It is worth noting, however, that the TCPA suggest that if a single figure for optimum density were to be chosen, they would choose 35 dwellings per hectare. Crucially, they add that this figure is heavily contingent upon local circumstance, and will need to be varied accordingly (TCPA, 2003).

8.4 Thresholds, Tipping Points and the Timing of Identifiable Impacts

The notion of a 'tipping point,' a concept originally coined by Grodzins (Grodzins, 1960) in the context of racial segregation, is relatively new in policy terms. The notion of dramatic systemic change is familiar enough from chaos theory, and Ruelle points out that social systems in particular are both highly complex and have a high a degree of uncertainty in mathematical terms (Ruelle, 1997).

The identification of tipping points is thus no easy task, and tipping points in social systems are particularly difficult to predict, even after the kind of detailed and close study that is both required and not possible in a literature review such as this. The very nature of a tipping point is such that both the time and effects of its arrival are not easily predictable, even with the benefit of hindsight (Green, 1999), and decisions about tipping points with regard to climate change also have a political dimension (Fairbridge, 2006).

Perhaps unsurprisingly, it follows that there is little on the timing of identifiable impacts of the different types of settlement pattern. Perhaps it is safest to quote Peter Hall, who when asked at a seminar whether, in his view, Letchworth Garden City had been a success, quipped 'Too early to tell.'[12]

Thresholds are less intractable, but by no means simple. Banister and Newman & Kenworthy point out that larger settlements can be expected to be more efficient (Newman & Kenworthy, 1999;

[12] Personal communication from a member of the audience at the seminar.

Banister, 2005). Banister (Banister, 2005, p.112) offers the following, fairly specific figures for new settlement sizes: 'new development should be of substantial size and located near (or within) existing urban areas so that critical size thresholds (at least 25 000 population and preferably over 50 000) can be achieved.' Such settlements should have 'mixed densities greater than 40 persons per hectare, with mixed use developments in public transport accessible corridors and near to highly accessible public transport interchanges' (ibid). Banister continues, echoing Howard (1898) and more recently Hall and Ward (1998): 'Settlements of this scale would be linked together to form agglomerations of polycentric cities, with clear hierarchies that would allow close proximity of everyday facilities and accessibility to higher order activities.'

Owens (Owens, 1992) notes that a density of more than 250 dwellings per hectare in an existing small city will provide a break-even point for Combined Heating and Power/District Heating (CHP/DH) assuming constant fuel prices, a discount rate of 10% and a power station 15km from the edge of the city. Put like this, it is easy to see that the density threshold is only one variable in a complex equation, that includes: thresholds for fuel prices, both present and future; the discount rate, itself dependent on prevailing economic conditions (which may in turn depend on oil prices); and the distance of the power station from the edge of the city. As Owens puts it 'the relationship between spatial structure and the viability of CHP/DH is dynamic' (Owens, 1992, p.98). Owens does make the point that higher densities tend to be more economically favourable to CHP, and adds that built forms need to 'facilitate internal routing, linear layout and mixing of land uses' (ibid). The complex relationship between urban form and energy use is evident in Table 3.

Table 3 Energy Implications of Structural Variables (source: Owens, 1992, p.100)

Structural Variable	Mechanisms	Energy Implications
Shape	Travel requirements	Variation of up to about 20%
Interspersion of activities	Travel requirements (especially trip length)	Variation of up to 130%
Combination of structural variables (shape, size, land-use mix etc)	Travel requirements (trip length and frequency)	Variation of up to 150%
Density / built form	Surface area:volume ratio affects energy requirements for space heating	200% variation between different built forms
Density / clustering of trip ends	Facilitate running of public transport system	Energy savings up to 20%
Density / mixing of land uses	Facilitate introduction of energy-efficient chp/dp systems	Efficiency of promary-energy use improved by up to 100%
Density / siting / orientation and landscaping	Maximises potential to use 'free' ambient energy	Can reduce conventional energy-consumption by at least 20%

8.5 Managing the Impact of Development

As this review has shown, development brings benefits but not without impacts. Impacts can be identified and addressed at all levels in the planning process, from strategic environmental assessment of policies, plans and programmes to review of individual development proposals.

Impact assessment is given a new impetus in the context of climate change when poorly sited development may be put at risk as environmental hazards intensify and ill-considered development may significantly increase greenhouse gas emissions. This presents a formidable challenge to the planning profession (Wilson, 2006) and to environmental governance (Bulkeley & Betsill, 2005).

In this review, a consistent feature of all development 'options' is the exchange of 'natural' for built environment, with political consequences for human wellbeing, as well as biodiversity. We now recognise that many of these services relating to the natural environment can be sustained in urban areas by incorporating a multi-functional network which includes the totality of urban green space, public and private (Barker, 1997; Benedict & McMahon, 2002; Hough, 2004). These functions include the moderation of climate change impacts and new research has begun to quantify the benefits (Whitford *et al.*, 2001a; Gill, 2006). Design guidance is now being developed (URBED, 2004) and checklists with helpful guidance for developers on adapting to climate change (GLA, 2005). However, the wider use of adaptive measures such as sustainable urban drainage systems (SUDS) will require heightened awareness within the planning profession (Howe & White, 2001) and determination to overcome the many barriers that still stand in the way of effective implementation (White & Howe, 2005).

8.6 Spatial Form and Overall Benefits

With regard to *energy consumption due to transport* the relationship between urban form and transport efficiency is a complex one, but Breheny et al found a consensus amongst a number of different studies that some form 'decentralised concentration' is 'relatively efficient', since different models suggest that constraints on mobility will tend to encourage people to use those jobs and services that are nearest to them (Breheny *et al.*, 1993), a consensus supported by Owens (Owens, 1992).

Banister (Banister, 2005) refers to the ABC location policy of the Netherlands, which is a means of allocating particular settlement types a place in a simple hierarchy using the following basic criteria.

- highly accessible by public transport and tight restrictions on parking (10 spaces per 100 employees in Randstad, 20 elsewhere); the target group involves labour or visitor intensive companies such as office or public facilities;
- good accessibility by car (fewer parking restrictions, namely 20 spaces per 100 employees in the Randstad and 40 elsewhere) and public transport;
- highly accessible by car and less reachable by public transport, no parking restrictions; the target group are companies that need to be accessible by car and truck (quoted from Banister, 2005, pp.114-5).

In a study of *energy use in transport* in English towns having populations of approximately 100,000, Rickaby et al (1992) found that as density increases, so energy use tends to decrease, reinforcing the findings of other research on this topic, although as Breheny points out, Rickaby has also found that in theoretical models, the most efficient urban forms tended to include urban concentration plus nearby villages, in a polycentric regional structure (Rickaby, 1987; Breheny, 1992b). As Orrskog and Snickars point out, this prescription is very close to that set out by Howard over a century ago in his concept of the 'social city' (Howard, 1898; Orrskog & Snickars, 1992).

8.7 Further Work

This review merely scratches the surface in what is a hugely important, complex and invidious debate. Although its remit has been to answer questions, it would be fair to say that in attempting to find answers, it has also raised yet more questions. This is not surprising. There are many issues to do with land use and spatial planning that have been discussed by other commentators, and that could reasonably be stated as being of relevance to the issues discussed in this review. The wider role of the rural-urban fringe, for example, has been discussed recently by Gallent et al (Gallent *et al.*, 2006), and this debate is clearly one that crosses over into debates about urban extensions.

The role and purpose of green belts is also salient in this context, and the long-running and heated debate shows few signs of letting up (see for example Elson, 1986; Evans, 1988; Herington, 1991; Elson *et al.*, 1993; Elson *et al.*, 1996; see for example Mawson & Tewdwr-Jones, 1997; RTPI, 2002; TCPA, 2002).

The emergent issue which is likely to reactivate this whole research agenda concerns climate change. As Owens showed some twenty years ago (Owens, 1986), settlement form and density can have profound implications for energy use. Modelling, of the type described by Brown (Brown, 1998), can help to shed light on the merits of alternative development scenarios and transport management strategies. That work showed that urban densification may have unexpected consequences and we now realise that this could involve reduced adaptive capacity in the face of climate change. Work in both areas, mitigation and adaptation, clearly remains a priority, but especially where measures to reduce greenhouse gas emissions can also increase resilience. The development of viable 'green infrastructure' is just one way in which a positive interaction might be encouraged.

8.8 Key Messages for Policy Makers

- There are no easy answers.
- Urban infill is a question of balance: if overdone, it may make cities less pleasant places to live, exacerbating the problem it is intended to solve.
- New settlements and large urban extensions have the potential to be sustainable if:

a. they are not dormitory settlements, but properly self-contained;

b. they are built to sufficiently high densities and standards to support initiatives such as CHP;

c. they are properly served by public transport.

d. they are supported by an extensive and well managed green infrastructure.

- Key village extensions may provide 'the worst of both worlds' (Breheny *et al.*, 1993).
- Balanced growth is as much about spatial planning as settlement form.

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11 Appendices

11.1 Appendix 1 - Project Brief (July 2006)[13]

11.1.1 Purpose

DCLG Communities and Local Government wish to commission the Planning Research Network to undertake a literature review. The review will look at the impacts of different settlement patterns to accommodate further growth, in order to update our understanding of available research and findings. It is intended that the review will help inform the development of the forthcoming planning policy statement (PPS) on climate change and will provide information of value to the Barker Review of Land Use Planning.

11.1.2 Background

Planning has a key role to play in delivering sustainable development. The key principles for ensuring planning decisions contribute to sustainable development are set out in paragraph 13 of PPS1 – Delivering Sustainable Development. In setting the general approach expected from planning authorities PPS1 underlines the importance of:

- focussing developments that attract a large number of people, especially retail, leisure and office development in existing centres to promote their vitality and viability, social inclusion and more sustainable patterns of development;
- reducing the need to travel and encouraging accessible public transport provision to secure more sustainable patterns of transport development. Planning is expected to manage patterns of urban growth actively to make the fullest use of public transport and focus development in existing town centres and near to major public transport interchanges;
- promoting the more efficient use of land through higher density, mixed use development and the use of suitably located previously developed land and buildings.

A growing challenge in ensuring sustainable development is climate change. In March 2006 the Government announced its intention to develop a PPS on climate change which will set out how the Government expects participants in the planning process to work towards the reduction of carbon emissions in the location, siting and design of new development. There is stakeholder concern that the PPS should also consider the planning response to adapting to the change in climate we can already reasonably expect. The aim is to consult on a draft of the PPS later in 2006.

[13] Formatting has been changed to match remainder of this document.

11.1.3 Scope

Drawing from available literature and emerging work about spatial planning and growth[14], the review will contribute to our understanding of the social, economic and environmental implications of accommodating growth in different spatial forms in rural and urban contexts. The review should address the following research questions.

For different spatial forms of development and growth, including[15]:

a) infill of existing urban areas ("intensification");

b) extension of existing urban areas on the margins;

c) 'key villages' approach (extension of key existing, outlying settlements);

d) balanced growth of all existing settlements;

e) entirely new settlements;

assess the different type of impacts, their scale and any inherent risks against the following criteria:

11.1.3.1 Economic criteria

- Cost of the end product
- Economy in the provision and use of infrastructure
- Maintenance costs
- Access to employment
- Potential to generate economic growth within the settlement
- Potential to regenerate depressed areas
- Economic viability of public services
- Road congestion

11.1.3.2 Social criteria

- Access to social facilities (social inclusion)
- Potential sense of community

[14] DCLG will submit references for key known research and proposals for other areas to consider, for instance, the European Union's research programmes.

[15] It may be appropriate to include additional spatial forms of development suggested by the literature such as the Dutch model of poly-centric settlement.

- Breadth of social mix
- Potential affordable housing contribution
- Local acceptability
- Quality of life / local satisfaction with neighbourhood
- Impacts on different social groups
- Car dependency
- Human health

11.1.3.3 Environmental criteria

- Loss of land
- Loss of natural habitats and impact on biodiversity
- Energy consumption – transport (mode and distance travelled, associated CO_2 emissions)
- Energy consumption – space heating and cooling, lighting, use of renewables (and associated CO_2 emissions)
- Pollution (air quality, noise)
- Contribution to 'greening' the urban environment
- Town-cramming effect
- Thermal comfort (heat island effect)
- Impact of environmental hazards (flooding, storms)

The criteria are not intended to be exhaustive and the trawl of available literature may suggest they should be added to.

Urban density (in terms of built development, occupation and population) and the location and concentration of major trip generating developments (e.g. retail stores) are intrinsically linked to the impacts that arise from and in these different spatial forms of development, and in some cases, could be equally important factors in determining impacts. The literature review should include these factors in the overall discussion and analysis together with a consideration of settlement size.

11.1.4 Methodology Issues

In addressing the questions set out above, the review should draw out the assumptions made in the literature where these are relevant to the research findings, the robustness of the evidence

underpinning available research and competing claims from differing research. The review should be clear and transparent about key methodological issues such as:

- difficulties in quantifying effects and impacts;
- the transferability of older and international research to the current UK situation;
- differences in definition of key terms and concepts such as, "intensification", "urban sprawl", "high density development".

11.1.5 Outputs

The review should be bought together in a written document with a clear stand alone summary. (no more than 8 pages - DCLG may propose a summary template or matrix for the review). In addition, there should be a well presented bibliography.

The focus should be on identifying key messages for policy makers and ensuring that the review picks up the major key research on these issues. Where there is no consensus on the issues, it will be helpful to comment on the relative degree of support for the different positions.

Key outputs of the review will be:

- the key criteria to consider when evaluating different settlement patterns, both at a local level and also at a regional level;
- any thresholds at which spatial form, density, settlement size and the concentration of different functions have different impacts on the criteria and evidence for any tipping points (e.g. establishing car dependency, reducing quality of life through over-crowding, the size of settlement needed to support local services, the degree of mixing of different functions necessary for a successful community);
- the expected timing of the impacts arising (short, medium or long-term);
- measures that have been used or proposed to mitigate any negative effects that are a side-effect of a potential benefit;
- to the extent possible, an indication of whether the planning process is the most cost effective and appropriate delivery vehicle for achieving a particular beneficial outcome in practice;
- evidence for recommendations for the spatial form, densities, concentration and location of functions that produce the biggest overall net benefit.

The findings will be presented to DCLG and also to academics, policy colleagues and government analysts at a Planning Research Network seminar later in the year.

11.1.6 Timing

The first stage of the work is to provide a list of key literature. For the second stage, the analysis of the literature, there is a need to 'fast track' consolidation of the material addressing climate change issues. Analysis on climate change issues should be provided as soon as it is available. The draft final report for the whole project should be delivered by the end of September.

11.2 Appendix 2 – Summary of CURE Literature Review on Impacts of Climate Change on Urban Environments (Gill et al, 2004)

The research project on *Adaptation Strategies for Climate Change in the Urban Environment* (ASCCUE) is part of the Engineering and Physical Science Research Council's *Building Knowledge for a Changing Climate* initiative. A literature review for the ASCCUE project (Gill *et al.*, 2004) followed the 'Driver-Pressure-State-Impact-Response' framework of the European Environment Agency (EEA, 2003). The main findings were:

- The key drivers of change in the urban environment are greenhouse gas emissions, lifestyle changes, and urban development. These drivers act in conjunction with each other as well as with other environmental, socio-economic and political drivers.
- The drivers exert pressures on the urban system, which again act both independently and in conjunction with each other to produce impacts. Pressures not only result from changes *per se*, but crucially depend on other factors including climate variability and extreme events. Climate change in the UK will result in warmer wetter winters and hotter drier summers, with an increased occurrence of extreme events such as heatwaves and intense precipitation. In addition, urban intensification, which is partly dependent on lifestyle choices, reduces greenspace cover and puts pressure on the urban ecosystem, impacting on, for example, surface temperatures and stormwater runoff.
- The severity of the impacts of climate change depends upon the state of the urban environment. In particular, urban environments already have their own distinctive microclimate, air quality and hydrological regimes. Climate change tends to reinforce this distinctiveness by intensifying the urban heat island effect and surface run-off of rainfall. The green space to built surfaces ratio is therefore important for the environmental functionality of urban areas.
- Climate change impacts on air quality (e.g. decreased mean and episodic winter concentrations of particles, NO_2 and SO_2, increased summer ozone episodes), hydrology (e.g. altered river flows, decreased annual and summer average soil moisture, changes to surface runoff, flooding), urban green space (e.g. changes to species range, phenology, physiology and behaviour, susceptibility to drought, increased irrigation demands, increasing importance for reducing flooding and temperatures and meeting recreational demand), human comfort and health (e.g. winter comfort increases and mortality decreases, more heat stress in summer which may result in deaths within vulnerable populations), and building integrity (e.g. through wind, driving rain, subsidence and soil movement, flooding).

The response to these impacts involves measures to reduce greenhouse gas emissions, ensuring that pressures are not intensified by inappropriate development and improving the state of the built

environment and preparedness in the face of extreme events, so as to reduce climate-related impacts.

11.3 Appendix 3 – Summary Table from (LCCP, 2002)

Higher Temperatures	• There is likely to be an increase in the demand for cooling and thus for electricity in summer. • Against this, there will be a reduction in demand for winter heating providing a financial advantage for bill payers and reducing incidences of fuel poverty.
Flooding	• Increased risk of flooding is expected for many parts of London. • More frequent intense winter rainfalls are expected to increase the likelihood of flooding by rivers and flash flooding when urban drainage systems become overwhelmed. • Rising sea levels and possible increased winter storminess would require more closures of the Thames Barrier.
Water Resources	• Water demand will be heightened during hot, dry summers. • Longer summers with higher temperatures and lower rainfall will reduce soil moisture and the chance to replenish groundwater supplies. • River flows are likely to be lower in summer and higher in winter. • Lower river flows in summer will raise water temperatures and aggravate water quality problems in the Thames and its tributaries, especially following heavy summer storms.
Health	• Poorer air quality poses health problems for asthmatics as well as causing damage to plants and buildings. • Higher levels of mortality related to summer heat stress are expected. • Higher winter temperatures would be likely to lead to a reduction in winter cold spell related mortality.
Biodiversity	• Warmer weather would favour conditions for increased competition from exotic species as well as the spread of disease and pests, affecting both fauna and flora. • Rising sea levels will threaten rare saltmarsh habitats. • Increased summer drought will cause stress to wetlands and beech woodland. • Earlier springs, longer frost-free seasons and reduced snowfall could affect dates of bird egg-laying, as well as the emergence, first flowering and health of leafing or flowering plants.
Built Environment	• The building industry will be likely to benefit from an increased number of available construction days. • Subsidence will worsen as clay soils dry out in summer and autumn. • Alternate wetting of clays in winter and drying of clays in summer may cause increased ground movement resulting in increased potential for damage to underground pipes and cables. • Increased temperatures will reduce comfort of occupants in domestic, commercial and public buildings, and could lead to business disruption.
Transport	• London's transport system and ancillary services are vulnerable to disruption from flooding and other extreme weather events that are expected to increase in frequency and intensity. • Increased temperatures on the London Underground, exacerbated by the urban heat island effect, will lead to passenger discomfort. • Hotter summers may damage elements of transport infrastructure, causing buckled rails and rutted roads, with their attendant disruption and repair costs. • Higher temperatures will lead to a reduction in cold weather-related disruption.
Business & Finance	• The London insurance industry could be exposed to an increased volume of claims from wind storms and flood events. • Lower income households may find it more difficult to access adequate insurance cover in the face of increased flood risk. • The risk management of potential climate change impacts may provide significant opportunities for London businesses.
Tourism	• Increased temperatures could attract more visitors to London, benefiting the tourist sector. • Leisure and recreational facilities and tourist attractions will need to be able to cope with climate change by providing a pleasant environment for visitors. • High temperatures could lead to residents leaving London in search of a more comfortable environment on holidays or breaks.
Lifestyle	• Outdoor living may be more favoured, although some members of society may be less able to take advantage of this due to lack of facilities locally, fear of crime or other forms of social exclusion. • Green and open spaces will be used more intensively.

11.4 Appendix 4 – Recommendations for Urban Environmental Management (Gill, 2006)

1. Raise awareness of the environmental services provided by urban green space and their importance for climate adaptation. The creative use of the green infrastructure for climate adaptation is one of the most promising opportunities in urban areas as it provides other social, economic and environmental benefits. Awareness of the functionality of urban green space, based on robust evidence, must be raised at all levels and in all sectors, including the general public.

2. National guidance within policies, plans and programmes should recognise the functional importance of the green infrastructure in adapting to climate change. Within the planning system, national policy tends to favour urban densification and the use of brownfield land for new housing developments. A greater emphasis should be placed on the role of the green infrastructure in adapting to climate change within Planning Policy Statements (PPS). In particular, the proposed PPS on climate change should have a strong reference to this. Whilst the planning system is critical in ensuring adaptation to climate change via the green infrastructure, changes to the Building Regulations as well as other policies, plans and programmes, and economic instruments and mechanisms such as tax breaks, subsidies, grants, and incentives are also important. For example, within the Government's Sustainable Communities Programme it is crucial to take the opportunity to 'climate proof" new developments in the Growth Areas and to reintroduce functional green infrastructure during the redevelopment process in areas subject to Housing Market Renewal.

3. It is essential that the green infrastructure is strategically planned and delivered, with climate change adaptation in view, at the regional and local levels. This must be reflected in policies, plans and programmes. In particular, green infrastructure policies should be incorporated into Regional Spatial Strategies together with recommendations for the development of tiered green infrastructure strategies and plans from the regional to the local scale. Local Development Frameworks should recognise the potential of the green infrastructure in adapting to climate change within their core strategies. At this level greenspace strategies, or green infrastructure strategies, could be developed, potentially as supplementary planning documents. These strategies should be based on CABE Space's good practice guidance (CABE Space, 2004) but should go further by being explicit about the environmental services provided by urban green space, including private gardens.

4. Strategic planning at the city-regional level is likely to be particularly effective. Whilst much of the emphasis within the planning system is placed on the regional and local levels, the conurbation level has been highlighted as crucial for climate adaptation via the green infrastructure. At this level, greenspace strategies could be developed to create a truly functional network that crosses local authority boundaries.

Strategies firstly need to understand the environmental functionality of green space under present and future climate scenarios. Next, they should take into account the potential impacts of climate change on green space itself. They should then seek to preserve, create and enhance green space to form a functional network, ensuring that critical environmental capital is preserved absolutely, especially nodes and corridors which provide non-substitutable climate related benefits such as a city centre park or river valley flood plain. Whilst such areas merit absolute protection, beyond this there should be no net loss of green space to development. Different approaches will be required in different urban neighbourhoods. For example, it is crucial to take opportunities to create and enhance the functionality of the green infrastructure in areas of structural change and new development. Section 106 agreements can be used to require developers to support and maintain tree planting and greenspace provision, whilst programmes at the local level, such as Green Streets of the Red Rose Forest (Red Rose Forest, no date), are very important in securing street tree planting. On the other hand, the creation of Conservation Areas in lower density areas which provide key regulatory functions such as the interception and infiltration of rainfall.

5. Greenspace strategies, or green infrastructure strategies, will require a suite of complementary measures to realise the full adaptation potential of the green infrastructure, particularly in relation to the following climate related functions:

a) Interception

Tree canopies intercept rainfall, with large mature trees being especially important. Mature trees should be maintained in urban environments using Tree Preservation Orders and new planting of tree species which will have large canopies when mature should take place. This is very important in highly built-up town centres and high density residential areas. Trees are able to exploit soil water reserves at greater depths and it should be possible to select species which can tolerate the warmer, drier summers expected with climate change.

b) Flood conveyance and storage

River corridors and canals are especially important for conveyance of flood waters and for flood storage. Green space, which can be flooded in times of high flow, should be retained within floodplains. Selected roads could also perform a flood conveyance and storage function if required as already happens in some cities with a tropical climate. The use of SUDS for flood storage within parks is also important, and these should be sited on soils with a high infiltration potential. Excess rainwater should be stored and used to irrigate green space during drought.

c) Infiltration

The nature of the surface cover within the built-up matrix is crucial for rainwater infiltration. This is especially true where soils have a fast infiltration rate and where the provision of green space will help to reduce surface water runoff. Conservation Areas could be created to restrict infill development in such areas and economic incentives could help to stop the gradual erosion of this functionality. The provision of SUDS could also promote infiltration, especially within parks.

d) Evaporative cooling

Parks provide areas where evaporative cooling is beneficial. In particular, parks of over 1 hectare have their own microclimate. Within the built matrix street trees, green roofs and vegetation on building facades also provides evaporative cooling, and key streets could be pedestrianised and greened. Irrigation must be provided during droughts to maintain this functionality, recognising that benefits go beyond amenity. A supply of water could be ensured by capturing, storing (potentially as SUDS within parks and in individual water butts) and distributing excess winter rainfall; or by using water from low quality or rising aquifers and canals. Water surfaces are very important in providing evaporative cooling, especially during drought. Maximum use should be made of any water bodies and features, for example, through the 'daylighting' of culverted rivers and canals.

e) Shading

Large mature tree canopies provide important shading in the built matrix for both people and buildings. The addition of street trees is especially important in town centres where there is little opportunity to create significant new green spaces, as well as in schools, hospitals and high density residential areas, which suffer from socio-economic disadvantages and a low tree cover. New tree planting should include species which will have a large canopy when mature and an ability to withstand hotter drier summers. Trees should be sited preferentially to the south, east and west of

buildings. Green roofs and vegetation on building facades can also shade buildings from sunlight. Shading is important within parks for human comfort, and the role of trees in providing shade is invaluable during droughts.

6. Faced with the challenge of climate change and recognising the multifunctional benefits of the green infrastructure there is a case for an organisation such as CABE Space to develop and promote a greenspace charter which will require:

- Critical environmental capital, where greenspace assets have a demonstrable level of climate functionality, to be protected absolutely. This includes town centre parks, flood plains, and areas of lower density settlement where the soil has a high infiltration capacity;
- No net loss of greenspace cover;
- Creative greening to enhance greenspace cover. Particular attention should be given to the public realm in town centres to ensure a sufficient range and quality for human comfort, and to new planting in locations where a low greenspace cover combines with socio-economic deprivation and/or human vulnerability;
- Opportunities to be taken to improve levels of greenspace provision during urban restructuring and new developments;

Innovative measures to secure an alternative water supply to sustain the functionality of green space during times of drought.