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The conditions for, and challenges of, adapting England's suburbs for climate change

Katie Williams*, Jennifer L.R. Joynt, Catherine Payne, Diane Hopkins, Ian Smith

Centre for Sustainable Planning and Environments (SPE), Department of Planning and Architecture, University of the West of England (UWE), Frenchay Campus, Coldharbour Lane, Bristol BS16 1QY, UK

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ABSTRACT

This paper outlines the conditions for, and challenges of, adapting suburbs in England for climate change. The paper introduces the 'suburb' as a spatial setting vulnerable to climate change related threats that have been largely absent from previous adaptation studies. It argues that in terms of the impacts of climate change on the daily lives of the UK's population suburban neighbourhoods need far more attention. It sets out a typology of English suburbs (including inner-historic suburbs, pre-war garden suburbs, interwar suburbs, social housing suburbs, car suburbs, and medium-high density suburbs), and argues that these suburbs will experience both gradual changes in climate and extreme events. The changes will have impacts on 'place' and 'people', and modifications to the physical environment to respond to climate change will need to take place if they are to be sustainable in the future. Modifications can be at different scales: home and/or garden and/or neighbourhood. However, whether or not such modifications to the physical environment will be implemented is a function of the 'response capacity' in the suburb: *and this* is determined partly by the existing physical conditions of the suburb, and partly by economic, governance, knowledge and cultural contexts. *The paper* describes the conditions that underlie the response capacity in suburbs, and reveals the complexity of attempting to 'climate proof' some of the most established and valued parts of the English urban landscape.

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'Some suburbs have problems of success; others have problems of failure. All have issues of adaptation' [1].

1. Introduction to suburban adaptation for a changing climate

The UK is experiencing unprecedented changes in its climate and will continue to do so for at least the next 40–50 years [2,3]. As a consequence, there is now broad political agreement that as a society and individually we need to act to avoid further change, but also to adapt to forthcoming climatic conditions [4]. For most of the population, the effects of climate change will be experienced predominantly in their own homes. Other settings (for example, workplaces, hospitals, schools) are important, but domestic space is by far the most critical. People spend the majority of their time in their own homes, making the effects of climate change on their domestic comfort and safety significant. For the majority of the population their house or flat is also the largest single financial investment they make (69.8% of English households own their home) [5]. Hence, the impacts of climate change on building fabric, gardens and surrounding neighbourhoods are significant economically and psychologically.

In England and Wales 86% of the population live in urban areas formally categorised as suburbs. National census analyses indicate that 23% live in areas termed 'suburban/urban', 43% in 'suburban', and 20% in 'suburban/rural' [6]. Although these categories may seem broad, and contain places such as ex-council estates and New Towns, they do highlight the small proportion of the population that reside in the central city (only 9%), and the predominance of suburbs as the most common domestic setting.

Most of the current dwelling stock in suburban areas was built in the last century, but will still be here in 2050 (at least two thirds) [7,8]. The rate of change in the built environment is relatively slow (around 1% per year), and the morphology of suburbs, in terms of groups of houses, street layouts and open spaces, is even more enduring. The majority of suburbs are also dominated by private ownership of homes and other uses (business premises, garages, local shops, etc.), although responsibility for the public realm lies largely with local authorities. Hence, the challenge of adapting such areas is a complex picture of modifications to an existing (and

* Corresponding author. Tel.: +44 117 3283202.
E-mail address: katie4.williams@uwe.ac.uk (K. Williams).

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ageing) building stock and public realm, with mixed patterns of ownership and responsibility. Added to this, there are aspirations to fulfil a large proportion of England's future housing needs within existing suburban neighbourhoods, so continued patterns of infilling and intensification are also likely [9]. Within this context, it is critical that suburban areas find ways to function as comfortable, liveable and resource efficient places in the future. This needs to be seen as an important part of the national 'climate proofing' strategy.

Yet, suburbs have received very little attention in either climate change research or policy [10]. In general, people have been 'interested in urban problems or rural problems but not the bit in between' [11]. The focus has been more heavily on: urban centres (as opposed to the periphery), particularly in relation to the urban heat island effect; energy efficient *new* housing (as opposed to considerations of how to adapt *existing* dwellings); and individual buildings (as opposed to clusters of buildings or neighbourhoods). While research, policy and guidance in all these facets of climate change are essential, the omission of a clear conceptual and practical basis upon which to adapt suburbs is a significant problem [10].

The purpose of this paper is to set out the conditions for, and challenges of, adapting English suburbs for climate change. The paper focuses on changes to the physical environment (built and natural). It acknowledges that the sustainability of suburbs is dependent on a host of behavioural, social, environmental and economic conditions, and that a number of future scenarios might play out [12–14]. But it argues that the physical environment of English suburbs will need to be adapted if they are to continue to provide comfortable living space for the majority of the population in the future. However, these physical changes need to be viewed within the context of wider factors affecting suburban sustainability. This position is in contrast to much thinking in suburban studies internationally (particularly in Australia and the USA), which predicts 'the death of the suburbs', given their relative resource-intensive nature and inability to decouple from car-reliance in the face of peak oil [15]. In England, suburbs are less expansive and sprawling than their American and Australian counterparts, and need to be viewed as part of the solution for more sustainable futures, rather than places to be vilified or consigned to history.

The paper argues that English suburbs need to *respond to* climate change. Response in this context is '… any action taken by any region, nation, community or individual to tackle or manage environmental change, in anticipation of that change or after change has occurred.' [16]. Hence the paper addresses *mitigation* and *adaptation*, in the suburban setting, whilst accepting that achieving both simultaneously can raise issues of compatibility of solutions and differences in approaches, motivations and capacity.

1.1. The Suburban Neighbourhood Adaptation for a Changing Climate (SNACC) project

The paper presents findings from Phase 1 of the SNACC (Suburban Neighbourhood Adaptation for a Changing Climate) research project. These findings are largely conceptual in nature, with empirical results coming as the project progresses. The project seeks to answer the question: How can existing suburban neighbourhoods be *best* adapted to reduce further impacts of climate change and withstand ongoing changes? It will determine which neighbourhood adaptations perform 'best' against three criteria: *technical performance*, *practicality* and *acceptability* (as explained below).

SNACC adopts a socio-technical approach which involves establishing the performance of a number of potential adaptation and mitigation measures and testing their practicality and acceptability with a range of stakeholders likely to be involved in their implementation. It is seeking to understand which adaptation options are 'best' in different suburban contexts, and also the conditions in which they are likely to be implemented. The research methods are a combination of modelling, visualisations and stakeholder workshops. Phase 1 of the research has involved literature reviews, development of the models used in the project, and 'round table' meetings with English and international practitioners and policy makers. The next Phase involves fieldwork, which will be carried out in six case study suburbs in three cities (Oxford, Bristol and Stockport). The case studies are areas of approximately 150–200 dwellings, and each represents a different suburban typology (as explained below).

The *technical performance* of the measures will be assessed through modelling (for some measures) and by using existing data (for others). The project seeks to find out which adaptation measures 'work', i.e. do the job they were designed to do, be it, for example, cooling or allowing storm water to drain away, without negative impacts. The DECoRuM model will be used to assess the performance and cost of a number of adaptation options, at the individual home and neighbourhood scale. DECoRuM is a GIS-based bottom-up model for counting, costing and reducing energy-related CO_2 emissions. It will estimate CO_2 emissions for the dwellings in the case study suburbs, and evaluate the potential for (and financial costs and savings of) domestic CO_2 emission reductions from a range of adaptations [17,18]. For measures not assessed by DECoRuM the best available performance data from previous research will be used. These data will not be specific to our case studies but will give enough information on the performance of a wide range of measures to engage in meaningful dialogue with stakeholders. Much of this data will be gleaned from current projects funded under the Living With Environmental Change (LWEC) Programme [19].

To determine whether measures are *practical* (in terms of, for example, scale and cost) and *acceptable* to those implementing them, and affected by them (in terms of, for example, visual impact, effect on house prices, or compliance with planning policies or building regulations) a series of stakeholder workshops will be carried out. At these workshops, information on the types of adaptations' and their performance will be presented for each neighbourhood respectively. The set of adaptations available for consideration will vary between cases. A 'master list' of potential adaptations at the dwelling, garden and neighbourhood scales has been drawn up from a literature review. From this list, through a combination of expert review and modelling (see below) a suite of potential adaptation options that would assist mitigation and adaptation in each type of suburb is taken forward for further investigation by residents and other stakeholders. The stakeholders are given information on what each adaptation would achieve and also how much it would cost and any other potential impacts it might have (e.g. affect on house prices).

The neighbourhoods' adaptations will be shown to stakeholders in visualisations of a typical house, 'streetscapes' and the neighbourhood itself. These visualisations will be presented using a 3D Web-based technology. This tool is a modified version of the VEPs (Virtual Environmental Planning) system which has been replaced with GIS (MapInfo) generated 3D virtual environments ($\times$3d). Each 3D environment will contain 'before' and 'after' models of a neighbourhood that will provide stakeholders with an understanding of their neighbourhood as it is and after physical changes have been made. More precisely, photorealistic 3D models will assist the stakeholders to view, explore and assess the potential adaptations within their suburb [20] and as such assist in making an informed appraisal of their acceptability. The stakeholders will also be informed about the potential impact on house prices of

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making modifications to their home. This data will be provided from a hedonic model being developed as part of SNACC. The stakeholders will be both residents of the suburbs and other agents of change (local authorities, NGOs, utilities etc.). During this phase the project will explore with stakeholders:

- their experiences and attitudes towards climate change;
- their familiarity with a range of adaptation measures that could be effective 'technically' in their neighbourhood (i.e. we are not testing measures that are simply not viable, or necessary, in any given neighbourhood. For example, we are not testing attitudes to flood-resilience measures in neighbourhoods where there is minimal flood risk);
- whether they have (or would consider) implementing these measures, and their reasons for doing so; and
- if they would not consider implementing the measures, then what the key barriers and incentives might be.

The workshops will pinpoint practical and acceptable measures to adapt to and mitigate further climate change. They will also build up a picture of the factors affecting response capacity in suburbs.

As a foundation for this fieldwork phase of the study the existing conditions for, and challenges of, adapting England's suburbs need to be established. In order to do this, the paper first sets out a conceptual rationale of conditions for, and challenges of, suburban adaptation in three steps (A–C in Fig. 1), that build towards the fieldwork phase of the project 'step D' (Fig. 1). It discusses each of the three elements of the rationale in more detail, building up a knowledge base from which to identify and develop empirically tested adaptation measures, which are then validated by stakeholders.

2. Suburban adaptation: a conceptual rationale

Fig. 1 presents the conditions for, and challenges of adapting suburbs, which underpin the SNACC project's approach to the empirical work. It draws on several studies that have set out approaches to conceptualising adaptation and mitigation, for example Smit et al's [21] work on the 'anatomy of adaptation', Jones and Few's [22], analysis of community adaptation, and Tompkins and Adger's [16] analysis of response capacity.

Fig. 1 shows that the starting point is the realisation that England's suburbs will be affected by climate change for the foreseeable future (A, in Fig. 1). These impacts will be on both 'place' and 'people'. Places (homes, gardens, streets and open spaces) will be affected by, for example droughts, flood and storm damage. People

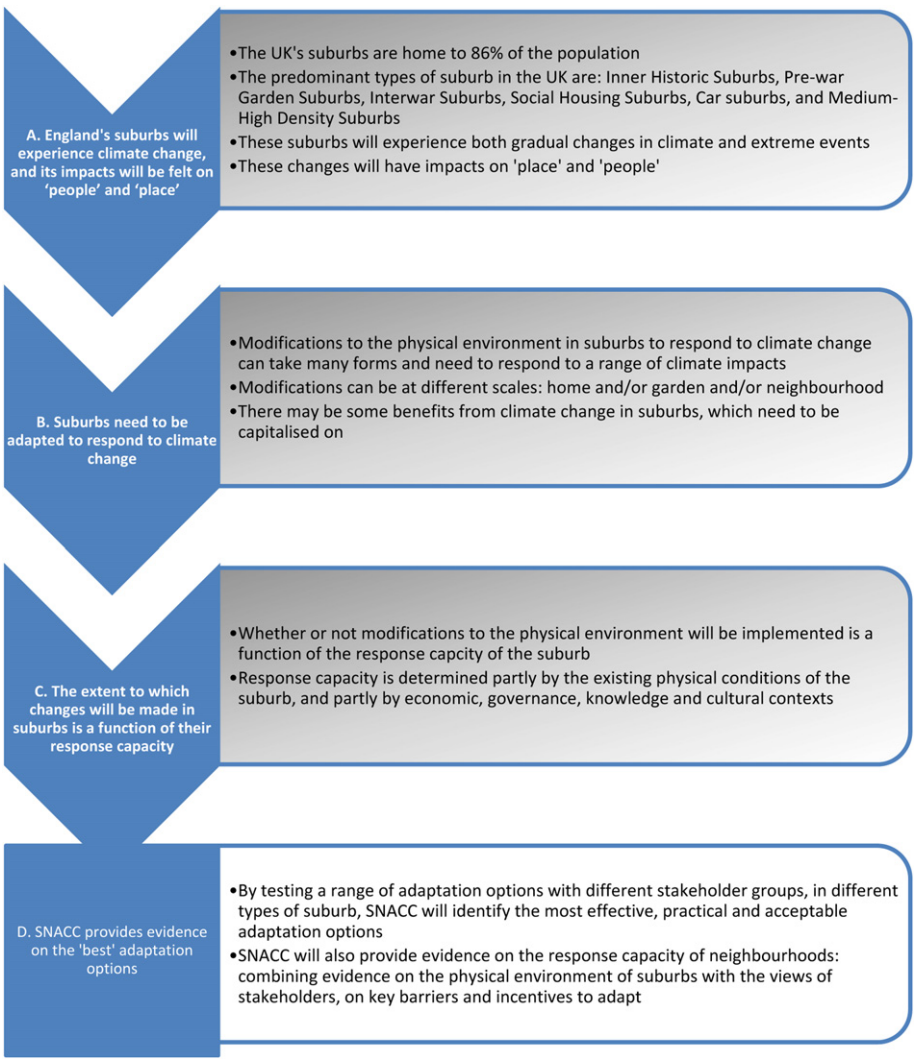

Fig. 1. Conceptual rationale for the conditions and challenges underlying suburban adaptation (shaded sections correspond with the main sections in the paper).

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will be affected through issues such as comfort, cost of damage to buildings, and health impacts. The impacts may be gradual (e.g. brought about by increases in summer temperatures) or the result of extreme events, such as floods and heat waves. In order to minimise future climate change, suburbs will also need to become less energy rich and reduce emissions.

To ensure suburbs are climate proof a range of measures to adapt the physical environment to cope with, and mitigate, future change could be employed (B, in Fig. 1). These measures range from small scale changes to homes, such as attaching shutters to external walls, to major remodelling and landscaping projects, such as introducing sustainable urban drainage systems. Different adaptation measures can be employed against different climate threats, and not all will be appropriate in all suburbs.

From this range of potential adaptation measures, the 'best' (see above) options need to be implemented if suburbs are to become resilient and liveable. Yet, the ability of agents of change within suburbs to make changes is a function of their 'response capacity' (C, in Fig. 1). Response capacities will vary depending on a number of factors. The existing location and nature of the physical environment will be significant, but the economic, governance, knowledge and cultural conditions are also likely to matter. Within these contexts, a number of potential stakeholders *could* be involved in making the required changes. Major players are likely to include residents, communities, landlords and local authorities. However, their reasons (including ability and motivation) for acting are likely to be complex, and form part of the response capacity.

The purpose of the project is to determine, from this contextual starting point, which adaptation measures are 'best' in different suburban contexts (D, in Fig. 1). It is also important to identify the conditions that might hinder or facilitate their implementation. This will be explored empirically during the fieldwork. This stage of work can only be undertaken with a detailed understanding of each of the underlying conditions, and the challenges and opportunities they raise (A, B and C in Fig. 1). Hence the remainder of this paper sets these out in more detail.

3. A. England's suburbs will experience climate change, and its impacts will be felt on 'place' and 'people'

3.1. A definition and typology of England's suburbs

In order to understand how best to adapt suburbs, it is important to determine precisely what a suburb is. However, this is not straightforward: as the RICS and CABE commented recently: 'One of the key challenges affecting our understanding of suburbia is the failure of definition and classification' [9]. Categorisations of suburbs have been developed in a number of disciplines including geography, demography, urban morphology, sociology and politics. Broadly, suburbs have been defined either by their physical characteristics (usually dominated by morphology, related to the era in which they were built, see for example [23]), or by the characteristics of their populations (socio-demographic, functional and socio-political typologies have been developed, for example by Bond and Insalaco [24]), or by characterisations of physical and social demographic criteria in combination [25]. Of course, critical studies have questioned these categorisations from a number of perspectives: Liebman [26], for example, argued against the convenient conceptual coupling of functional and political characteristics in American suburbs, and Peacock et al. [27] and Frey et al. [28] urge caution around simplified categorisations.

SNACC is adopting an overarching definition of 'a suburb', but has also devised a typology, based on *physical* characteristics (adapted from [23]). The project uses URBED and SEERA's definition of a suburb, which recognises both similarities and differences in characteristics [29]. This is presented in Fig. 2 below, with the left hand column showing the common elements and the right hand the key variations. It shows that England's suburbs are largely residential, peripheral (to the city centre), low density, owner-occupied and dominated by family housing. However, it highlights the differences in age, location, linkages, layouts, accessibility and so on. This definition emphasises physical characteristics, but includes some social elements (such as home ownership).

Some of the common characteristics in this Figure have been challenged by suburban scholars. For example: rather than being predominately residential, some suburbs are now very 'mixed' in terms of use [8]; some recently developed suburbs are medium-high density, rather than 'low' [30]; and some suburbs are inhabited by more retired households than families with children. However, at present, such cases remain exceptions and do not invalidate the definition. This said, future demographic and urban form trends will clearly make revisions necessary in years to come.

The typology of suburbs used in SNACC is shown in Fig. 3. It is adapted from Gwilliam et al. [23] who developed the categorisation based on built form and neighbourhood setting. Gwilliam et al.'s typology is the most widely cited in British suburban studies (e.g. [8,31–33]). The types of suburb identified are; historic inner suburb, planned suburb, suburban town, public transport suburb and car suburb. We have updated and slightly refined this typology to include: inner-historic suburb, pre-war 'garden suburb', interwar suburb, social housing suburb, car suburb and medium-high density suburb (partly after [32]). The addition of 'medium-high density suburbs' covers the policy-led trend for more intensive built form development since the mid 1990s. To assist in clarifying the typologies, photographs have also been added of each of the types described.

In using this typology it is also recognised that suburbs are not static environments: they are continually changing, and there are those who argue that many suburbs are now so 'mixed' in terms of building type that morphological typologies are redundant [25]. It

Characteristics in common	Important differences
• Predominantly residential areas • Towards the edge of towns and cities • Primarily favored by and for families • Serving an urban area(s) • Relatively low density housing • Mainly owner occupied • Often with green, public space • 'Detached' or semi-detached in terms of preferred living style	• Desirability and value • Age • Location • Access to public transport • Parking provision • Linkages with other places • Road layout e.g. extent of culs-de-sac • Access to (and quality of) services (schools, health facilities, shops) • Quality and quantity of open space

Source: [26]

Fig. 2. Defining characteristics of suburbs.

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Type	Characteristics	Era	Examples	
Inner Historic Suburb	Established terraced or semi-detached developments. These areas display mainly urban qualities, including high densities, a mix of uses, good pedestrian and public transport links	Victorian / Edwardian - up to 1919		
Pre-War 'Garden Suburb'	Medium-large semi and detached homes with large gardens. Former enclaves that have been absorbed by the town or city (usually successfully)	1900s-1930s		
'Interwar period':	Medium density, homogeneous speculative suburbs, usually semi-detached, in a closely structured urban fabric	1920s-1930s		
Social Housing Suburb	'Council Estates' with a mix of house types including detached and semi-detached houses, short terraces and medium rise blocks	1950-1970s		
Car Suburb	Low density, detached housing in homogenous house types. Developer–led, speculative suburbs, often located within 'open' townscape fringe areas including within close proximity to motorways, and out-of-town shopping centres. Sprawling suburbs, including culs-de-sac.	Late 1970s-2000s		
Medium - High Density Suburbs	Medium-high density, often with a mix of house types including town houses, detached and semi-detached houses, terraces and apartments. An outcome of the policy drive for more intensive development in urban extensions and within existing suburbs	Mid-1990s - present		

Fig. 3. Typology of English suburbs (adapted from Refs. [23] and [29]).

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is also the case that the 'non-physical' differences between suburbs, in terms of socio-economic and governance conditions are important, particularly in framing response capacity. However, as a basis for understanding the physical conditions of different suburbs, it is important to identify the predominant built forms present in England, and to test adaptation measures in these different settings (SNACC's 6 case study suburbs are representative of each of these types). Suburbs clearly do change from their original forms, but in most instances the original layouts and dwellings predominate, and it is these that adaptation solutions need to be found for.

3.2. Climate change impacts in suburbs: effects on 'place' and 'people'

England's suburbs will all experience climate change, and this section of the paper sets out the nature of these changes, and potential impacts. All areas of the UK are getting warmer, and the warming is greater in the summer than in winter. There is likely to be little change in total amount of precipitation (rain, hail, snow etc.) that falls annually, but more of it will fall in winter, with drier summers for much of the UK [2]. There will also be rises in sea level, with increased storm surges, which could affect coastal suburbs. As a result of these changes there are likely to be more extreme events, such as flooding and heat waves. Water scarcity (droughts) will also be more problematic in summer time.

Due to their proximity to central cities, and other aspects of the microclimate of built-up areas, many of these climate effects will be moderated in suburban areas. For example, they will experience the effects of the urban heat island, but to a lesser degree than city centres. They may also be cloudier and foggier than rural areas, and have less sunshine duration.

The potential impacts in suburbs are summarised in Fig. 4. This Figure complements de Wilde and Coley's Figure [4] to emphasise neighbourhood level effects. It shows potential impacts as a result of both gradual and extreme events, and the impacts are categorised as those affecting 'place' and 'people'. Only climatic impacts directly or indirectly related to the physical environment are included. For ease of communicating the impacts with stakeholders, SNACC has summarised them as 'summer' and 'winter' impacts (although accepting that this is an over-simplification that masks events such as summer flooding, and does not consider transition periods in spring and autumn).

Although the main climate change impacts in suburbs are likely to be negative, it is important to acknowledge that there could also be some benefits from climate change. However, capitalising on these opportunities may also require some modifications to the physical environment. For example, the hotter summers will prolong the growing season for certain fruit and vegetable crops, allowing suburban households with gardens to grow more of their own food: this may require setting more land aside for gardening. Warmer weather may also offer more opportunities for people to enjoy outdoor public and private spaces, if they are well designed. Warmer winters may benefit the 'fuel poor', if their homes are well insulated. Hence, it is important to factor in these opportunities for

Examples of expected climate change impacts in English suburbs[1]

Likely climate changes	Impacts on 'place'	Impacts on 'people'
'Summer' impacts (hotter and drier)	• Deterioration of green space, gardens, playing fields and public parks • Reduced air quality • Changes in biodiversity (although may allow a greater variety of garden crops and longer growing season) • Increased likelihood of subsidence due to soil shrinkage (particularly on clay soils) • Reduced design life of non-adapted buildings	• Reduced comfort: heat stroke, difficulty sleeping and carrying out general domestic activities (indoors and outside) • Reduced productivity (for home workers, employees in suburbs) • Increased respiratory problems • Reduced security due to use of natural ventilation • Increased costs related to building subsidence • Increased costs due to mechanical cooling • Water shortages: restrictions on domestic supplies and quality reduction
'Winter impacts' (slightly warmer, but wetter, with more storms)	• Flood damage • Storm damage to buildings, natural landscape and infrastructure • Increase in damp and mould	• Human impacts of flood damage: displacement, trauma, costs (worse for some groups, e.g. elderly people) • Increased costs of repairing flood and storm damage and maintaining homes • Investments in homes less stable after floods • Health problems linked to poorer indoor air quality: respiratory problems • May be cost saving on winter fuel

[1]: impacts related to sea level rise are not included

Fig. 4. Examples of expected climate change impacts in English suburbs.

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positive outcomes from inevitable change, as well as seeking to reduce negative impacts and mitigate further change.

4. B. Suburbs need to be adapted to respond to climate change

The previous section has set out the potential impacts of climate change in suburbs, and the argument that some form of modification needs to happen in order to ensure their future sustainability. Yet responses can take many forms.

Actions to *mitigate* further climate change focus on reducing CO^2 in suburban neighbourhoods. Household energy consumption is the main contributor, hence physical changes to homes to reduce energy need to be a key focus. Transport emissions are also a suburban problem, although the extent to which physical changes at the neighbourhood scale can reduce car use are questionable [34]. Research has shown extensive remodelling of urban route ways can reduce car use [31], but small-scale adaptations (such as reducing parking spaces or adding in cycle paths) have a more limited impact [35].

In terms of *adaptation* to the impacts of climate change, UKCIP (quoted in Ref. [36] after Ref. [37]) provide a useful characterisation of adaptation strategies which help to position the approach taken in SNACC. They argue that adaptations can take the following forms:

1. Share the cost of an impact;
2. Bare the cost;
3. Prevention of effects through structural/technological measures (e.g. adapting homes, gardens and neighbourhoods to cope with climate change impacts)
4. Prevention of effects through legislative, regulatory, policy measures;
5. Avoiding or exploiting changes in risk;
6. Research;
7. Education or behavioural change;

SNACC is concerned primarily with preventing the effects through 'structural/technological' measures (no.3). However, these physical measures (and those designed to mitigate further climate change) may also be conditional on legislative, policy or regulatory measures, research or behavioural change (4,6 and 7). Hence, although the focus is physical change, this can only be understood in a wider context of other related adaptation and mitigation strategies.

In addition, the specific nature of potential change in suburbs needs to be understood. Although suburbs change relatively slowly, incremental adaptations take place continually. Small scale changes, such as paving over drives, or adding extensions, can add up to significant modifications in built forms over periods of 20–30 years [25]. Suburbs are 'co-produced' over time by homeowners, communities, public bodies, private companies and third sector organisations. This can happen through *autonomous* adaptations, which are those done largely by private householders or companies for their own benefits [38]. Examples of such adaptations are planting trees to increase shading and improving passive ventilation. Change can also happen through *planned* adaptations, undertaken largely by public bodies, usually Local Authorities, for the public good [38]. Examples of this type of change include measures such as, providing additional public open space or installing Sustainable Urban Drainage Systems (SUDS). There are also changes which blur the distinctions between *autonomous* and *planned* and can be delivered through public-private coalitions where communities work in partnership with other agents of change for both individual and collective benefit.

A number of examples of adaptations being investigated in SNACC are shown in Fig. 5. These range from the scale of the individual home and garden (or private land around the home, including driveways), through to the neighbourhood scale (including streets, open spaces and other aspects of public realm). The adaptations chosen were drawn from a literature and policy review, and through engagement with practitioners and the project's advisory group. They are all relevant at the suburban neighbourhood scale, and they are the most widely citied and commonly advocated adaptations in climate change guidance and policy documents. The practicalities of the project meant that a potential 'master list' of potential adaptations had to be cut down to a manageable suite to take forward to be modelled and considered by stakeholders. Some key decisions were made: for example to exclude very large-scale infrastructure changes, such as flood defences and major remodelling of suburban road layouts (for example to reduce car use or incorporate public transport infrastructure) as these are beyond the general scope of the study (and are well researched elsewhere). It was also decided to omit adaptations relating specifically to sea level rises, as these relate only to a small proportion of suburbs, and require specific attention in their own right.

Clearly, not all of these measures are relevant in all suburbs. Part of SNACC's purpose is to explore which are more suitable in different types of neighbourhood, hence it is important to reiterate that we are not *advocating* these measures, merely presenting them as common options to be tested (and added to). These measures are also not likely to be required 'all at once', and any spatial adaptation is likely to be phased over a long period of time, and in response to different drivers. As Mendelsohn [38] states: 'the efficient response to climate change will often be a series of subtle changes over time. The problem can not be solved with a single one-time action.' He goes on to state that such a dynamic policy is particularly important in 'capital intensive sectors', which the suburban environment clearly is.

5. C. The extent to which changes will be made in suburbs is a function of their 'response capacity'

The adaptation of the suburban built environment is a function of the interplay between the physical characteristics of the neighbourhood and the host of stakeholders who own, shape and live in them. In order for agents of change within suburbs to respond to the impacts on place and people set out above they need to have a 'high' response capacity [16]. This has been described as a situation where '… there is a high degree of awareness of vulnerability/risk and the need for adaptive actions is recognised' (p.565). Coupled with the recognition of the need for change has to be the *ability* to act, in terms of available resources, technologies and knowledge. However, response capacity in most English suburbs is far from 'high'. While there is a growing uptake of some mitigation measures, and there is evidence that places that have experienced extreme events (such as floods) have implemented both autonomous and planned changes, by and large, very little in the way of climate proofing is happening on the ground.

Tompkins and Adger [16] argue that 'the path taken to reach "high response capacity" is determined by a much larger set of issues' (than just awareness and availability of technologies). This argument resonates well with the challenges of adapting suburbs where a multitude of conditions affect ability to respond. This section sets out some of the key factors that have been identified in Phase 1 to contribute to suburban response capacity. It deals firstly with the physical characteristics of suburbs, then turns to economic, governance, attitudinal, knowledge and cultural conditions.

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Built Environment scale/element	Examples of potential adaptation and/or mitigation options
NEIGHBOURHOOD	• Increase greenery: green infrastructure • Improve water/drainage features: install Sustainable Urban Drainage Systems • Install localised flood defences - to protect a single dwelling or group of dwellings in a neighbourhood • Restrict infill development on soils with good infiltration and flood plains • Adapt public amenities: add shade and storm protection to public buildings, bus stops, cycle paths etc. introduce community cool rooms • Replace pavements and roads with porous, 'cool' materials • Introduce infrastructure to encourage walking and cycling, reduce parking spaces, add cycle paths • Allocate communal land for food growing • Install community energy generating infrastructure • Install energy efficient street lighting
GARDEN	• Increase greenery: plant trees with large canopies and heat tolerant plants • Install water features • Install rainwater harvesting systems • Remove non-porous surfaces • Set aside space for food growing • Improve/maintain garden structures (fences, sheds etc. against storm damage)
HOME	• Regulate temperature: e.g. add external shutters, shades or canopies to walls, install solar shading, interpane glazing, solar film, install windows that lock open to aid ventilation, solar chimney or downdraught evaporative cooling towers, introduce thermal mass, add green/brown roof • Protect home from storms and floods: e.g. weatherproof doors, windows, walls, floors and roof; elevate entry thresholds, internal sockets and services; install air brick covers and flash flood doors • Improve air quality: e.g. use UV light or antimicrobial solutions to prevent mould, improve natural ventilation • Install water efficiency systems (e.g. grey water recycling) • Mitigate against further climate change: e.g. insulate walls and lofts, draft proof homes, introduce micro CHP, ground source heat pumps, solar PV and water heating

Fig. 5. Potential climate change adaptation and mitigation options in suburbs.

5.1. The existing physical characteristics of the suburb

The extent to which a suburb can respond to climate change will be determined partly by its existing physical form. The extent of green space, building mass and density, the amount and distribution of space around buildings, construction materials and so on will all matter. For example, low-density suburbs with a lot of green space may cope better with high levels of precipitation, whereas suburbs with less permeable surfaces may be more likely to flood. The type of soil in a suburb and its roofscape will also affect drainage and runoff. Hence the 'response capacity' of any given setting will be conditioned by the range of natural and built environment characteristics that the neighbourhood is 'starting with'.

5.2. Economic conditions

The costs and economic impacts of climate change are likely to be significant elements affecting response capacity. In simple terms, the more economic resources available to stakeholders (residents, local authorities, NGOs, businesses etc.) the greater their capacity to make potentially costly changes may be. Whether they choose to use these resources for adaptation is a broader issue. For private residents, economic questions about adaptations are complex: how much will the change cost? Will it save money in the long term (for example, will it reduce fuel bills)? Will a small outgoing now prevent a larger cost in the future (for example, in the case of maintenance against storms, or small scale measures to prevent flooding)? In addition, homeowners also need to consider if making changes (or not making them) will affect the market value of their home. Also factored in will be the impacts of acting (or not) on the costs of insurance, or, indeed, the ability to gain insurance at all [39]. For other stakeholders (particularly local authorities) resource constraints mean that decisions are always made in the context of regulatory obligations around risk, which often mean immediate climate change problems (such as flooding) are addressed, but spending on less 'urgent' (but important) issues is postponed.

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5.3. Governance context

Arguably, the governance context of suburbs areas makes them poorly equipped to respond to climate change, on anything but an individualised, autonomous basis. Suburbs are not recognised as a spatial focus in planning or climate change policy terms, so it is difficult to define where collective responsibilities lie for their adaptation. They are places with little or no integrated management. The concept of territorial governance that most closely relates to the suburb is that of the 'neighbourhood' [40,41] which is also ill-defined [42]. The problem of achieving collective action in neighbourhoods is summed up by Hajer [43], quoted in Smith and Hopkins [41], who describes neighbourhoods as places where there are 'no generally accepted rules and norms according to which policy making and politics is to be conducted'. The current emphasis in English planning on Neighbourhood Plans may assist in building governance capacity in some neighbourhoods and this may also prove an opportunity for suburban stakeholders, including residents, to act collectively to adapt their neighbourhoods. However, the 'suburb' as a territorial locus for enabling change in the built environment remains nebulous and problematic, especially during periods of austerity.

5.4. Differing knowledge of, and attitudes to, climate change (and its risks)

Stakeholders' knowledge and experience of climate change, and their attitudes towards it, are likely to affect whether or not they respond to it. For autonomous adaptations, residents' personal values and their own experiences of floods, overheating etc. will come into play. But recent research found that suburban residents knew less about climate change than their 'big city' or rural counterparts [44]. In addition, collective decision making is also difficult: the nature of climate change adaptation itself makes it problematic. Differences in views about the extent and impacts of climate change, and about the relative importance of adapting, or the means of doing it, are likely to be voiced [45]. As Few et al. argue, '… when stakeholders need to make decisions about anticipatory interventions, around "vague" long-term changes with low immediate impacts the chances of consensus are slim.' [45]. In addition, they point out that formulating adaptation responses can be particularly problematic where adaptation might imply high costs or radical alterations [45]: both of which could apply to suburban change.

5.5. Cultural context

Many suburban scholars have argued that suburbs have their own culture, which is characterised by the primacy of stability and resistance to change. Hence any response to climate change that requires significant modifications of the built environment is likely to be resisted. Gwilliam et al. [23] state that 'the predominant character of suburban communities (is) a wariness of change, with that change usually being perceived as a threat.' Research for the Urban Task Force, in 2002, found that most people have a combination of 'urban' and 'suburban' aspirations. Their 'urban side' desires life, diversity, convenience and excitement while their 'suburban' alter-egos crave peace and quiet, greenery, safety and privacy. Importantly suburban homes provide the setting for these more 'private' aspirations to be realised [31].

The drive by many English suburbanites to have their neighbourhoods designated as Conservation Areas is also testament to their desire to preserve the status quo. Many suburbs have extremely high aesthetic qualities, and are valued for their historic buildings and streetscapes, and, understandably, almost any changes to buildings or the public realm are viewed negatively [46]. Additionally, suburbs are also often places where residents feel and value a sense of propriety and control [47]. In this context proposed changes to homes and neighbourhoods are often viewed as direct threats to residents' rights. This point is made by Lomas [48] when discussing decarbonising housing. He states that '… effecting change in democracies where private home ownership is high requires the consent of homeowners, and there are a myriad reasons why they may resist interventions in what they see as their domain.'

6. Conclusions

This paper has set out the conditions for, and challenges of, adapting suburbs in England. It has presented a typology of suburbs, and an analysis of potential impacts. It has also identified a range of measures that could be implemented to mitigate and adapt to climate change. It has highlighted some of the conditions that underlie the response capacity in suburbs, and revealed the complexity of attempting to 'climate proof' the most stable and valued parts of the English urban landscape.

In presenting some of the detail of the SNACC project, the paper has also highlighted the tensions, and the value, of socio-technical studies of climate change adaptation. The mix of methods (modelling, visualisations and discursive workshops) and discourses provide conceptual and practical challenges, but also allow for a 'real world' assessment of the 'best' adaptation solutions, and investigation of the barriers and incentives of change in suburbs. There will not be a 'one size fits all' solution that works for all suburbs, but rather a range of multiple pathways to climate proof neighbourhoods [49].

In developing the knowledge base around the underlying conditions for suburban adaptation, a simple, key message, must not be overlooked. For any change to happen, and for the stakeholders to be in favour, it must been seen as an 'improvement'. This paper has presented many challenges to change, but has also identified some opportunities for 'climate proofing' to be seen in a positive light. The best solutions for suburbs will reduce risks and improve liveability for residents. Where such changes can be incorporated into regeneration schemes, ongoing maintenance, greening initiatives and so on the chances of them being welcomed are higher. As Falk states: 'Creating sustainable suburbia should not abandon the principles on which the best suburbs are founded' [50].

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