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The future of the urban environment and ecosystem services in the UK

Future of cities: working paper

Foresight, Government Office for Science

The future of the urban environment and ecosystem services in the UK

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October 2015

This review has been commissioned as part of the UK government's Foresight Future of Cities project. The views expressed do not represent policy of any government or organisation.

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Foreword

The Future of Cities project is informed by working papers which are commissioned by the Lead Expert Group and written by authors from academia and industry.

These papers highlight the key challenges and opportunities facing cities in the UK out to 2065. The Expert Group will draw upon this evidence base to develop project outputs which will be published in 2014 and 2015.

These outputs will aim to inform near-term policy making in both local and central government, which achieves desirable long-term outcomes for UK cities.

Professor Sir Alan Wilson

Acknowledgements

While this paper is a single author production, it aims to build on the expertise of many. In particular the comments on previous drafts of this paper from anonymous reviewers have been invaluable. Also I would acknowledge the contributions since 1999 of the members of the Centre for Urban Resilience and Energy (formerly, Centre for Urban and Regional Ecology), colleagues in the School of Environment, Education and Development, at the University of Manchester, and colleagues at the Manchester Institute of Innovation Research.

A note to colleagues in Wales, Scotland and Northern Ireland: apologies that most of the accessible spatial datasets cover only England, thus leaving out the UK's other half. Hopefully a more comprehensive study in the near future will redress this balance.

Abstract

Cities in the UK are dependent on ecosystems and their 'services' to society and the economy. These services include provision of physical resources, urban climate and environment, urban greenspace and biodiversity, and downstream assimilation of pollution and waste. Ecosystem services have recently emerged as a policy priority, and there are now methods and tools for stakeholder collaboration, spatial planning, economic valuation and payment schemes, and information technologies. In the future, changes in the UK city systems and 'system of cities' will cause – and be caused by – changes in urban ecosystems and their services. There are many aspirational models for sustainable cities or 'resilient cities', but these have to fit with current realities and projections, both positive and negative.

Overall this paper explores the interactions of UK cities and urban systems with ecosystems and the 'services' they provide, with a particular focus on the future. On the urban side we take a multi-scale approach, from neighborhoods, urban fringes and peri-urban areas, up to the UK system of cities. For ecosystems services, we follow the definitions of the UK National Ecosystems Assessment, 2011 (NAE) ('socio-cultural, provisioning, regulating and supporting'). Then we analyse the urban-ecosystem interactions within four broad domains: ecosystems **within** the city; ecological flows **through** the city; location types **around** the wider city-region; and ecology-related human systems **for** the city. This is a complex task with generally patchy evidence. The paper therefore follows a method designed for such tasks, in the form of the 'Synergy Foresight' approach.

This first takes an overview, or 'landscape mapping', of the state of the art in urban-ecosystem interactions. Then follows a 'change mapping', with analysis of trends, projections and alternative scenarios. Thirdly we explore deeper challenges, system transitions, and synergistic risks and/or opportunities. Finally comes a discussion of 'future-proofed' policy responses, pathways, methods and tools, which are suited to the complex challenges of urban ecosystems.

Executive summary

1. Aims and methods

This working paper looks at the interactions of UK cities and urban systems with ecosystems and the ‘services’ they provide, with the main focus on the future. As part of a set of papers commissioned by the Foresight Future of Cities project, this one links in particular to the working paper on ‘Urban Metabolism’, which focuses on energy and material flows.

Overall, on the **urban side** we take a multi-scale approach, from neighborhoods, urban fringes and peri-urban areas, up to the UK system of cities. On the **ecosystems services** side, we follow the definitions of the UK National Ecosystems Assessment, (i.e. ‘socio-cultural, provisioning, regulating and supporting’) (NEA, 2011). Then we analyse the urban- ecosystem services (ESS) interactions in four broad domains: ESS **within** the city; spatial ESS patterns **around** the wider city-region; ESS and physical flows **through** the city, such as food, water, energy and materials; and ecology-related human systems **for** the city. In each of these domains, the policy agenda is currently framed as the **‘Ecosystems Approach’**, as promoted in the UK by Defra (Department for Environment, Food and Rural Affairs) and its partners (Defra, 2007). However, in order to achieve this, this paper recommends a combined ‘Eco-Urban Systems Approach’.

In terms of methodology, we follow the general foresight approach, where the future is not only an issue for technical forecasts, but a space of potential transformation. The method includes baseline studies, trends and projections, alternative scenarios, goals and transitions, and road-maps and strategies. The overall result is a set of pathways for urban-ecosystem interactions, which as far as possible are systematically ‘future-proofed’.

The scope covers all cities and settlements in the UK, with some reference to the international context. For the baseline evidence, the primary source is the Urban Chapter of the UK NEA (Davies et al, 2011): but, as this readily admits, most of the available data is patchy and uncoordinated. The timescale covers an approximate 50 year span to 2065. As this is beyond most forms of projection or forecast, it can only illustrate the potential for structural change.

We use the abbreviation ‘urban ESS’ for ‘urban ecosystem services’: definitions are reviewed in the next chapter. Overall this section is a brief summary, and full citations are in the main text to follow.

2. State of the art: landscape mapping

Most forms of ecosystem **within** the typical UK city have improved over the last 50 years, including habitats and micro-climates, greenspace and green infrastructure, air quality, water quality, and land contamination. However, risks continue to be generated by urban development and infrastructure, increased urban densities, exotic and invasive species, soil degradation, and climate-related flood, storm, heat and drought. Air pollution and waste generation both continue at levels which are deemed unacceptable. There are economic risks in the lack of public funding for investment and maintenance, and political risks in reduced public access to privatised space.

The domain '**around'** the city refers to the various spatial layers between city centres and rural hinterlands. Here, there have been recent improvements with access to rights of way and country parks for example. There are also increasing risks from climate change-related flood, heat, storm, drought and sea-level rise. Green Belts are the first line of defence against urban development and speculation on land values, but are under pressure from housing and commercial development. Intensive agriculture in some areas also undermines the 'green' qualities of the Green Belt. Meanwhile large areas of hinterland are now effectively urbanized or urbanizing in many social and economic functions, and it is debatable whether these areas, along with their ecosystems, are in fact urban (Piorr et al, 2011).

For ecological flows **through** the city, i.e. energy and material resources, the picture is mixed. Improvements in the efficiency of buildings, transport and industry are often outweighed by growing demand for energy, water, construction materials, and the general flow of globalised consumer goods. While most of these 'provisioning' services are external to urban areas, responses such as local recycling, food cultivation or energy efficiency can be more localised. In practice, many cities have low-carbon or 'climate-proof' goals, but lack the political powers, resources and know-how to achieve them. Many organisations and many citizens are in a state of 'dissonance', where their low-carbon aspirations seem to conflict with high-carbon activities such as travel and shopping.

Regarding **'ecosystems for the city'**, the UK is on a learning curve. Integrated systems for industrial ecology are making progress, through schemes such as the National Industrial Symbiosis Program, but these are still in the minority. Eco-design and eco-investment are slowly gaining ground. Political ecology and social ecology principles are often not well-formed, but show up in ad-hoc protest movements. At present, the most topical of these is the 'Fractivism' opposition to 'hydraulic rock fracturing' which is contentious in many countries including the UK.

The context here is the UK **system of cities**, in both the spatial arrangement of settlements, and the underlying socio-economic interactions. The first issue is the dominance of London and the greater Southeast. Continuing the trends of growth and agglomeration would then have major effects on urban ecosystems across southern England. Urban growth areas would see intensification, densification, gentrification and over-development, which are likely to result in further habitat loss and more extended supply chains for energy, water, waste, biomass and minerals. In contrast, areas of urban decline in the Midlands and North could see increases in derelict and vacant land. This raises social and economic problems, but it can also bring new opportunities for localised ecosystems and urban biodiversity.

3. Future scenarios: change mapping

There are many possibilities for ESS within, around and through the city, for both 25 and 50 year horizons. These are summed up in a set of 'urban-ecosystems-services scenarios' (with a scheme based on the IPCC global Special Report on Emissions Scenarios). It is important to note that there is no 'central' forecast or BAU ('Business as Usual') scenario; the four alternatives shown here are simple caricatures, whereas reality would of course be more complex. Each scenario can be illustrated with a different urban 'model' from around the world, as follows:

- **Technology urbanist scenario** (Singapore model): 'smart' climate controlled sealed buildings are the norm, as environmental hazards and social divisions increase, food, water, and energy etc come through hi-tech centralised systems, and urban greenspace which is not developed is generally privatised and intensively managed.

- **Technology hinterland scenario** (Los Angeles model): car-based land-extensive urban sprawl: many local ecosystems are destroyed or degraded, or turned into private leisure, golf courses and high-value tourism. Food, energy and water are imported over large distances, by privatised utilities according to the global market logic.
- **Ecological urbanist scenario** (Freiburg model): this can be low-tech and/or hi-tech / 'smart'. The classic 'sustainable urban form' with dense, mixed use urban forms: greenspace is used and managed intensively, increased resilience to climate and other environmental hazards, and urban ecosystems are designed around social quality of life factors.
- **Ecological hinterland scenario** (Greater Stockholm model): many households relocate to peri-urban and rural areas, to be in closer contact with nature and to produce local food, energy, natural materials etc, and local economies are revitalised and better connected with local ecosystems, with alternative forms of ownership and management.

4. Challenges and transitions: synergy mapping

This stage is more exploratory of critical perspectives and bigger pictures. First we look for ESS-related social-economic challenges, such as demographic change, changing natures of work, and new patterns of physical and mental health. There are political and cultural challenges, such as the privatisation of space, distrust in governance, and environmental justice conflicts. This leads to a wider view on 'transitions' and 'discourses': here are some of the most topical, with their implications for urban ESS:

- 'resilient city': ESS will aim at capacity to withstand / adapt to physical pressures;
- 'liveable city': ESS will aim towards social and cultural benefits;
- 'smart city': ESS can be enabled by digital technology;
- 'transition towns': ESS can enable 'descent' towards low / zero carbon performance;
- 'circular economy': ESS will be geared to material recirculation and zero waste; and
- 'sustainable community' or neighbourhood: ESS will aim towards meeting the needs of the present and the future, locally as far as possible (in this very loose definition).

Each of these is a bundle of goals, aspirations, perceptions, visions or strategies, which are often quite fuzzy, but no less significant. Each is relevant to the question of 'goals', i.e. 'what should policy try to achieve?' Without prejudice to the policy process, here we sketch some interim goals, based on the above propositions:

- goals for ESS **within** the city: to sustain local ESS to meet the needs of the city (environmental / social / economic) and to sustain the city to meet the needs of the ESS;
- goals for ESS **around** the city include: to sustain ESS in each location, and the interactions between them, so that the whole city system can meet the sustainability goals above (at local, city-region, national and global levels);

- goals for ESS **through** the city include: to sustain the ESS flows to meet the needs of the city and to sustain the city for sustainable ESS flows (at local, city-region, national and global levels); and
- goals for ESS **for** the city include: to promote ecological principles and practice in all sectors, (industrial ecology, social ecology, political ecology, ecological design etc), to enable the above goals.

Each of these stretches in some way the current status quo, and calls for new ways of thinking and collaborating. The principles of the Ecosystems Approach also call for new ways, not only in ecosystems but in the social, economic and other systems which impact on them. So the 'synergy mapping' here looks for opportunities for innovation, and current signals of change, in each broad sector.

In the **social sector**, there are emerging multi-sector stakeholder partnerships, focused on social inclusion and participation. In the **technology sector** there are socio-technical systems which are not only smart but 'wise'. In the **economic sector**, there is a shift from ESS as mono-functional commodities, to 'relationships', where a 'circular economy' is not only about materials and recycling, but a circular flow of finance, business value and social value. In the **governance sector** we look for signs of more integrated and intelligent governance, more responsive to the complex needs of communities and cultures.

5. Responses and policies: pathway mapping

From these challenges, transitions, goals and synergistic opportunities above, we developed some future-proofed pathways (i.e. 'success scenarios'). Again, these can be tracked to each of the four ESS domains.

For ESS **within** the city, there are opportunities in community greenspace and food cultivation, and benefits in health, education and local enterprise. Creative adaptation to climate change is a new agenda for the interactions of humans and ecosystems. The principal threat may be the privatisation and enclosure of public and ESS space (just as in the 18th century). The response is in new systems of access, stewardship and investment for such spaces.

For ESS **around** the city, there are opportunities in wider patterns of green infrastructure. These include local food supply chains, climate change adaptation to floods, heat and drought, and invasive species. New settlement forms may see new kinds of interaction between humans and ecosystems, as in 'Eco-belts', forest gardens, water parks, outdoor schools, community orchards, co-eco-housing, and so on. The main threats to ESS may be direct pressure for development, or related problems caused by policy restrictions.

For ESS **through** the city, there are growing policy pressures to move towards the low-carbon, zero-waste type of city system. Achieving these physical goals is technically feasible for the most part, but is likely to involve similar changes in economic, social and political systems. The current direction is towards 'smart' digitally enabled cities, however this may bring its own risks and unintended consequences. There is now much discussion of urban 'resilience', which may have a narrow technical definition, or something rather wider and possibly more effective.

In ESS **for** the city, there are many opportunities in industrial, social and political ecological thinking. Industrial ecology aims towards a circular economy or bio-economy. For instance, characteristics can include integrated systems of algae bio-mass, materials recycling, ecological habitat and micro-climate management. There are opportunities in social ecology, for example where urban food growing can promote education and health, community cohesion, social enterprise and resilience. Urban political ecology is also relevant where ESS enhancement promotes empowerment, inclusion and public participation in the neighborhood or the city.

For the UK **system of cities**, it is clear that many ecosystems qualities depend on the pattern of development, in the context of population and housing growth. However the crucial factor is about **how** development happens, not only **where** or **how much**. The ecosystems opportunities above seem to depend not only on technical ingenuity, but also on the crucial factors of social learning, creative collaboration, community mobilisation, and wider thinking on social / political ecology.

If London and other city centres continue to increase urban densities, new and exciting forms of urban-eco-systems could emerge. Some possibilities include green roofs and living walls, elevated walkways and cycle ways, vertical gardening and aquaponics, semi-enclosed micro-climates in public spaces and atriums, bio-mimicry on urban rivers and waterfronts, and creative landscapes for climate adaptation. In many urban forms there is potential for ordinary dwellings to host diverse ecological habitats, with integrated breathing walls, passivhaus-type conservatories, flow-form waterfalls, rare species nests, and generally with eco-design embedded in the low-carbon re-engineering of the building stock.

In a wider context the international perspective is important. Globally, cities are now the primary hubs of resource depletion, climate emissions and impacts, and ecological degradation. They are also the hubs of potential innovation, investment and exchange. Many cities overseas are keen to learn from the UK, as the world's first industrial and urbanised nation. Likewise, the UK has much to learn from others in new or old forms of ecological wisdom, integrated planning, circular economies and community empowerment.

6. Recommendations

Finally we propose a set of recommendations, for each of the four urban ESS domains. These are aimed at policy-makers, but would also involve business, NGOs and others. A full set is in the conclusions of the main study, so here is a summary:

- **Urban ESS within the city**. This is the basic portfolio of urban ESS, within built up areas. We should safeguard and enhance each of the ESS types: 'provisioning, regulating, supporting, and socio-cultural'. In practical terms, we should enhance green infrastructure: efficiency in energy, water and resource use, and social-ecological interactions and participation.
- **Urban ESS around the city**. This includes a range of location types around a wider city-region area. From city centres to rural hinterlands, we should promote multi-functional land use, community stewardship and reinvestment, reciprocity in local resources and assets, and integrated planning and management of landscapes, catchments, networks and other ESS features.
- **Urban ESS through the city**. We should promote sustainable integrated systems in each of the main infrastructures e.g. energy, water and waste. We should enable industrial ecology systems, eco-innovations, digital systems for energy and resource flows.

- **Urban ESS for the city**. A wider scope, to include all kinds of human activity with potential to follow ecological principles and applications. We should promote social ecology, industrial ecology, ecological finance, eco-design and political ecology.

1. Introduction

1.1 Context

Cities through history have grown and prospered by inter-dependency with their hinterland and natural resources, i.e. their ‘ecosystems’. These can be seen as providing ‘services’ to human societies and economies, and are thus framed as ‘Ecosystems Services’ (‘ESS’).

Water, for instance, is many things to many cities. It is an ecological habitat, a flood risk, a resource for food and energy, a transport mode, a regeneration waterfront, or a leisure and heritage asset. UK cities have been shaped around availability of water access by rivers and the sea, and access to water resources for households and industry. Water is therefore a key urban ESS, for each type of service – ‘provisioning, supporting, regulating and socio-cultural’ services. But for the future, it can’t be assumed that urban water needs will be met. Most housing demand is in areas of water shortage, climate change is projected to bring more droughts and floods, water transfer technology is costly, and the organisations involved are fragmented. Climate change is anticipated to cause major disruption to world food supplies, which in turn will impact on the UK’s farming system and its water needs. Similar questions are raised for most other kinds of ecosystems, and the ecological / material needs of cities, including soil, biodiversity, minerals, farming, forestry, fishing, energy, waste disposal and other needs.

The upshot is that securing the future of water and similar urban ESS requires not only technical projections but also a wider view on inter-connections, risks and opportunities, and a creative approach to collaboration and synergy between different actors and sectors. This is the essence of the Foresight approach, where the future is about not only technical forecasts, but spaces of potential for transformation.

To do this we can look at the baseline, the dynamics of change, the opportunities for transformation, and the responses which follow. The baseline here starts with the Millennium Ecosystems Assessment, and its UK application in the UK NAE (MEA, 2005: Davies et al, 2011). These define ecosystems services in four main types: direct ‘***provisioning’*** of resources and goods; ***‘socio-cultural’*** services for amenity, identity and quality of life; ‘***regulating’*** services which manage the effects of natural events such as floods; and ‘***supporting’*** services which are essential to human life, but less directly visible.

In reality these four types are only a starting point for a wider and more complex field of enquiry. This combines physical science with technical innovation, socio-economic linkages, policy implications, the uncertainty of the future, and the potential for social transformation. Some of these are involved in the current policy response to the challenge of ESS, the Ecosystems Approach (Defra, 2007. This has seen rapid progress but there is a long way to go.

Overall this paper faces a number of challenges. The future of cities and the future of ESS are inter-dependent; prospects on the local scale are inter-dependent with those on the global scale. There are widespread aspirations for ‘sustainable cities’ or ‘resilient cities’, which are green, compact, low carbon and so on, but there are barriers and countervailing forces. If the future is likely to be ‘more of the same’ then the responses are also a known territory. However, if the future brings surprises, tipping points or transitions, then the responses call for more creative thinking. This study aims to point at such possibilities.

1.1.1 Structure of this working paper

In this introduction, we first define the scope and objectives of this paper. We then look at concepts and definitions, of urban ecosystem services, of cities and the urban environment, and of the current response in the shape of the Ecosystems Approach. We review the current evidence base with its many gaps, and then outline the 'Synergy Foresight' methodology used throughout this Working Paper.

The next chapters follow the four-stage structure of the Synergy Foresight approach, using a series of analytical tables as the backbone. Chapter 2 sets out a 'landscape mapping' or a baseline for the various urban ESS types at a range of scales. Chapter 3 looks at the 'change mapping', with future trends and scenarios. Chapter 4 explores deeper questions, with a 'synergy mapping' of discourses and emerging opportunities. Chapter 5 brings these back towards practical action, with a 'pathway-mapping' focused on strategy and policy for a 'future-proofed' system of urban ESS. Chapter 6 provides a synthesis, along with international comparisons and key recommendations. The Annex contains further background information.

1.1.2 Limits of this working paper

This working paper, within limited resources, is NOT an encyclopaedia of the urban environment. Other sources provide that as far as possible (see the bibliography in the Annex). Within its limits, this paper is based on available evidence, but in reality, UK baseline data is patchy, time-series are lacking, and 'integrated models' of urban ecosystems are few. It is left to the professions to start a national mapping / analysis process, which in other countries is done by government (Wong et al, 2012). However, recent developments in geo-spatial data such as www.magic.gov.uk , and the INSPIRE programme, should begin to add up (Local Government Association, 2014). For the future, there are just a few demographic projections and climate change scenarios, and the rest is up for debate. It might appear that the UK is largely prosperous and stable with little change in sight, but the scale of change in the next 50 years could be equal to or greater than it has been previously.

Overall, in this kind of Foresight study, the technical evidence and modelling base is more or less absent, and more creative and anticipatory kinds of thinking are needed. So within the limits of this study, the author has attempted to 'join the dots', in what is inevitably a personal view, but one based on the best available evidence.

1.2 Scope and objectives of the study

Commissioned by the Future Foresight of Cities project to provide information on issues relating to the urban environment and ESS, the main purpose of this paper is to inform the overall program of the issues surrounding the urban environment and ESS. Its objectives are focused on four components that feed into the Foresight Future of Cities project:

1. ***providing pictures of the system of cities in the UK -*** an overview of the urban system and its environmental history and geography, its natural resources and a wide range of ESS issues;
2. ***considering the future of UK cities -*** with review of linkages from a range of future cities to future ESS, and from ESS back to cities, using as far as possible, trend projections and a scenario framework;

3. ***exploring the range of possible policies, for future liveability, resilience, sustainability and adaptability, in relation to economic stability / growth -*** similarly, explore the potential linkages from urban / economic / social policy, to ESS policy, and vice versa; and
4. ***reviewing the science of analysis and policy development -*** the analytical framework and evidence base points towards research themes and policy development opportunities.

The scope of potential issues is wide and could fill many reports. Here, the challenge is to focus on the crucial issues and key opportunities:

- what are the most critical factors in UK urban ESS? (for the present, and for 25 and 50 years ahead);
- what are the most critical linkages of urban ESS with other domains? (following the schema of 'social, technology, economic, environmental, policy, cultural');
- how could these change over time, with new structures, new problems or new opportunities emerging?;
- what are the implications of these problems / opportunities, for strategy and action by public policy? (also looking at business or civil society); and
- what are the implications for the evidence base, and for future research and innovation programs?

1.2.1 Four domains

The above are complex questions with many inter-connections. We approach these through defining four main ESS 'domains' (Douglas and Ravetz, 2011):

1. ESS **within** the city - urban green space / infrastructure, urban habitats, trees, vegetation and water, and urban micro-climates, all within the 'continuous built up area'. This is the 'urban broad habitat' as defined by the UK NEA and its urban chapter (Davies et al, 2011);
5. ecological zones and ESS **around** urban areas, including all spatial components of an extended city-region i.e. the urban fringe, peri-urban, catchments and hinterlands. This builds on many city-region studies, most recently the European PLUREL project (Piorr et al, 2011);
6. resource flows and ESS **through** the city, including farming and forestry, water and energy, minerals and aggregates, and control of flooding and extreme events. These issues are covered partly by the Foresight paper on 'Urban Metabolism', so here we look more at the links to ecological, spatial and urban dimensions; and
7. ESS **for** human systems - a wider set of activities which are involved directly or indirectly with ESS, such as industrial ecology, political ecology, ecological economics, eco-design, eco-innovation and others.

In reality these domains are simply different angles on a highly inter-connected system, as on the left side of Figure 1. For instance, the River Thames is a physical ecosystem directly **within** the city area, providing resources, habitats, social amenities, cultural value, micro-climates and so on (a). This has a spatial dimension **around** the city, as the river and its catchment in different locations have different functions within the inter-connected whole (b). The river also provides a flow of water for consumption, i.e. a service as it passes **through** London (c). Finally, managing the whole river system involves ecological thinking (i.e. the 'ecosystems approach') **for** the London system, with many parts including governance, urban planning, eco-design, industrial ecology and so on (d).

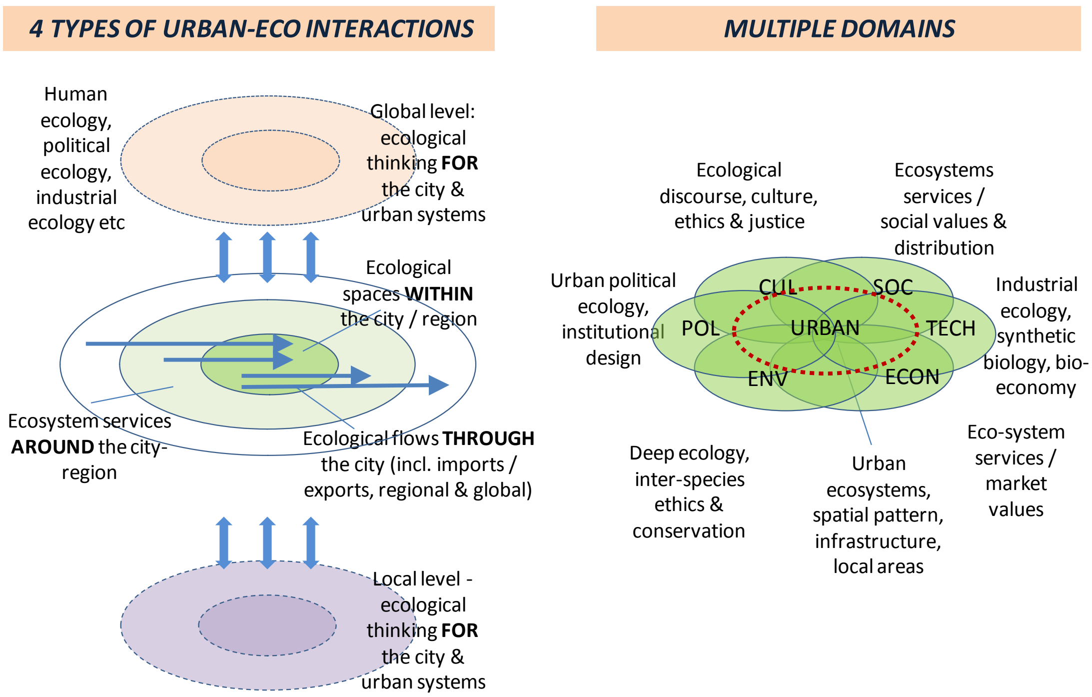
1.3 Key themes and concepts

1.3.1 Cities and ecosystems

The first question for this study is 'what is 'urban'?' 80% of the UK's population is concentrated on 9% of its land area (UK NEA 2011), but much of the rural hinterland is predominantly urban in social and economic structure (even in rural areas only 3% of the population works in farming). The study of urban ESS reinforces the view of a wider inter-dependency between built areas and their fringes, catchments, peri-urban and rural hinterlands. These categories may be changing rapidly. For instance, the European project PLUREL defined the 'peri-urban' with a density threshold of >35pp/ha. On this basis, most of England, and large parts of the remainder of the UK, are effectively peri-urban areas of low-medium density urbanisation, cutting across boundaries of administration and other functions (Piorr et al, 2011;Ravetz et al, 2013). The implication is that, in order to understand urban ESS, we need to look beyond the 'built-up boundary' to a wider view of urban activity systems and their hinterlands.

The second question is, 'what is an urban ecosystem, and what are its 'services'?' (Douglas and Ravetz, 2011; Defra, 2013: Gaston et al, 2013). According to Defra (2013), '*ecosystem services can be defined as services provided by the natural environment that benefit people'.* One way of unpacking this is to look at the interface of ecosystems with other domains and policy agendas, as on the right hand side of Figure 1. This shows an extension of the typical foresight 'STEEPV' layers (Loveridge, 2008), to form a larger 'STEEPCU': with broad sectors including the 'social, technical, economic, environmental, policy, cultural and urban'. Each of the circles overlaps or inter-connects, with possible tensions or conflicts, but also with potential for synergy and added value. This can also be framed as a 'human urban environment' which links physical environments / ecosystems to social, economic and other broad sectors (Roberts et al, 2009).

Figure 1: Urban ecosystems: scope and framework



The central concept of ESS here builds on established thinking, particularly the global Millennium Ecosystem Assessment (MEA, 2005) and its UK application, the UK NEA. These each recognise four main categories of ESS: 'supporting services, regulating services, provisioning services, cultural services' (Box 1). These categories are a starting point rather than an endpoint of analysis, which the UK NEA then applies these to eight types of 'broad habitat', of which 'urban' is one (Davies et al, 2011).

Box 1: Ecosystems Services definition: (from the Defra 2011 paper on Natural Capital)

Provisioning services: products from ecosystems, such as: food (crops, meat and dairy products, fish and honey); water (from rivers and also groundwater); fibre (timber and wool); and fuel (wood and biofuels).

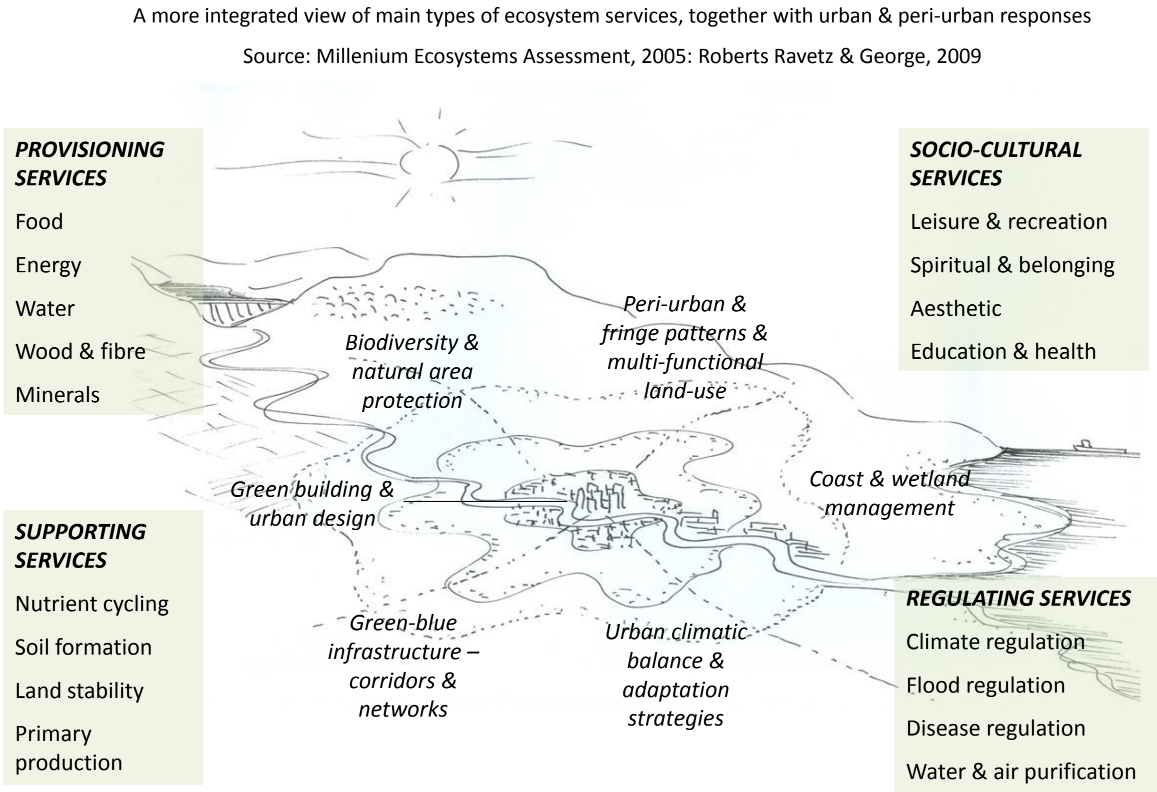
Regulating services: ecosystem processes, such as: pollination (of wild plants and cultivated crops and flowers); water purification (in wetlands and sustainable urban drainage schemes); climate regulation (through local cooling and carbon capture by trees); noise and air pollution reduction (by urban and surrounding vegetation); and flood hazard reduction (by floodplains and sustainable urban drainage).

Cultural services: non-material benefits from ecosystems, for example: through spiritual or religious enrichment, cultural heritage, recreation or aesthetic experience. Accessible green spaces provide recreation, and enhance health and social cohesion.

Supporting services: functions that are necessary for the production of all other ecosystem services, for example: soil formation (for example, in woodlands or in well managed allotments) and nutrient cycling (for example, soils breaking down animal waste).

The ESS concept leads directly to a range of policy and economic applications. Recent activity in the UK has focused on the Ecosystems Approach (Defra, 2007 and 2011). Economic applications are being developed in the international program 'The Economics of Ecosystems and Biodiversity' ('TEEB'), and there are also UK applications of Ecosystem Markets and 'Payment for Ecosystem Services'. (TEEB, 2010; Ecosystem Markets Task Force, 2013; Defra, 2013). The ESS concept is also a spatial concept, involving relationships, exchanges, flows and distributions between the ESS in different places, from local to urban, regional, national and global scales. These ESS types are sketched on a spatial basis, in a generic city-region, in Figure 2.

Figure 2: Urban ecosystems services: city-region perspective



1.3.2 Ecosystem services with complexity and co-evolution

However from experience, this ESS framework can be over-simplistic when working with complex, dynamic and inter-connected systems such as cities. For instance,

> "*if a community is vulnerable to flooding (as many are), we need to analyse the problem in terms of water, ecosystems, land use, climate change, flood policies etc. And then the agenda shifts to the question of 'so what?'.... We need to think about the community's technical resilience to extreme water events: its social resilience for working together in emergencies: and its economic resilience for investment before / after the event. Then we find that many communities in this age of austerity, are vulnerable not only to flooding, but to the whole combination of physical, social, cultural, economic, health and other pressures. So we have to look at these not just one by one, but a more system-wide picture of risks, vulnerabilities, and resilience of various kinds. Then we can look for system-wide changes through transitions, at the scale of city-regions or other social, economic or ecological units. And if we want these transitions to be deliberate rather than incidental, then we have to learn the art of collaboration and pathway forming in complex situations…*" (Ravetz, 2013b).

One example is the Irwell Country Park in a run-down area of North Manchester (Tippett et al, 2007 Ravetz, 2011). The ESS include amenity, health, flood alleviation, and local micro-climate. In social terms the area is perceived as a 'problem', with stolen cars, drug use and illegal waste tipping, and needing costly remediation to recover negative economic values. There are conflicts between dog walkers, bird-watchers, cyclists, land managers, security, the youth and the elderly. Then it emerges that creative social innovation has the potential to turn conflicts into collaboration, e.g. through schemes in local food, education, health, ecology, events, markets, cafes, playschemes. In other words the ESS and their socio-economic values are not fixed; they are more like potential opportunities which reflect creative collaboration and social innovation.

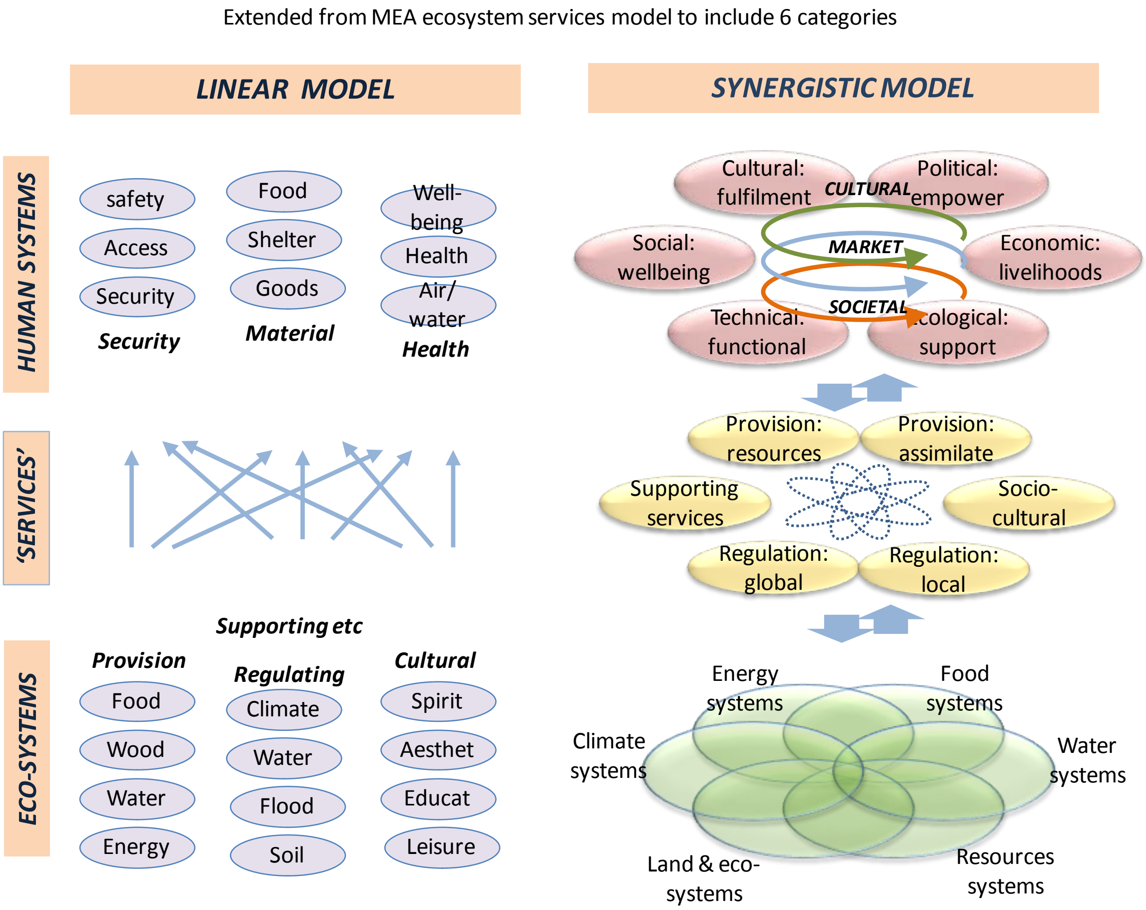
This and similar examples lead us to question the application of ESS. While the concept of ESS enables insight into human / ecosystem interactions, it might also squeeze real-life complexity on both sides into an over-simple functional frame. This is topical for the economic valuation of ecosystems, which can be problematic. For example, the UK NEA presents valuation figures with little indication of uncertainty or confidence (Bateman et al, 2011). Policy responses, such as the Ecosystems Approach, recognise the complexity of human and natural systems, and look at 'services' as a process of social learning and co-evolution. For instance, the farming community 'learns' how to work the land, while farmers and land use patterns co-evolve with markets, technologies and so on (Waltner-Toews et al, 2009).

We can visualise the shift from a linear concept of ESS, towards a more complex, emergent and synergistic model, as in Figure 3. This shows on the left a diagram based on the MEA, with checklists of human and ecological systems. A more synergistic model on the right hand side reflects the complexity of many inter-connections. The ecosystems in the lower right corner are inter-connected between energy, water and land. Here, the ESS are less like commodities and more like collaborative learning and value generation.

This provides a topical context for the economic valuation of ecosystems, as in TEEB, PES and many other variations (TEEB, 2010). For ESS with human benefits which are specific, tangible, tradable and substitutable, economic valuation and 'marketisation' can be relevant and useful. If other conditions are more significant, then a purely economic focus is not enough. Overall the implications are that with the capacity to learn, collaborate, innovate and strategise, value added and valuation can rise beyond that of a zero-sum game (Jacobs, 1997; Ravetz, 2015b).

The implications are topical for this study. As explored in Chapter 5, to protect and enhance the urban ESS in an uncertain future is more than a linear 'policy lever' type question, and more than a 'winner-takes-all' market type question. The real value-added is in the social learning, collaboration and synergy of all stakeholders (see the example in Chapter 5). This is the aspiration of the current focus on the Ecosystems Approach. The question is how to turn it into reality, not only for ecosystems but also for urban systems.

Figure 3: Ecosystems services: from linear to synergistic concepts



1.3.3 Scope and diversity of urban ecosystems services

The interactions of urban systems and ecosystems cover a wide range of human experiences, and the Foresight approach calls for a wide-ranging exploration. Here lies a challenge in attempting firstly to describe highly technical factors alongside social trends, political discourses, and ethical values, secondly in attempting to link the global and local dimensions, and lastly to describe issues which are dominated by controversy?

One approach is shown in Table 1 below, based on the STEEPCU domains (i.e. 'social, technical, economic, environmental, policy, cultural, urban', Loveridge, 2008). First, on the left side the 'global agendas provide a context and backdrop to UK issues. Here, technology change has globalised the supply chains of food, energy, and minerals, economic change has globalised finance and labour markets, environmental change has globalised climate change, and urban change has globalised the division of cities for basic production and consumption patterns.

Second, the 'discourses and narratives' column provides a variety of framings. For instance, urban ESS can be framed in a technical sense as land use and micro-climates. Meanwhile, on a cultural axis there is a 3000 year tradition of urban parks and gardens (Benton-Short, 2008; Dalley, 2013). In the social domain there is a strong discourse on local identity and cultural landscapes (Kaplan, 1995; Sandifera et al, 2015). However, in the political domain, a question arises regarding property rights, stewardship, and the meaning of the 'commons' and public realm (Kaika, 2005). In the technical domain we see the phrase 'green infrastructure', known in

Europe as ‘green-blue infrastructure’ (GBI) (Landscape Institute, 2013; Gill et al, 2007; Kazmierczak and Handley, 2013).

Third, the column of ‘conflicts and dilemmas’ brings up typical debates, tensions and controversies. For instance, parks and gardens might be framed as collective goods in the public realm, or they can be regarded as private property and investments. Flood defence might focus on concrete, or on community cohesion. Fourthly, the ‘localist’ agendas on the right hand column shows that urban ESS can be highly place-specific at the micro-scale; individual trees or hedges might enable or inhibit human interaction. In each of these exists the possibility of co-existence (e.g. public and private greenspace can co-exist in the same city), but overall there are competing pressures which shape the complexity and diversity of the urban ESS agenda.

Table 1: Scope and discourse of 'urban ecosystem services' by broad sector

	Global agendas	Discourses, frames, narratives	Conflicts and dilemmas	Local agendas
Social, community	Migration, demographics, human development, social change	Environmental justice, ethics, poverty: Social and community identity of place, habitats, food types:	Social / community needs **VS** market / economic development.	Local community and empowerment
Technology, infrastructure	Global supply chains for energy, food, materials etc	Green-blue infrastructure (GBI): political ecology of investment, access, allocation, price, markets	Local needs and values, **VS** larger scale infrastructure for city-region needs	Decentralized infrastructure for energy, water, food etc.
Economic, employment	Modernisation, globalisation, international division of labour	Economic / functionality, market logic, cost recovery: Framing of 'natural capital' and 'ecosystem services'	Functional services with cost-benefit implications: **VS** intangible non-functional relationships and values.	Local economic and micro-enterprise
Environment, ecology	Global climate change, environmental limits, new pollution pathways	Natural features: rivers, coasts, mountains etc: Natural hazards and human defence: flood, fire, drought, storm etc. Env sustainability, low-carbon etc	Hard defence against hazard, **VS** soft management or retreat: Environmental justice in distribution of risk, **VS** economic efficiency.	Local distinctive landscape ecology and habitat
Policy and institutions	Restructuring of governance, new urban-regional agendas: Geo-political tension: democracy under threat	Natural assets as public goods for stewardship Neoliberalism and privatisation of natural assets:	Rational management mode of policy, **VS** entrepreneurial deregulation	Local autonomy and self-determination
Cultural, ethical	Cultural diversity and tolerance, VS mono-culture and extremism	Environmental justice, ethics and conservation:	Culture of natural assets and wilderness: 'barbarism' **VS** 'salvation':	Local cultures and customs
Urban, spatial	Global urban system and divisions: rapid unplanned urbanisation	Urban parks and gardens as roots of human civilisation: Role of greenspace in of urban form and structure.	Urban parks and greenspace as public collective goods, **VS** commodities in age of privatisation and austerity	Village style urban forms and patterns
INTER-CONNECTIONS	Global 'wild cards': climate-related: economic or geo-political	'Sustainability' VS 'resilience' concepts	Areas of growth and activity **VS** areas of decline and dereliction	Local community and social innovation:

1.4 Evidence base and methodologies

1.4.1 Overview of state of the art

As above, and also spelled out in the urban chapter of the UK NEA, much of the evidence needed is patchy, out of date, and lacking theoretical analysis and applied models (Davies et al, 2011):

> "*The UK NEA Conceptual Framework (Chapter 2) acknowledges the value of the urban environment in providing ecosystem services by including urban as one of its eight broad habitats. Assessing urban habitats in the UK poses a number of challenges since they are not systematically monitored and the wide range of organisations collecting data often use inconsistent typology*".

For example the baseline assessment of urban greenspace in Chapter 2 struggles with different greenspace definitions, urban boundary units, ownership and use data, making an objective assessment of conditions and trends very difficult. Then, for futures evidence on projections and scenarios, or the analysis and modelling of policy options, there are not only quantitative uncertainties but qualitative 'indeterminacies' (Ravetz, 1998). Even the basics cannot be assumed: for example, while urban air quality statistics look impressive, there are ongoing arguments about the choice of monitoring sites, techniques, interpretation and interpolation, spatial mapping resolution, particle size and other determinants, epidemiological thresholds, confidence limits and robustness (Ricardo-AEA, 2014).

In some ways this is now changing rapidly. There are rapid developments, as above, through many kinds of 'big data' and 'open data' (Ravetz, 2009b). Current directions include:

- geo-spatial data with layering, analytic and interactive functions;
- remote sensing with wifi functionality, wearable monitoring and similar;
- satellite / aerial imaging with processing and analytics;
- geo-located social media, with feeds from twitter or Tumblr;
- citizen science, participative mapping and environmental monitoring;
- 'open data' principles for government and public agencies;
- transparency in corporate supply chains and policy evidence; and
- stakeholder processes which are digitally enabled or enhanced for greater capacity in deliberation, inclusion, diversity and participation.

However there are strong counter pressures. As urban infrastructure and many forms of ESS are privatised, vital data becomes confidential. The new Payment for Ecosystem Services partnerships will tend to obscure the data on commercial grounds. Where there is public data such as benchmarks or league tables, then target-focus, threshold fatigue and gaming may be the norm. As and when ESS are marketised (as is already the case with some forms of CO_2 emissions) every type of manipulation, asymmetry and speculation can be expected (Lohman, 2006).

There are also rising expectations. For example, climate adaptation policy should in principle forecast climate impacts 25-50 years from now, and connect these to projections of urban development, urban infrastructure, social lifestyles and so on. In reality each of these is surrounded by uncertainty, indeterminacy, controversy and conflict.

So we can say clearly that a better data and evidence base is urgently needed, both spatial and temporal, and for both urban and environmental sides. Better knowledge management is needed in terms of analysis, open access, visualisation and so on: and better processes are needed to enrich the evidence base, through stakeholder-based deliberation, participation and evaluation (Fish et al, 2011). All this forms one of the main recommendations in Chapter 6.

This technical evidence base is then part of a bigger picture. Following the discussion above of 'complexity and co-evolution', it appears that progress on the Ecosystems Approach needs more than an evidence base and its technical applications – it is as much about the human processes of turning information into learning, and learning into wisdom, to enable responses to complex and uncertain problems.

1.4.2 Existing methods for urban ESS analysis

A vital part of the evidence base is the use of methods and tools relevant to urban ESS – conceptual, technical and practical – which help focus research questions, gather data, analyse the results, and synthesise actions. Recent progress has come with the 'Tools: Applications Benefits and Linkages for Ecosystems' ('TABLES') project of the NEA Follow-On (Scott et al, 2014). This provides a toolkit for decision support or behaviour change in categories including futures; valuation; incentives; regulatory; ecosystem services and public engagement. For a wider context, below is a view of concepts and methods, on the lines of the STEEPCU format:

Social focus: social impact assessments and health impact assessments provide a first level of insight into the human side of the ESS (Birley, 2011). Social return on investment (SROI) and social innovation benchmarking aim to capture the creative process in the Ecosystems Approach. 'Social learning' looks at processes deliberation and collaboration in management of complex ecosystems (Rodela et al, 2012). The environmental psychology concept of 'affordances' is another way to frame these human-ecosystems interactions (Gibson, 1979). There are many linkages between ESS and human physical health (Sandifera et al, 2015; Berto, 2005).

Economic focus: ESS valuation methods and tools show a wide range of contingent valuation or hedonic pricing models. Recent developments include the program TEEB (The Economics of Ecosystems and Biodiversity), and the UK application PES (Payment for Ecosystem Services), as above (TEEB, 2010; Smith et al, 2013; Quick et al, 2013; Everard et al, 2011). The example of a ESS-PES approach is discussed in Chapter 5, and there are many critiques of the economic valuation framing of complex human-ESS interactions (Jacobs, 1997; Reed, 2013).

Environmental focus: for the physical metabolism side of ESS, material / energy flow analysis is a starting point for analysis and modeling. For indirect impacts, the 'footprint' approach continues to develop, now including carbon and water flows alongside the composite indicator of ecological footprint, at local and global levels (WWF, 2012).

Policy focus: The Ecosystems Approach is discussed in depth in Chapter 5, as a broad-based response to the challenges of enhancing and protecting ESS. As a flexible and inclusive way of working it combines many types of methods and tools. Multi-criteria decision analysis is a method which continues to be re-invented. One topical application involves highly uncertain and inter-dependent values and priorities (Munda, 2008). Institutional Analysis and Development is aimed at situations of collective management of common resources (Ostrom, 2005). Much environment-urban policy has revolved around impact assessment, appraisal and evaluation, where questions of cumulative effects, distribution of risk and uncertainty, and policy learning have been refined over several decades (George, 2013).

Cultural focus: methods of landscape assessment have developed in the context of 'cultural landscapes', i.e. those which support local identity, heritage, and time-depth. Concepts of local identity have then included questions of multi-cultural identity and diversity (Low et al, 2005; Rishbeth, 2001). A generation of eco-cultural-creative arts have burgeoned (in some countries) with woodland arts, outdoor performances, outdoor schools, walking philosophies and so on (Stine, 1997). There are also socio-cultural linkages from greenspace, allotments and urban parks to mental health and well-being, and the intangibles of 'sense of place' and/or 'local identity' (Kaplan, 1995; Rishbeth, 2001).

Generally the Ecosystems Approach has brought to the fore the local dimensions of place identity and the participative engagement of local communities (Defra, 2012). Methods such as 'planning for real' offer a hands-on interactive approach. Games such as 'Rufopoly', however, look at wider territories, together with many digital online platforms and experiments in community participation (Wates, 2014).

1.4.3 Comparator study from Natural England

The nearest UK comparator to this working paper (at the time of writing) is the study on *Greening of Urban Areas to 2060* (Cranfield and Natural England, 2014). This sees the pattern of urban development and infrastructure as driving climate change impacts and pressure on greenspace. It presents 21 insights that suggest 'what is changing and why', and then a series of questions such as 'what are the opportunities and risks to delivering green infrastructure?' and 'which are the priorities, and how we should respond now?' From expert and stakeholder consultation, it identifies further evidence and research needs.

This working paper by contrast is a more wide-ranging Foresight study, looking not only at greenspace **within** cities, but also at the ESS **through**, **around** and **for** urban systems. It explores the possibilities of multiple cause-effect chains, and it reviews the multiple layers of the baseline situation. It also explores drivers of change and alternative scenarios, develops key opportunities for transitions and responses, and outlines key elements of a roadmap.

1.4.4 Implications for methodology for this study

The general principle for this Working Paper is that the future is there not only to be projected; it is also to be anticipated and created by people and organisations with the capacity to think, learn, deliberate and innovate. The broad approach is to look for opportunities and synergies, between pressures and problems, projections and scenarios, and road-maps and strategies. This draws from the author's research on the sustainable city-region (Ravetz, 2000), and its evolution towards the 'synergistic city-region' (Ravetz, 2013a and 2013b). A practical method for exploring this has been developed as the Synergy Foresight method, which is similar in many ways to the thinking of the Ecosystems Knowledge Network (Carter and Kazmierczak, 2013). As outlined in the Annex, the Synergy Foresight follows a simple four-stage cycle:

- ***landscape mapping*** - a review of the conditions and trends on urban, ecosystems and socio-economic-technical factors;

- ***change mapping*** - exploration of a futures perspective on urban change: climate / ecosystems change and socio-economic change;
- ***synergy mapping*** - systematically developing the causal linkages and opportunities (functional, entrepreneurial, and cognitive, i.e. based on social learning and collaboration); and
- ***pathway/ road mapping*** – convergence towards practical action, strategic directions and policy responses.

These stages can be approached in various ways. These include the use of an interactive workshop process, flow charts and network diagrams; creative media; and a structured ‘morphological analysis’ based on a ‘family tree’ of analytical matrices. Here we follow the latter, which allows for a wide range of information to be collated and cross-linked in a systematic way. There are numerous matrices in the following chapters and Annex. These are not intended to be read line by line, but they do provide a reference framework and navigation aid for a complex field.

(Note the tables to follow are colour coded to aid navigation: faun colour = ESS ‘domains’, green = scenarios, blue = others.)

Overall this structured approach aims to contribute to and coordinate with other themes in the Future of Cities project.

2. Outlook and landscape mapping

This chapter is a 'landscape mapping' or baseline review: first on the structure and typology of the UK urban system: and then on the ESS 'within, around, and through' the city. We aim only to summarise what is covered in detail elsewhere, principally in the NEA.

2.1 Urban systems: state and outlook

The pattern of cities and city-regional territories, notably their internal structure and external linkage, are important for the urban ESS theme. Again, the evidence base is patchy, so we have to interpolate and extrapolate where needed.

In terms of area, more than 6.8% of the UK's land area is now classified as 'urban', with more than 10% of England, 1.9% of Scotland, 3.6% of Northern Ireland and 4.1% of Wales contributing to this 'habitat type' (Davies et al, 2011). The UK 'system of cities' is a concept as yet in search of an agreed definition; Figure 4 shows two contrasting maps of the UK space. On the right is the NW Europe 'spatial vision' key diagram, as used in the UK Spatial Development Framework (Wong, Turner and Ravetz, 2000). This shows around a dozen urban hubs of international significance, in relation to our neighbours. Underlying those are several layers, each with issues and opportunities.

2.1.1 London / Greater London

London is the global gateway and engine of the British economy. Its continued growth and intensification presents huge challenges for urban ESS at all levels. For instance, at the time of writing, developers won permission to build 5000 homes on a nature reserve of regional importance[1]. For ESS **within** the city, there are challenges presented by the growing conflict between greenspace and housing or other development land. For ESS **around** the city-region, there are major issues over the location of physical, social and economic infrastructure in the hinterland. For ESS **through** the city, London's mega-city metabolism shows both problems and opportunities on a massive scale. Further detail on London's climate change profile is in Revi et al (2014b), green infrastructure (Mayor of London, 2014), the urban metabolism in BioRegional (2009), and political ecology issues in Ginn and Francis (2014). At present there are ambitious proposals for a London National Park (Greater London National Park City Initiative, 2015). While the whole scheme would need massive investment, it is possible that just by changing the terms of debate and policy agenda, major improvements could result: some of the Pathways in Chapter 5 aim to contribute.

2.1.2 Rest of South East (ROSE)

The ROSE and the Home Counties is by far the most affluent and well-connected region, which for the most part enjoys a rich and diverse landscape. Again there is pressure of economic and urban growth, coupled with the current trends of social segregation, property inflation, and service privatisation. Landscape quality and ESS integrity is often high, but under pressure from development and infrastructure of all kinds, while water resources will be stressed in the face of climate change (see section 2.5 below).

[1] see www.theguardian.com/environment/2014/sep/25/-sp-nightingales-lodge-hill-sanctuary-conservation-britain

2.1.3 Industrial / post-industrial conurbations

These are seen in urban patterns of the Midlands and the North which evolved around the functions of the industrial revolution. With the post-war industrial restructuring, large spaces were left vacant, derelict and often polluted. This brought opportunities for urban ecological succession, with new uses for these spaces as country parks and industrial heritage sites (Nicholson-Lord, 1987). So for ESS **within** the city, greenspaces and GBI are an opportunity for regeneration of many kinds. For ESS **around** the city-region, areas of shrinkage and growth change the city-region development pattern. For ESS **through** the city, there is potential for new energy or resource systems, on supply or demand sides, to be generators of growth, employment and investment (Ravetz, 2000).

2.1.4 Market towns and coastal towns

These areas illustrate huge contrasts between affluent, high-growth 'shire towns', and declining ports, resorts, mining towns or remote market towns. Urban ESS are often abundant in adjacent rivers, coastlines, agricultural or natural areas. However, but such settlements are part of the national / global industrial system, often disconnected from local food or energy resources, encircled by industrial farming, and choked with congestion. For ESS **within**, greenspaces and GBI may be generators of community development. For ESS **around** the settlement, new connections can be made with surrounding areas. For ESS **through** the settlements, there are new opportunities for localised food, energy, water and forestry systems.

2.1.5 Remote rural areas and settlements

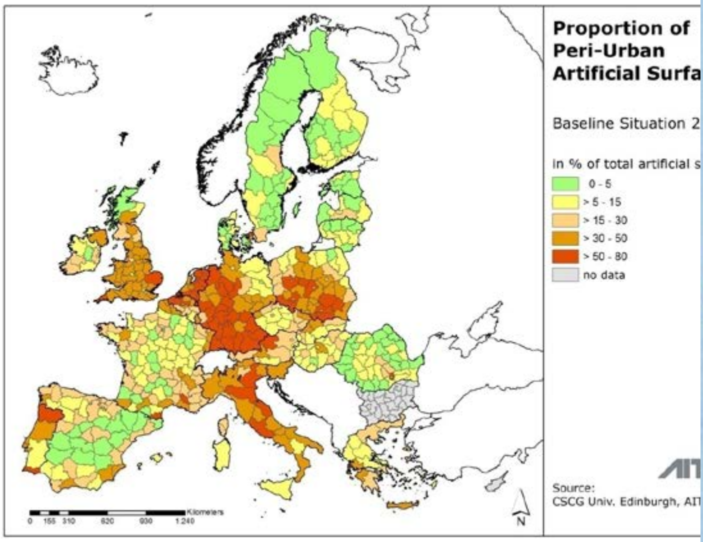
As in the further reaches of Scotland and Wales or Northern Ireland, these can appear as textbook examples of the city / settlement in its hinterland, surrounded by natural resources and ESS of many kinds. For ESS **within** the settlement, greenspaces can be a focus for the community. For ESS **around** the settlement, we need to look more widely at the regional pattern of resources. For ESS **through** the city, there is potential for local food or energy or forestry to be used as social or cooperative enterprises where commercial markets are not viable (Perry and Alcock, 2010).

This is a very brief sketch of spatial types in the system of cities, and in the absence of much evidence to date, it's also a proposition for a future research agenda.

Figure 4: UK system of cities in European context

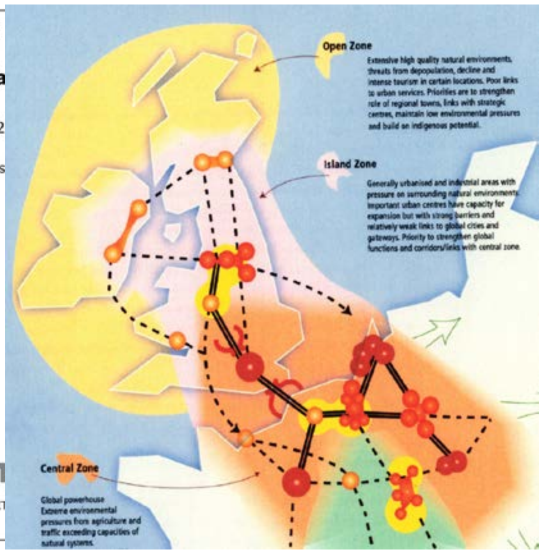
Peri-urbanization: EU mapping

Illustrates the scale of counter-urbanization and peri-urban development: brown areas show NUTS 3 units with >30% of area at peri-urban densities. Source www.plurel.net (Piorr et al 2011)



Urban hub system: NW-EU mapping

Illustrates the main hubs in the urban system of UK and Ireland, in relation to European core Source: NW-Europe Spatial Vision 2004



2.1.6 Urban-regional patterns and pressures

Other important factors for urban ESS concern the regional scale of growth or decline, in production and/or consumption. Again more research is needed, but the combinations of production and consumption types are a starting point (Casalegno et al, 2014; Barrett et al, 2006):

- **high production / high consumption -** this type focuses on enterprise / growth areas, such as in the major growth zones (M4 corridor and M40 / M11 triangle), and parts of the affluent greater ROSE (i.e. Southeast and Eastern) regions. Urban ESS will be under pressure, but investment will be more available for both public and private goods;
- **high production / low consumption -** industrial manufacturing areas with relatively low incomes, still widespread around the Midlands and North. Such areas often see higher levels of pollution, contamination and waste, but industrial shrinkage also leaves gaps in the urban fabric, allowing large scale ecological colonisation (Rall and Haase, 2011; Nicholson-Lord, 1987);
- **low production / low consumption -** declining and/or downshifted areas, including areas of redundant or obsolete industries without adequate replacements, but also offering new kinds of opportunities for micro enterprise and community activity. Typical gaps in the urban fabric are then available for allotments and country parks with related urban ESS; and
- **low production / high consumption -** this type includes areas with more affluent consumers, including market towns and retirement suburbs, with high value service sector based areas, concentrated in the Greater London and ROSE regions. Urban ESS depend more on the suburban fabric: some argue that the suburbs contain greater biodiversity

than surrounding farmland, and can shift from 'asphalt and grass' to a more diverse ESS mix (Gwilliam et al, 1999).

These four types are shown as simple and static, whereas in reality there is complexity and continuous change. To explore further we can draw on the concept of **panarchy**, i.e. multi-scale cycles of dynamic change, and apply to both ecosystems and urban systems (Gunderson and Holling, 2001):

- areas of **rapid urban growth** bring pressures on local greenspace, GBI and supply chains for energy, water, waste and so on. Growth pressures often result in building on floodplains or on sites of ecological value. They can also bring potential opportunities for investment, remediation of polluted land and water, and new and more eco-efficient infrastructure;
- areas of **consolidation and conservation** include many suburban areas. As above the density of species and habitat can be greater than in surrounding farmland: but this depends on the micro-scale management of gardens, greenspaces or other infrastructure, the intensity of pesticides and fertilisers, and the planting and watering regimes. The implication is that urban ESS can be quite vulnerable to changes which are less directly visible in the urban fabric, and more about the surrounding socio-technical 'relational' systems (Karvonen, 2011);
- areas of **urban crisis or decline** often struggle for investment and maintenance of urban ESS, where older infrastructure which is less efficient is kept in use. Ironically there may be greater opportunities for ecological colonisation of derelict, vacant or under-used land and habitats left over after industrial shrinkage (Nicholson-Lord, 1987; Haase et al 2014); and
- areas of **restructuring and re-organisation** may bring opportunities for innovations in ESS, from a technical or social agenda, as per the examples in Chapters 5 and 6.

2.1.7 City-region dynamics and peri-urbanisation

Over-arching these urban patterns is a structural shift in urban systems, which appear to be moving away from a 'textbook' model of a freestanding city and hinterland, and towards a more networked and diffused urban system. This can be framed as the 'metroscape' (Kraffcyk, 2004), 'city of flows' (Castells, 1997), 'post-metropolis' (Soja, 2001), 'cognitive capitalism' (Scott, 2000), or an emerging peri-urban society (Ravetz et al, 2013). This shift is less obvious in the UK, which is relatively crowded and highly regulated compared to most other countries. There is, however, evidence for a pervasive trend towards peri-urbanisation, not so much in physical development, but in the conversion of rural types of social and economic systems, towards urban types. For the UK the implication is that the majority of its sub-regions are effectively peri-urban, as they contain 30%-50% of all built area (i.e. 'artificial surface') in peri-urban areas (i.e. defined as *'discontinuous built development, containing settlements of each less than 20,000 population, with an average density of at least 40 persons per hectare (averaged over 1km cells)'* . The result can be seen on the left side of Figure 4, with one of many maps from the EU-funded PLUREL project on peri-urbanisation (Piorr et al, 2011).

A family of spatial types exists within each city region, functional urban area, or ‘rural-urban-region’, however that is defined. Each of these spatial types has a different profile for its urban ESS. The following are the types elaborated on in the PLUREL project:

- urban core - including the central business district and other civic functions;
- inner urban area - generally consisting of higher density built development (built-up areas);
- suburban area - generally lower density contiguous built-up areas, which are attached to inner urban areas and where houses are typically not more than 200 metres apart;
- urban fringe - a zone along the edges of the built-up area which comprises of a scattered pattern of lower density settlement areas and urban concentrations at transport hubs, together with large green open spaces; and
- urban periphery - a zone surrounding the main built up areas, with a lower population density, but belonging to the Functional Urban Area. This can include smaller settlements, industrial areas and other urban land-uses.

This so-called peri-urbanisation, or ‘edge city’, on the fringe of conventional urban areas, is now increasingly the locus of newer kinds of activities, such as airports and interchanges, business or retail parks, health or education campuses, heritage or tourist destinations, and commuter-type housing developments (Gallent, 2006; Garreau, 1991). The notion of the ‘aerotropolis’ sums up the emerging pattern of urbanisation, which may be more planned, more sprawling, or a combination of the two (Kasarda and Lindsay, 2011). Such areas are often undergoing rapid change and growing pressure on the urban ESS of all kinds, so it is not easy to generalise. For instance the ‘urban ecological gradient’ appears to be much more complex than any single curve (Zasada, 2011). Issues of prei-urban ESS can be best understood as being integral to the wider city-regional system of ‘relationships’ (Ravetz et al, 2013), than as purely free-standing zones. This is then the focus of the ESS ‘around the city’, as in the next section and in column (b) of Table 2. This Table shows the different domains (social, technical, economic etc), in relation to the spatial structure **around** the city-region.

Table 2: UK system of cities: state and outlook

(Showing issues and patterns in the UK urban system, which are relevant to urban ESS)

	ESS '*Within*' the city (local and micro-scale ESS) (a)	**ESS '*Around*' the city (spatial dimensions of ESS) (b)**	**ESS '*Through*' the city (metabolic flows of ESS) (c)**	**ESS '*For*' the city: (ESS-related socio-economic systems) (d)**
Social, community	Community access to local greenspace for food, leisure etc: Citizen participation in nature conservation	Spatial distribution and access to urban open space, sports, leisure, tourism:	Lifestyle and behaviour in leisure, tourism: Access by social / ethnic groups	Demographic and occupational trends: Housing and welfare policies.
Technology, infrastructure	Localised water, energy, waste, food etc: potential for micro-scale decentralised systems.	Water, energy, waste, minerals, farming, forestry etc: spatial distribution across city-region	Water, energy, waste, minerals, farming, forestry etc: potential for regional-scale integrated low-impact systems.	Water, energy, waste, minerals, farming, forestry etc: national policy, technology, markets.
Economic, employment	Local and neighbourhood level of economic activity in ESS, formal and informal.	Spatial distribution of investment and employment in infrastructure and ESS	Regional distribution of investment and employment in infrastructure and ESS	Privatisation and property rights on land and ESS: marketisation and payment for ESS: green economics, values and markets
Environment, ecology	Urban form and design which includes micro-level and local GBI, greenspace, habitats etc.	Spatial distribution and access to urban green space, GBI, habitats, corridors, etc:	Urban-regional flows and stocks, in energy, food, materials, forestry etc	Urban climate impacts: flood, drought, heat, storm: resource policy and markets in food, energy, materials etc
Policy and institutions	Local and neighbourhood level planning / building codes and regulations:	Changing governance / devolution of urban-regional agglom-erations, spatial planning etc:	New political economies for infrastructure and ESS	Climate policy, mitigation /adaptation: role of outdoor and greenspace in health and education services
Cultural, ethical	Local level sustainability / ethical VS material values	Culture for/against coordination / redistribution at city-region scale	Ethics of ESS capture and management	sustainability / ethical VS material values
Urban, spatial	Access and pressure on green space, greenfield / brownfield sites: Community access and use, food, leisure etc	Urban growth, spatial devt, counter / re-urbanisation: greenbelt and similar policies etc: strategic ESS corridors etc.	urban infrastructure, location and spatial patterns in transport, energy, water, waste, minerals etc.	UK urban system: London effect: Regional growth / decline:
INTER-CONNECTIONS	Community local resilience	Urban sprawl VS planned settlements	Resilience to systems shocks and shortages	New paradigms in social-economic systems

2.2 Ecosystems: general state and outlook

As above, we take a wider view here on the scale and scope of ‘urban ESS’ than is generally the case in most studies on ESS. The summary of this wider view is shown in the columns of Table 3 below, (from the left hand side):

- ESS **within** the city (physical features in urban area). This focuses on the greenspace, ecological habitats and ecosystems inside the built up area, particularly at the very local scale. This is covered in some detail by the NEA urban chapter (Davies et al, 2011);
- ESS **around** the city (spatial patterns and distribution). This includes a finer typology of the ‘urban’ habitat, and then extends outwards to the urban fringe, peri-urban and rural hinterlands. For each spatial type there are different pressures and opportunities arising;
- ESS **through** the city (environmental / resource flows and metabolism). As this is covered largely by the Foresight paper on ‘Urban Metabolism’, we include this here to see the inter-connections with other themes; and
- ESS **for** the city (ecological principles). This takes a mainly national and global perspective on industrial ecology systems, ecological investment, ecological design and so on. This helps to explore responses to the challenges of ESS in the above ‘within, around, or through’ the city.

Firstly, here is an overview of the national outlook, which is rather mixed (NAE, p11):

> *“The UK’s ecosystems are currently delivering some services well, but others are still in long-term decline. Of the range of services delivered in the UK by eight broad aquatic and terrestrial habitat types and their constituent biodiversity, about 30% have been assessed as currently declining. Many others are in a reduced or degraded state, including marine fisheries, wild species diversity and some of the services provided by soils. Reductions in ecosystem services are associated with declines in habitat extent or condition and changes in biodiversity, although the exact relationship between biodiversity and the ecosystem services it underpins is still incompletely understood.”*

A summary table is shown below (Table 3), with a breakdown of the ESS types across the four domains, and then a mapping to each of the ‘STEEPCU’ domains. Firstly, ‘socio-cultural services’ concern public services, urban quality of life, and local community activity. Then, ‘provisioning services’ are more relevant to technology and economic activity. ‘Regulation and supporting services’ fit directly with environmental and physical features. Other layers include policy and institutions, cultural and ethical issues, and the urban-spatial level itself.

Generally this shows the profile, location, climatic position and ESS vulnerability of the UK as relatively benign, compared to many other countries (Revi et al, 2014a). Much urban pollution and dereliction of the UK’s industrial past has been cleaned, and much rural activity is closely regulated. Many UK environmental impacts are now being displaced to the global level: i.e. climate change and supply chain related resource extraction (Barrett et al, 2006). Within the UK, however, the urban ESS themes with the most clear negative trends are summarised by the NEA as: climate change impacts; continuing breeches of air quality standards; other hazards including flooding; landscape fragmentation; urban noise and light pollution; and deteriorating soils in all locations.

Table 3: Ecosystems features: state and outlook

(General issues on environment and resources, relevant to urban ESS)

(below: based on the NEA typology)	ESS '*Within*' the city (local and micro-scale ESS) (a)	ESS '*Around*' the city (spatial dimensions of ESS) (b)	ESS '*Through*' the city (metabolic flows of ESS) (c)	ESS '*For*' the city: (ESS-related socio-economic systems) (d)
Social, community *(~ 'socio-cultural services')*	Local identity Community access and use of green space .	Landscape amenity: Eco-cultural sites: Nature conservation:	Social and community access to ESS infrastructure in energy, water, etc	Education and health system policy: Housing and community policy
Technology, infrastructure *(~ 'provisioning services')*	Localised / community monitoring and management of ESS and environment	Urban-regional monitoring and management of ESS and environment	Energy and emissions: Industrial material: Construction material: Urban food supply: Waste / recycling:	Industrial ecology systems: Ecological infrastructure:
Economic, employment *(~ 'provisioning services')*	Individual / household level of investment and value generation.	ESS investment / enterprise / employment: access and location	Investment / employment for ESS-infrastructure: water, energy, minerals etc.	Industrial growth strategy and transition: Infrastructure policy:
Environment, ecology *(~'Regulation and supporting services')*	Micro-climate, public spaces, gardens, indoor habitats	Spatial distribution of: Flood defences Air emissions / quality Water poll / quality Ground / soil quality Waste management	Industrial and infra-structure sources of: Air emissions: Water discharges: Ground pollution: Waste arising:	Climate systems and climate change: Global soil and food systems: Global biodiversity and habitat: etc.
Policy and institutions	Urban planning and design: building regulation and design	Spatial environmental policy, e.g. green belt, nature conservation, water management, GBI etc	Regional applications of environment policy: strategic planning institutions and capacity:	UK / EU / global environment policy: incl. energy, transport, construction, agriculture
Cultural, ethical issues	Cultural issues in use of greenspace and GBI	Ethics of nature conservation Environmental justice for clean air and water	Environmental justice in access to resources	Ethics and justice for environmental quality, impacts, supply chains etc
Urban, spatial issues	Community access and use, food, leisure etc	Urban/rural space for GBI, eco-infra-structure, other ESS	Urban growth, spatial development, counter / re-urbanisation: greenbelt policies etc: green corridors etc	Planning / building codes and regulations:

2.2.1 Urban ecosystems as 'providers' of services

With further discussion, the outlook for urban habitat types seems rather problematic, according to the NEA chapter on the 'urban' broad habitat (Davies et al, 2011):

- the ecosystem goods and services that could potentially be derived from urban greenspace are substantial. In the past, the importance of these areas for the health and general well-being of society was not appreciated and their potential not realised;
- provisioning services are limited and the majority of goods are imported; but there is evidence of changing attitudes towards urban food production;

- many of the supporting and regulating functions that urban soil could provide have been reduced and restricted;
- urban air quality has significantly changed over the last 60 years with consequences for clean air that extend far beyond the urban boundary;
- urban greenspace is fundamental to sustaining urban life and, therefore, should be integral to the way in which it is planned and managed; and
- trade-offs and synergies in ecosystem goods and services are complex. As yet, they have not been widely investigated in the urban environment.

This implies an emerging picture of a typical UK city that is disconnected from its surroundings, dependent on globalised supply chains for food, energy, minerals and forest products, exporting many environmental impacts overseas, but still managing to choke on its own traffic emissions and with reducing capacity to feed itself should it need to.

2.3 Ecosystem services: within the city

For an overview of the ecosystems and their services **within** the city, we draw on the urban chapter of the NEA as in Table 4 (Davies et al, 2011). For the direct evidence we can only refer to the NEA, but we can provide some interpolation, to include wider trends and outlooks, opportunities and synergies, and threats and risks for each ESS type.

2.3.1 Ecosystems within the urban matrix

Natural / semi-natural greenspace (including woodland, SSSIs, urban forestry, and scrub). The proportion of green space within urban areas ranges from 23% (Liverpool) to 58% (Newcastle), with London midway at 38%. However these figures are based on the local authority boundaries which vary widely, in that some are drawn tightly around urban areas, while others include large rural areas (NEA, 2011 p368). Generally, designated natural / semi-natural greenspace takes up 11% of urban land in the UK; approximately 600 sites with SSSIs are within or near urban areas (GLUD, 2005). There is an increasing trend in many schemes for urban / fringe forests which increase the total wooded area. There are further opportunities with increase in GBI strategies. However, these are countered by threats from climate change, invasive pests and pathogens such as ash die-back disease.

Urban trees. The most recent national survey shows that 66% of all urban trees are in gardens and grounds, while 20% are in public parks and 12% on streets (DCLG, 2008). While 70% of the total is reported in good condition, there may have been some decline over the previous decade. Future threats may arise from the combination of climate change impacts and groundwater depletion. While street trees are recognised to have a positive effect on quality of life and property values, they are seen by some as a maintenance and insurance liability. However there are opportunities in new eco-urban design concepts, e.g. see the case study in Chapter 5, from Circle-21 (2014).

Public parks and formal gardens. 13% of parks are reported to be in poor condition, and more than the pro rata share of these are located in deprived areas (CABE, 2010). Trends here vary, with some evidence of a loss of native species and an increase in non-native species. As parks are the largest green element in the urban morphology, this has a wider significance. There are opportunities in ecological planting regimes, community stewardship and social enterprise models, growing public health awareness, and efforts for social inclusion and diversity. However there are also threats from, for example, a lack of maintenance, conflicts between users, privatisation and deregulation of semi-public spaces.

Domestic gardens. These make up an estimated 13% of all urban land in the UK (Bibby, 2009). The most notable trend here is the increase in hard paving. For instance, in London 3200 hectares of garden area was reported paved for parking or housing infill: in areas such as the North East 47% of front gardens are more than ¾ paved (RHS, 2006). Opportunities exist in the growing awareness of ecological planting, permeable paving and sustainable drainage, and also some emerging technologies such as patio heaters and solar powered garden lighting. Meanwhile, there are existing pressures from: climate change that lead to water shortage, invasive species and pathogens; extensive use of hard paving / parking areas; and housing built on garden infill sites (Gaston and Gaston, 2011).

Green Corridors: these are now recognised in the UK Biodiversity Action Plan as Open Mosaic Habitats, serving both as conduits for species movement, and as linear habitats (Douglas and Sadler, 2011). Evidence is scarce but there is policy priority in the shape of recent GBI strategies. Opportunities for promoting green corridors arise where there is synergy with leisure routes for walking and cycling, maintenance of waterways, and long distance cycle paths or footpaths. However, threats to the corridors are common, particularly from privatisation of access, and severance by infra-structure.

Table 4: Ecosystems features: physical types

	State and profile	Trends and outlook	Opportunities and synergies	Threats and risks
Natural / Semi-natural Greenspace (Woodland, SSSIs, Urban Forestry, Scrub)	Total area 11% of urban land in UK: 600 SSSIs within or near urban areas.	Various urban / fringe forests are increasing total wooded area	Increase in Green / Blue infrastructure strategies	Climate change: pests and pathogens, e.g. ash die-back:
Street Trees	66% in gardens and grounds: 20% in public parks: 12% street trees	Mixed trends	New eco-urban design concepts	Climate change and groundwater change:
Public Parks and Formal Gardens	13% of parks in poor condition, most of these in deprived areas.	Mixed: some evidence of loss of native / increase in non-native species	New community stewardship models: public health awareness	Lack of maintenance, conflicts between users: privatisation and deregulation
Domestic Gardens	Total area 13% of urban land in UK,	Up to 47% of front gardens have been paved (NE region)	New awareness of ecological planting and paving	Invasive species: paving and housing infill
Green Corridors	Now recognised in the UK BAP as Open Mosaic Habitats	Increase in Green / Blue infrastructure strategies	Synergy with walking and cycling routes	Severance by infra-structure, privatisation of access.

2.3.2 Ecosystems features with urban functions

The next group of ecosystems features are more defined by their functions as outdoor locations for urban societies and economies (Table 5): (unless otherwise stated, sources are from Davies et al, 2011)

Outdoor sports, recreational areas, and amenity greenspace. As of 2011 there were over 10,000 sports and recreation areas, covering 8170 hectares; about 33% of total designated greenspace is outdoor sport and recreation (CABE, 2010). The main trend in recent times has been the privatisation of public facilities, where over 10,000 sites were sold between 1979 and 1997 (DCMS, 2009). This has now been almost halted, and 70% of local authorities have policies for the 'six acre standard' of provision, the average local authority is nearly on target for playing pitches, and about 20% under target for all forms of outdoor sports (FIT and NPFA, 2008). There are new opportunities with community partnerships for management and stewardship. Meanwhile, threats arise from public funding deficits, pressure for housing development, and the general growth of indoor lifestyles (Dawe and Millward, 2008).

Allotments, community gardens and urban farms. In the 1940s there were around 110,000 hectares in England producing 1.3 million tonnes (10%) of the nation's food supply. Now, the total area is around one tenth of the previous peak. There are no clear trends at the moment, but it seems that opportunities could arise from a new interest in local food for health, education, community enterprise; in urban areas, demand greatly exceeds supply for allotment space (Campbell and Campbell, 2009). Threats again are due to pressure for housing development, and growth of indoor lifestyles.

Cemeteries, churchyards and burial grounds. According to 2007 figures (Ministry of Justice), there are currently 16,000-18,000 Church of England burial grounds in the country. There are no clear trends at this moment, except that the shift towards cremations has reduced the pressure for burial ground expansion. Opportunities mainly come through neglect and vacancy, which can provide space for richer habitats. Threats are posed by the intermittent pressures for change of use and de-consecration of church grounds.

Previously developed land (brownfield). There is currently estimated to be 62130 ha of Brownfield land in England (2007 data, DCLG, 2010). Recent trends show that total previously developed land (PDL) declined slowly by 6% (2002-2010), while vacant land declined by 19%, and derelict land declined by 6% in the same period. Permeable vacant or derelict land can provide niches for rich habitats (Schadek et al, 2009), but there are also pressures from another environmental objective, that of densification of urban form. This was encouraged firstly by housing density standards, and recently by the deregulation of planning rules.

Table 5: Ecosystems features: outdoor functions

	State and profile	Trends and outlook	Opportunities and synergies	Threats and risks
Outdoor Sports, Recreational Areas, Amenity Green space	Up to 33% of design. Green space is outdoor sport and recreation.	Rapid selling off has been halted: but rising development pressure.	New community partnerships for management and stewardship.	Public funding deficit: pressure for housing development: indoor lifestyles.
Allotments, Community Gardens and Urban Farms	In the 1940s, around 200,000 ha, producing 1.3 million tonnes: now around 20,000 ha.	No clear trends.	New interest in local food for health and education.	Pressure for housing development: indoor lifestyles.
Cemeteries, Churchyards and Burial Grounds	16-18000 Church of England burial grounds in England.	No clear trends.	Neglect can provide rich habitats.	Change of use / de-consecration of church grounds.
Previously Developed Land (Brownfield)	Total 62130 ha (2007 England).	Total PDL declined -6% (2002-10): vacant land -19%, derelict -6%.	Vacant and derelict land can provide rich habitats.	Pressure for housing development.
Green Belt (Urban Fringe and Peri-urban)	Total 1983,000 ha, 15.2% of total area (2009). 60% of UK population live in areas surrounded by green belt.	Trends: over 80,000 dwellings and 1000ha of business parks have permission on GB sites (England) (CPRE, 2012).	New concepts for multi-functional 'ecological belt': new local economies and ESS in fringe and peri-urban areas.	Pressure for housing development: either piecemeal, or major areas for garden cities /urban extensions.

2.3.3 Urban environmental conditions

The third group of features are more concerned with environmental conditions and resources. Again, this is a brief overview of a large and complex field.

Urban water and water quality. 34% of urban water bodies are below good / moderate in key parameters (England and Wales) (Defra, 2013b). Longer term trends show generally rapid improvement in water quality since the 1960s, and more gradual improvement since the 1990s. Opportunities arise for investment and clean up, and for related social and economic services in waterfront development, urban heritage, outdoor leisure, and general lifestyle amenity. Threats are due mainly to the climate change effects of droughts, storm-water flooding, and saline incursion. Groundwater depletion and pollution also pose issues, particularly in areas where industrial restructuring has led to rises in water tables. In principle, these threats would be covered by the EU Water Framework Directive, a major step forward in environmental policy. However the practice appears very challenging (European Commission, 2000).

Urban air quality: London and other cities have major air quality issues. These are mainly traffic-related, and cause an estimated 29,000 early deaths each year (Environmental Audit Committee, 2014). In their words, "air pollution continues to be an invisible killer, costing the lives of 29,000 people per year. The UK Government has been found guilty of failing to meet EU air quality targets in our cities, some of which will not meet the required limits until 2030. However, meeting EU standards should be the minimum requirement. Regardless of EU rulings it is unacceptable that UK citizens could have their health seriously impaired over decades before this public health problem is brought under control".

There is a general trend of improvement since the 1956 Clean Air Act, when most urban energy was provided by coal, but most UK cities are projected to exceed EU limits up to or beyond 2030 (Environmental Audit Committee, 2014). These projections depend mainly on the rate of the replacement or upgrading of transport fleets. Meanwhile there are opportunities in GBI, with street trees and other urban ecological habitats which help to create micro-climates and natural filters. Threats are due to intensified urban heat island effects, tropospheric ozone, diesel particulates, and indoor air quality problems which are often found in large building complexes.

Urban Biodiversity: Urbanisation can cause a decline or an increase in richness and/or abundance of some species. An increase in non-native species can cause rapid change in habitat; otherwise there are no clear overall trends of biodiversity growth or decline. Opportunities exist in public ecological awareness, as well as in gardening, local food production, and open space management. There are existing threats from climate change, which include invasion by non-native species, pests and diseases, with species such as bees at particularly high risk from the use of agro-chemicals. Meanwhile there is a growth of new habitats for urban predators such as foxes, rats and bats, with many emergent symbiotic relationships between humans and urban wildlife (Adams and Lindsey, 2011).

Table 6: Ecosystems features: environmental qualities

	State and profile	Trends and outlook	Opportunities and synergies	Threats and risks
Urban Water and water quality	34% of urban water bodies below good / moderate in key parameters (England and Wales).	General improvement since 1960s / 1990s.	Waterfront development, heritage, lifestyles etc.	Climate change, saline incursion.
Urban air quality	London and other cities have mainly traffic-related air issues: estimated to cause ~50000 early deaths.	General upward trend since Clean Air acts, , but some may exceed EU limits up to 2030: replacement of transport fleets.	GBI, street trees and other habitats can help to improve air quality.	Urban heat island, tropospheric ozone, diesel particulates, indoor air in workplaces.
Urban Biodiversity	Urbanisation can cause decline or increase in richness and/or abundance of some species.	Increase in non-native species can cause rapid change in habitat: otherwise no clear trends.	ecological awareness in gardening, local food, park and open space management etc.	Climate change: non-native species, pests and diseases. Some species e.g. bees at high risk due to agro-chemicals. New habitats for urban predators e.g. fox, rats.

2.4 Ecosystems services: around the city

This section looks at ESS 'around the city' and in the wider city-region, beyond the built up area, in the urban fringe or peri-urban areas. Local authorities and public agencies have different types of boundaries, so comparable data is not easy to find. Here, we focus on: flooding and water resources, as both depend on the wider water catchment that exists beyond the urban area; on the peri-urban landscape under pressure; and on the Green Belt as the foremost policy response.

2.4.1 Flooding and water resources

The most common types of 'services' around the city-region are flood management and water resources. At present, nearly 20% of all dwellings in England are in locations with some degree of vulnerability to flooding (Pitt, 2008; Houston et al, 2011). Effective responses are constrained by: institutions which are often fragmented and uncoordinated; a lack of funding following the public deficit; and a lack of strategies to deal with the growing threat from climate change impacts.

However, effective flood management needs more than a ‘linear’ policy approach which just aims to build higher defences. The water system is a highly integrated system, of both physical and socio-economic factors, working mainly on a river catchment basis, with special conditions for estuaries and coastal locations. The EU Water Framework Directive set out the fundamental principles of integrated catchment management, but this crosses many sectoral and administrative boundaries, making the longer term implementation challenging (European Commission (EC), 2000; Tippett et al, 2007).

The implication is that large parts of urban UK are vulnerable in some way to flood risk, which is likely to increase in the near future, and where the capacities for response seem inadequate. This might call for a step-change in policy development, with a focus on the interfaces of urban, peri-urban and rural areas (as in Chapter 4). One policy response is ‘integrated catchment management’ which builds partnerships between rural interests (agriculture, forestry, landowners), and urban interests (infrastructure, urban planning, landowners, finance and insurance) (EC, 2000). Another response is integrated eco-development, in which new housing areas are fully integrated with the ecological constraints and opportunities. This would include GBI for micro-climates, flood retention basins, sustainable drainage systems (SuDS) and permeable surfaces, and creative adaptation with ecological habitat opportunities, combined with creative social and community enterprise.

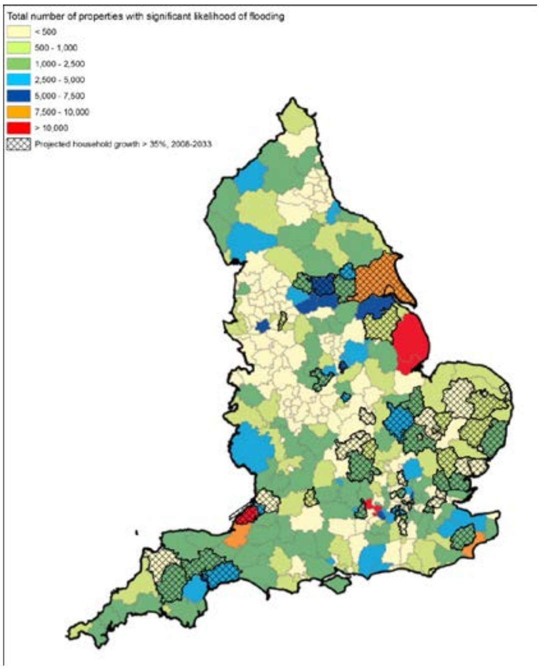
The UK’s diverse geography means there are wide variations in flood risk across the country, both fluvial (from rivers) and pluvial (from intense rain episodes) sources. The left hand side of Figure 5 shows the properties ‘at significant risk’ of flooding (the next chapter looks at the ‘socio-spatial vulnerability’ to future climate change risks). Most clusters are around coastal and estuarial towns, with those in Lincolnshire and Somerset particularly affected. Other clusters are in Greater London and the south coast, and in the industrial northern cities located around narrow river valleys. With the overlay of housing high-growth areas (i.e. areas with household demand projections of >35%, for the period 2008-2033), the areas of particular concern are visible: East and West Yorkshire, the Fens and East of England, Devon and Somerset, Thames Valley, Suffolk and other low lying areas.

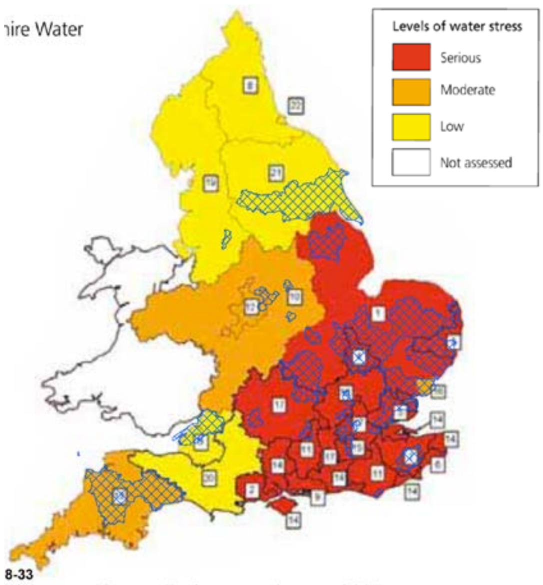
Similar concerns apply to the water resources and implications of housing growth on water stress. The right hand side of Figure 5 shows the regional scale mapping of water stress (i.e. resources over demand), overlaid with the same areas with high increases in housing. The majority of these areas is projected to be in the Southeast, east of England and east Midlands, which are already areas with the highest water stress (and some are also at high risk of flooding).

Figure 5: Household growth implications: flooding and water resources

(England data only): From Wong et al 2012

Implications for flood risk zones | *Implications for water resources*





2.4.2 Peri-urban and urban-rural hinterland

The UK system of cities on one level revolves around London and eight to twelve other hubs or core cities. Meanwhile, on another level, it shows a diffused networked pattern of large areas which are effectively urbanised at low densities in places including the urban fringe, infrastructure areas such as airports and malls, the wider peri-urban area, and then an urban-rural hinterland (Piorr et al, 2011; Ravetz et al, 2013). Firstly we can identify the spatial range and system level, of urban ESS interactions and hierarchies (shown in more detail in Table 19 in the Annex):

- local scale ESS - green space amenity, biodiversity, drainage, climate regulation;
- city-region scale ESS - water, waste, aggregates, energy, landscape amenity;
- regional-national scale ESS - water, energy, food, minerals; and
- global scale ESS - other supply chains and ESS regulation.

There are two implications for a crowded country such as the UK, and particularly England. First, apparently rural areas are intensive providers of ESS for their nearest urban systems, in terms of landscape amenity, leisure and tourism, and supply of food, forestry or minerals. Second, many of these services and underlying qualities are under threat, from change or growth in that urban system. In the background is the long term picture: the total stock of land and the dynamics of change in land uses, functions, ownerships, responsibilities and so on (Foresight Land Use Futures Project, 2010).

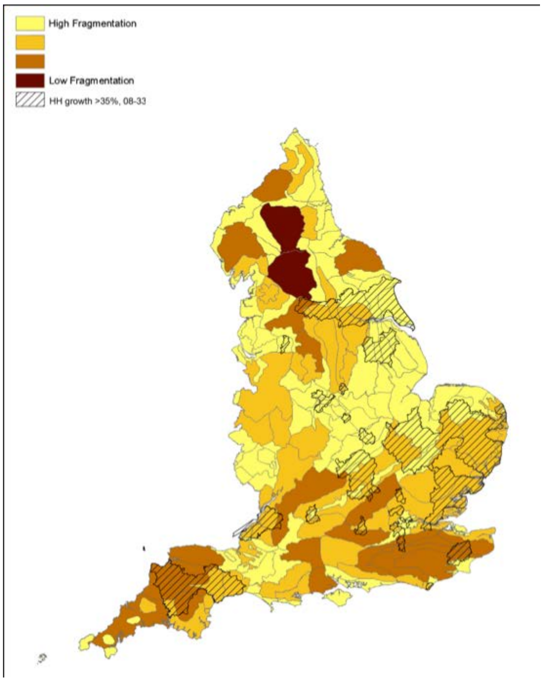
To explore the practical implications for urban ESS, again we refer to the Royal Town Planning Institute (RTPI) Map of England (Wong et al, 2012), and compare some key datasets with overlays, as in Figure 6. The map on the left hand side shows the index of ‘landscape fragmentation’ (allocated by Countryside Character Areas), as a proxy for ecological integrity and connectivity. Conflicts can be seen between areas of low fragmentation / highest quality, and household growth areas as above, particularly in West Yorkshire, East of England, Thames Valley and South Downs, and Devon and Somerset. In contrast, where there is high housing pressure in areas of low ecological quality, the highest quality eco-urban design will be needed.

The map on the right of Figure 6 shows the main landscape designations: National Parks, AONBs and Green Belts. Again there are potential clashes with household growth areas, particularly in West Yorkshire, Greater London and the Thames Valley, and also the sub-region of Avon, Devon and Somerset.

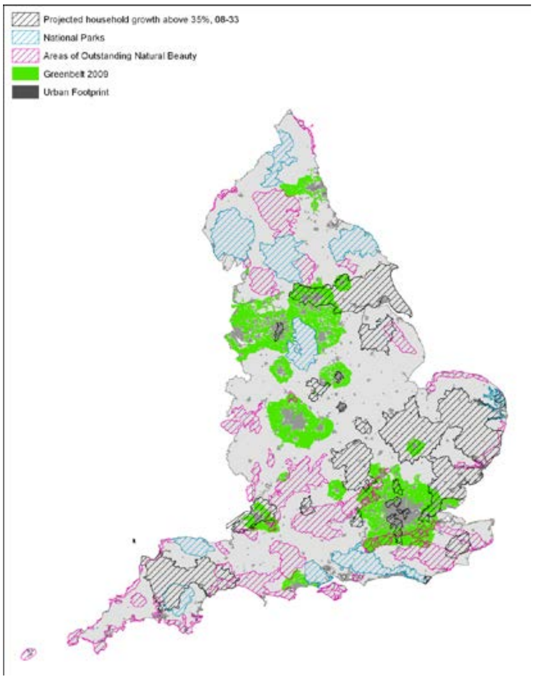
Figure 6: Household growth implications: landscape quality and policy

(England data only): From Wong et al 2012

Implications for landscape fragmentation



Implications for landscape designations



2.4.3 Green Belt

The mapping in Figure 6 shows National Parks, AONBs and the Green Belt as three major designations which together cover large parts of England. Of these the Green Belt is the nearest to the great majority of the population, perhaps the single most important policy in UK spatial planning, and emulated around the world. There are many arguments around the Green Belt. These include whether it succeeds in urban containment and compact cities, how far it brings negative side-effects to urban or rural areas, and how far it maintains the property and class hierarchy in access to land (Shoard, 1983; Elson et al, 1993; Fairlie, 1996; Gallent, 2006; Henderson, 2005; Westerink et al, 2013). One problem with the Green Belt is that the current policy does not aim directly to promote ‘green’ or ecosystems based approaches; some argue that ‘grey’ or ‘brown’ infrastructure is easier to locate in the Green Belt than ‘green’ (Natural England and CPRE, 2009). In response, a more appropriate policy mix could be framed as an

‘Eco-Belt’, which directly promotes ecological enterprises and sustainable urban ESS (Ravetz, 2000; CURE, 2003).

Two of the key features are visualised in Figure 7: the Green Belt and designated town and village greens. The map on the left shows the existing Green Belt with locations of major development threats. As of 2012, these include proposals for over 80,000 new houses, new roads, open cast coal mines, airport expansion, golf courses and industrial parks (CPRE, 2012): The map on the right of Figure 7 shows designated town and village greens, a more recent policy designation which reflects local priorities and the community interest in public green spaces (CABE, 2010b). This is shown by the impressive spread of sites, particularly in the Midlands/ east of England, and the northeast and northwest regions.

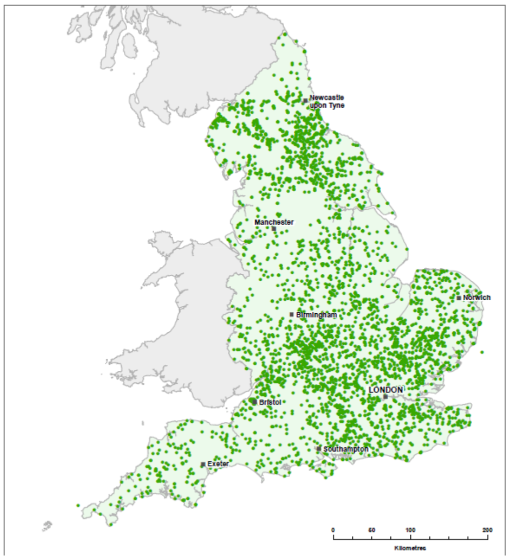
Figure 7: Green Belts and Town / Village greens

(England data only): Source: www.magic.gov.uk

Data on ‘threats’ from development to Green Belt in England, based on CPRE, 2012

Designated Green Belts, with ‘threats’

Designated Town / Village Greens



2.5 Ecosystems services: ‘through’ and ‘for’ the city

2.5.1 Energy water and material flows through the city

Technical issues of ESS **through** the city – energy and resources, climate change effects, and transitions in production / consumption – are covered in detail by the Foresight working paper onf ‘Urban Metabolism’. So here we point to some inter-connections between ESS ‘through’ the city, and localised ESS ‘within and around’ the city.

Water flows through the city. Across the UK, water resources are variable, and likely to be under increasing pressure in areas of shortage and housing growth (Figure 6). Both water resources and flood management are part of the Integrated Catchment Management approach (EC, 2000). In principle this would integrate urban housing, industry, infrastructure, agriculture and forestry into the city-region context in order to balance demand and supply with re-use and recycling (Defra, 2013; Wheater and Peach, 2004). This means that ESS in various parts of the catchment need to align with the ICM framework of catchment, storage, attenuation and so on, which may involve competition with other objectives, such as biodiversity, leisure or farming.

Energy flows through the city. A similar approach applies to a city-region energy system, but in this case there is no over-arching policy framework. There are many studies of urban energy / carbon transitions, but few look at the spatial implications (Stremke and van den Dobbelsteen, 2012; Ravetz, 2000). The combination of urban and energy system design would include urban heat networks and microgeneration, bio-mass and waste conversion, local renewable sources, industrial ecology, and energy cascades. Each of these has physical locations and implications for the urban / peri-urban form and fabric.

Material flows through the city. While UK cities and similar exist now in highly globalised chains of production and consumption, most heavy material flows are still localised. This includes bulk minerals and aggregates, construction and engineering spoil, dredging materials and sewage waste: forest products and waste, bio-mass and agricultural waste, and of course the urban waste stream itself. Such materials and industries are generally located in the fringe, peri-urban or hinterland areas. A coordinated system of extraction, storage, conversion and logistics (McEvoy et al, 2004) would be needed to optimise these material flows with the principle of the circular economy.

2.5.2 Ecosystem services principles for the city

Finally we flag up some of the ESS or ecological principles '**for'** the city, in terms of social, economic and political systems.

For social ecology, the questions start with 'who are the users or beneficiaries of urban ESS?', 'are the benefits and risks shared equally?' and 'are certain social groups excluded or included?' Social ecology is a perennial political debate, but a practical starting point is with ESS user 'types', which include:

- residents - types by age, gender, ethnicity, special needs;
- businesses - types by investors, owners, workers, service providers;
- institutions - major land-users and managers, as in finance, health, education, defence;
- visitors - leisure, tourism, and special interest groups; and
- infrastructure - road, rail, water, energy, waste, and others.

This debate points towards the questions of which people are located for which ESS qualities, and what the implications are for policy intervention. One line of thinking follows spatial analysis for the Public Benefit Recording System of the Forestry Commission. This is a kind of 'social ecology grid' of environmental qualities versus social priorities (NWDA, 2008):

- high quality environment / affluent community (low policy priority);
- high quality environment / deprived community (medium priority, to enable ESS access and community development);
- low quality environment / affluent community (low policy priority, as in principle the affluent community could invest); and

- low quality environment / deprived community (highest priority for public intervention).

In reality the distribution of funds is highly political and subject to interest groups and lobbies. This approach awaits further development, but the principle of making spatially explicit linkages between urban ESS, users / beneficiaries, and policy priorities seems useful.

2.5.3 Industrial ecology

The benefits to urban ESS seem clear, of a circular economy where wastes are continuously recycled. Industrial Symbiosis is defined as the synergistic exchange of waste, by-products, water and energy between individual companies in a locality, region or even in a virtual community: the key is collaboration between firms and the synergistic possibilities offered by geographical proximity (Lombardi and Laybourn 2012). The implication is that an urban or city-region area has great potential for industrial symbiosis, which then generates new potential in ESS functions, (for instance the 'service' of waste assimilation would shift to that of material exchange and conversion). In practice there are major barriers of information, trust, finance and continuity. Experience from the NISP (National Industrial Symbiosis Project) shows that a human engagement and facilitation approach is essential, beyond any technical information or marketplace (NISP, 2009). This is very topical as it shows that the apparently techno-economic agenda of waste / material exchange, depends on a very different socio-cultural agenda of engagement.

2.5.4 Political ecology

Overall the urban political ecology approach looks at questions of environmental distribution, social or ecological justice, power systems, ethics and futurity, and others, in the frame of urban ESS and urban metabolism (Heynen et al, 2006). One current example is the debate on energy from fracking (shale gas extraction from hydraulic rock fracturing) (The Royal Society, 2012). There is national scale debate on whether the nation's short term energy needs should encourage another source of fossil fuel. Meanwhile there are urban scale controversies on the local impacts and risks of fracking, and the rights of firms to drill under residential properties. This and similar political ecology dilemmas are the backdrop for the urban ESS changes, opportunities and pathway models, which are explored in the next three chapters.

3. Futures and change mapping

This chapter explores the time dimension with a 'change mapping'. We review the history and dynamics of the urban environment: drivers of change and tipping points: and alternative scenarios for the future, for a notional time horizon of 2040 and 2065.

3.1 Short history of the urban environment

Firstly we review the historic dimension with some brief notes on the 'urban environmental transition' (Douglas, 1983; McGranahan, 2006; Roberts et al, 2009).

In the pre-industrial cities of the UK, the nearby hinterland supplied most ESS types in the form of water, food, forestry, energy and minerals; permanent settlements often grow at confluences of rivers and coasts. The spatial structure of the city was based around defence, trade routes and interchanges, together with access to water, energy and food. This was overlaid by the emerging functions of government and civic society.

The earliest known forms of urban parks or gardens were possibly in Mesopotamia, where the evolution of cities went in parallel with the development of writing, from around 3,000 BC onwards. Temple gardens were built in the image of sacred groves: courtyard gardens were built for shade and water within the palace or city walls. Royal hunting parks were laid out with exotic animals and plants as the spoils of empire (Dalley, 2013).

3.1.1 The industrial city

With the growth of manufacturing through the industrial revolution, even more complex spatial structures were shaped firstly by transport infrastructure. This involved water provision up to the 18th Century, railways in the 19th Century, highways in the 20th Century, air travel in the present day, and possibly digital infrastructure in the future. Other public functions such as workers' housing, health and education also emerge as key elements in making up the urban form. Rapid population growth put water and sanitation systems under severe stress, with many outbreaks of infectious diseases. Coal was the primary source of energy for housing and industry, contributing to severe air pollution. Resources were exploited on a regional scale, although national and global supply lines soon followed. In the absence of controls, cities rapidly grew in a landscape of mining waste, industrial pollution, contaminated land, deforestation and rural poverty. Cities such as London or Manchester, which combined global trading functions with local manufacture, showed extreme levels of environmental pollution, and raised the agenda for radical political thinking. Through the 19th Century, environmental health became one of the defining forces in urban governance, planning and management. With new kinds of capital for investment, municipalities could fund city-wide infrastructure in drainage, water, electricity, gas, transport and later telephone systems.

3.1.2 The city of services

In the later stages of modernisation, larger cities developed a larger and more complex structure. The physical capacity for mass movement was provided first by the railway, then by urban tram and bus systems, and then by the private car. On the demand side, the rising affluence of consumers enabled migration of the more affluent to suburban locations, enabling the thinning of inner city and industrial areas. Then, further increases in mobility enabled the functional integration of groups of settlements into extended conurbations, transforming rural settlements into urban satellites. The urban structure was also shaped by policy innovations such as garden cities and new towns, Green Belts and brownfield targets. In the last half-century many environmental problems of production have been controlled to some extent, with major milestones such as the 1956 Clean Air Act. However, the problems of affluent consumption now involve both local waste and global supply chain impacts, and rising affluence tends to raise environmental standards and expectations. While most UK urban environments have never been cleaner, at least on the surface, major environmental impacts are now displaced to other nations, with pollution and expropriation of resources on a global scale (McGranahan, 2006; Ravetz, 2006; UNEP and International Resource Panel, 2014).

A summary of urban-ESS changes in the last 50 years can be seen in the case study of Greater Manchester (Wood et al, 197; Nicholson-Lord, 1987; Ravetz, 2000; Ravetz and Warhurst, 2013):

- energy sources - shift from coal fired power stations (>85% of electricity production in 1965) to gas, nuclear and some renewable sources;
- energy demand in buildings - the typical post-war house brick terrace with coal fires and outdoor sanitation has been replaced by gas central heating with fitted bathrooms and kitchens;
- air quality - major improvements in pollution control, alongside new hazards from vehicle-related particulates, tropospheric ozone, and urban heat island effects;
- water quality - major improvements in inland water quality, modernisation of sewage treatment, and return of fish to most inland waters;
- water resources - drinking water quality much improved, with mains provision to most rural areas;
- flood, drought and other hazards - flood defences have improved, but building continues in vulnerable locations, and there is growing risk from climate-related extreme weather events;
- urban fringe and peri-urban areas - Green Belt policy now covers all major conurbations and there are many social innovations in the urban fringe, with improved countryside rights of way;
- urban greenspace - reclamation of former industrial, mining or vacant land has increased the area of urban greenspace, but there has been a loss of playing fields etc to development; and
- urban biodiversity and habitat trends are mixed and evidence is patchy (as in Chapter 2).

3.1.3 The city of flux

The ‘splintering city’ describes a fragmented urban system, beyond former social or economic structures (Graham and Marvin, 2001). The ‘space of flows’ describes a city system which is as much about global connections as it is about its local economy and population (Borja and Castells, 1997). In economic terms, a ‘post-fordist’ city is a hub for global networks in media, finance, education or advanced technology. In social terms a post-fordist city is a playground for global elites, and a hub for migrants and diverse nationalities (Amin and Thrift, 2002). In spatial structure, such a city may be part of a functional city-region, conurbation, agglomeration or other geographical unit, without clear boundaries or definition: a fragmented and many-layered vision of an urban community (Soja, 2000). It would contain a complex mix of each of the urban development types, as in Table 7, which links urban change to its environmental implications (based on Ravetz, 2006).

The question then concerns the socio-economic-political dimensions of urban ESS. The ideal of orderly city-region governance managing all its many ESS in the best interests of all citizens seems further away. On current trends, physical environments are likely to be segregated and privatised, leaving the poor in sub-standard environments, and the middle classes struggling for liveable spaces. Even the elite have conflicts over territory and resources, for instance, where city airports expand, or where development displaces nature reserves. There are contradictions everywhere. For example, London's green space investment in former public housing areas can be seen as both urban ESS renewal and as neo-liberal gentrification (Ginn and Francis, 2014). The implication is that the new ESS concepts, methods and tools could struggle to keep up with the pace of change.

Table 7: Urban trends and environmental effects

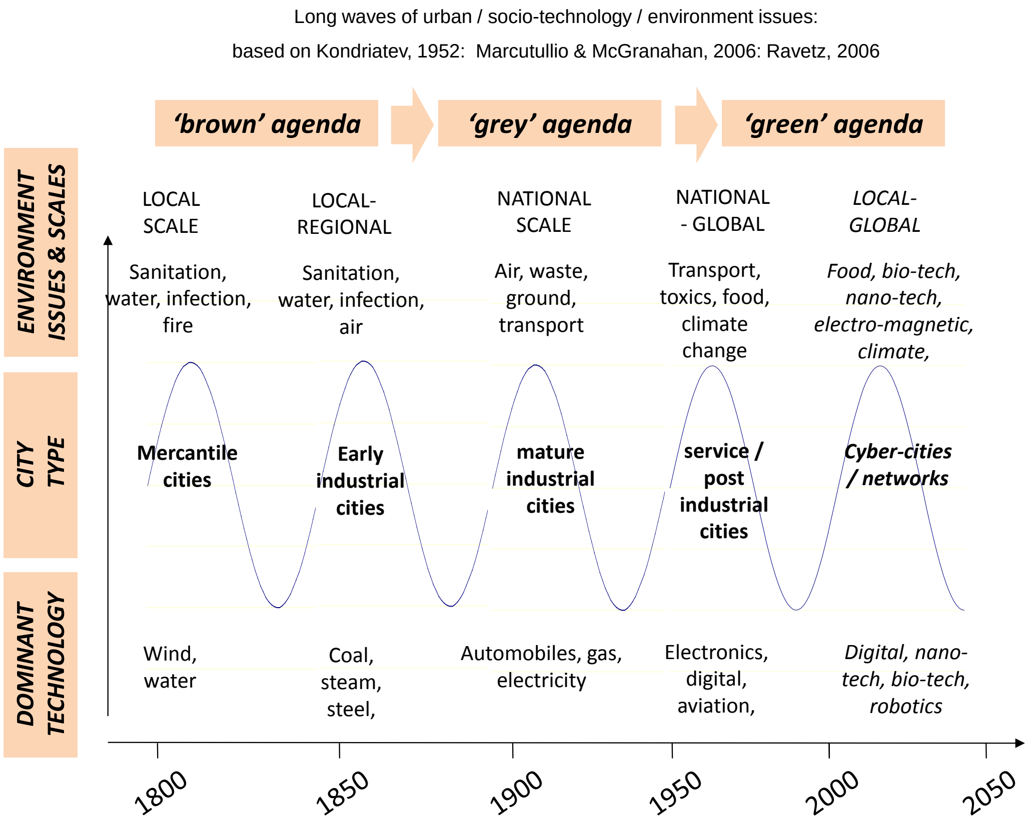
Environmental effects Urban trends	Environmental flows	Environmental stocks	Environmental conditions	Environmental impacts	Environmental benefits
Urbanisation (direct expansion of existing area)	Direct increase in urban metabolism	Direct land use change on fringe	Intensification of urban conditions	Transport demand growth	Transport and energy efficiency
Suburbanisation (expansion of lower density)	Increase medium range commuting	Wider land use biodiversity change	Outward spread of urban conditions	Transport / energy demand growth	Increase in domestic green space
Counter-urbanisation (urbanisation of rural areas)	Increase long range commuting / network pattern	Distributed change in socio-economic- ESS systems	Displacement of urban conditions	Transport / energy demand growth	New rural – urban fringe landscapes
De-urbanisation (shrinking)	Uncertainty and restructuring in ESS metabolism	Derelict and vacant land and buildings	Fragmentation of urban fabric	Pollution and declining infrastructure	Greening of vacant land and buildings
Re-urbanisation (regeneration and repopulation)	Shift towards affluent urbanist metabolism	Intensification of urban land use	Intensification of urban conditions with greater affluence	Gentrification with loss of biodiversity on derelict land	Land and water reclamation
Functional agglomeration (urban-regional)	Increasingly complex metabolism due to specialisation	Specialisation of land use and activities	Polarisation of conditions due to increased fragmentation and segmentation	Transport demand growth	Increased investment due to economic growth

3.1.4 Towards an urban environmental transition

We can put these developments of urban systems in context by charting the combined socio-economic-technical-environmental factors over several centuries (Figure 8). The so-called 'urban environmental transition' extends the concept of techno-economic Kondriatev 'long waves', to look at urban socio-technical-environmental 'agenda' (McGranahan, 2006; Ravetz, 2006). To generalise, a mercantile city was powered mainly by wood and water, and its main concerns were sanitation, water supply and infectious disease. The industrial city went through several stages, from coal and water transport, to electricity and automobile transport. The post-industrial city is oriented around digital systems, with a different pattern of environmental risks including global climate change, food chains, cyber-security and so on. Various ‘agenda’ can be seen:

- ‘brown agenda’ – a focus on poverty, including human sanitation, water supply, and air pollution;
- ‘grey agenda’ – more focus on production, where environmental issues focus on industrial pollution and urban transport impacts;
- ‘green agenda’ – more focus on consumption, including global climate emissions, consumer supply chains and corporate responsibility.

Figure 8: Urban Environmental Transitions



As each socio-technical-environmental long wave develops, so does its spatial extent: from local to regional, then national and global. However in the current wave of global resource extraction and supply chains, we can see a new focus on local environments, in terms of local landscapes, community enterprises and cultural identities.

With regards to the upcoming wave, there are no effective forecasts, but some plausible trends and challenges for the UK urban environment can be put up for discussion (Roberts et al, 2009):

- digital disruption and possible darkness – the ICT transition could continue with new means of surveillance, social engineering, cyber-realities, fundamentalist cults, sabotage and counter-terrorism. Social risk distribution could shift from gross pollution to more complex risks via food chains, bio-accumulation, occupational risk, bio-technologies and nano-technologies. Positional goods of space, territory and environmental quality, could continue to be appropriated by power and wealth, using cities and regions as the arena;

- climate, water, and desertification – the projected rise in global temperatures could hit urban ESS in unpredictable ways. Water could be in shorter supply and increasingly privatised, so the grass of the rich could literally be greener than that of the poor (Scheumann et al, 2008);
- new forms of social / cultural conflict, as the advent of the race riot and the suicide bomber could bring new kinds of asymmetrical conflict, transforming the public realm. Migration and mobility could see accelerated mixing of communities and cultures, from globalised production and consumption, and enhanced transport and communications. Segmentation and fragmentation could bring the partitioning of urban spaces into safety and danger; and
- regional spatial development – the shift could continue towards larger city-regional agglomerations, competing in global networks, with pressure for edge city business and retail parks. Meanwhile, local spatial development could see new forms of neighbourhood planning and environmental action. For urban form there could be new combinations of workspace, leisure, culture, education and retail, all controlled by private security.

3.2 Pressures and driving forces of change

As to the future, we need to explore the driving forces of change. Below is a preliminary set of '24 drivers' which are most relevant to the UK system of cities and urban ESS (summarised in Table 7). These are arranged in domains based on the futurists' 'STEEP' format, with the additions of 'cultural' and 'urban' domains (Loveridge, 2008). The list was road tested in the 'Future of Greater Manchester' project[2]. The list does not aim to be definitive; rather it is a set of notes for thought provocation and further discussion.

Social and community drivers

Demographic change: population growth and structural change; growing share of elderly and "100+"; changing family patterns; and growth of single-person households.

Inequality trends: growing enclaves of deprivation alongside enclaves of wealth, challenges to social cohesion, and possibly leading to new forms of social enterprise and self-help.

Health and lifestyle: continuing pressure / restructuring of health service; advances in biotechnologies (genomics, stem cells, prosthetics, etc.); and links to lifestyle, food etc.

Technology and infrastructure drivers

Digital revolution: continuing growth and power of information technology, including internet of things, wearable computers, AI and robotics, augmented reality, social media and 'Generation Y'.

Materials and manufacturing: "reinvention" of manufacturing; new materials, 3d printing, nano-technology, robotics, bio-mimicry: 're-shoring' and new business models; and re-use / recycling etc.

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[2] citations are located on http://gm2040.com/trends-drivers-of-change/

Transport and communications: urban mobility / accessibility transition; and smart integration / geo-location, electric shared or driverless cars, cycling or walking, HS2 or HS3, and virtual reality etc.

Economic and employment drivers

Globalisation: rise of emerging economies as major producers and as mass markets; and changing division of labour, with global value chains, offshoring, and new forms of regional specialisation.

Economic restructuring: continuing shift from industry towards services and finance; and growing power of investors and corporations over local economic affairs, governance, infrastructure etc.

Work and livelihood: rising insecurity and decline of traditional / formal jobs, rise of freelancing, changing work-life balance; increased automation, polarisation of workforce and career structures; and new markets and valuations for urban ESS.

Environment and resources drivers

Global climate and resources: impacts of climate change, incl. flood, drought, heat, storm; insecurity of resources (energy, water, food, materials); and indirect impact of migration and conflict.

Local environment: trends in air and noise pollution; pressure for urban climate adaptation, flood protection etc; and increases in urban food, greenspace and biodiversity, healthy living etc.

Energy and low carbon transition: pressure on energy system; new energy production, storage, distribution, harvesting; radical solutions in buildings and industry; and carbon budgets and markets.

Policy and governance drivers

Multi-level and devolved governance: trend of partial devolution to GM and other city-regions, elected Mayor etc; and changing relations between regions and nations of the UK and the EU.

Private-public balance: continuing public deficit and austerity pressures; privatisation of formerly public assets and public services; marketisation of public goods and ESS; and social innovation for public-private-community partnerships.

Trust in governance and society: Growth of political distrust, alienation, and extremist parties; and responses in activism, digital governance, crowd-source participation and investment.

Culture and values drivers

Lifestyles and well-being: diversification of lifestyles, rise of identity politics and new forms of community; and changing work-life balance, social enterprise and community networks.

Migration and diversity: continuing migration trends: internationally and within UK; both inward and outward; and leading towards urban ‘super-diversity’.

Education and skills: demand for new workforce skills, technical and social capabilities; and potential responses in new forms of education and training, e.g. online, blended, and lifelong learning.

Urban development drivers

Urban development and regeneration: continued growth of the regional centre/ higher education / airport axis; decline in town centres and polarisation of urban areas; and new forms of area and local regeneration.

Housing and community: growing housing stress, supply / demand market failures; transient neighborhoods and communities; and potential responses in new forms of housing design, tenure and finance.

Urban public realm of privatised spaces, housing and enclaves, at the expense of public or community spaces, public or social housing clusters.

Urban system driver

North-south and regional balance: growth and overheating of London and southeast; potential responses e.g. new regional distribution; and rural migration and shrinkage of industrial areas.

Urbanisation / peri-urbanisation of rural areas combined with 'rural-isation' of cities.

Shrinking of industrial cities and towns, coastal towns and remote rural areas; compact city and high density forms; in conflict with market pressure for suburban forms.

Overall, some drivers of change are fairly certain and predictable for some time to come: e.g. demographic ageing. However, even for these, the implications may be quite uncertain. For example, will the elderly prefer rural villages close to nature, or urban locations close to services, or other alternatives which depend on technologies yet to emerge? One way to explore drivers of change and uncertainties, is to identify the bilateral choices or 'forking paths', i.e. one option *versus* another option. This is not to imply hard and fast choices, rather to suggest a range of uncertainty between extremes, as summarised in Table 8. This can then be used as the basis for scenario development.

Table 8: Drivers of change and uncertainty

	ESS '*Within*' the city (local and micro-scale ESS) (a)	ESS '*Around*' the city (spatial dimensions of ESS) (b)	ESS '*Through*' the city (metabolic flows of ESS) (c)	ESS '*For*' the city: (ESS-related socio-economic systems) (d)
Social, community	Growing exclusion and fragmentation **versus** inclusion and community.	Polarisation of neighbourhood types and structures **versus** mixing and balancing.	Universal access to infrastructure **versus** selective, privatised access.	Demographic ageing trend favours rural locations **versus** urban locations.
Technology, infrastructure	Growth of micro-gen, novel greenspaces etc **versus** more centralised systems. Rise of smart / high-tech eco-management **versus** retro / low-tech.	Integrated systems of industrial ecology, energy cascade, carbon cycling etc **versus** individual systems.	Energy transition: fracking, nuclear, fossil **versus** wind, solar, bio-mass, bio-fuels. Water transition: centralised supply **versus** decentralised / DSM.	Social media / smart city infrastructure **versus** decentralised and downshifted.
Economic, employment	Growth of third sector / intermediate labour in local food etc **versus** formal employment structures.	Private investment and cost recovery for ESS **versus** public investment and multi-valuation.	Investment and jobs for low-impact energy, transport, building, agriculture etc **versus** conventional growth.	Investment and jobs for circular industrial ecology systems **versus** linear input-output.
Environment, ecology	Growing vulnerability of local habitats to climate change **versus** greater resilience.	Growth of GBI corridors, necklaces etc **versus** habitat fragmentation.	Environmental sustainability policy agenda **versus** material / economic growth policy.	Severe impacts of climate change, flood, storm, heat, drought, sea-level etc **versus** moderate impacts.
Policy and institutions	Stronger regime of private property **versus** stronger rights for public access.	Urban-regional spatial planning **versus** market deregulation approach.	Private investment and cost recovery for ESS **versus** public investment and multi-valuation.	Privatised property and enterprise **versus** shift to public assets and access.
Cultural, ethical	Rising collective responsibility for ESS **versus** individualist attitude.	Growth of rural / peri-urban cultural lifestyles **versus** urban / suburban.	Culture of growth and technology **versus** culture of low-impact lifestyles and conservation ethics.	Environment ethics and justice **versus** free market.
Urban, spatial	Urban and building design is flexible and open to habitats and ESS **versus** closed system air conditioned buildings	Urban population and/or area growth: counter-urbanisation **versus** re-urbanisation. New garden cities / extensions **versus** urban infill and brownfield development.	Supply side growth trends for energy, water, materials, transport etc **versus** sustainable growth demand management.	UK urban system: Greater London and SE growth **versus** regional growth. Regional economic divergence **versus** convergence.

3.3 Climate change projections, impacts and responses

Climate change is perhaps the most crucial of all physical factors, bringing increasing pressures on all types of urban ESS. So we here focus on climate change. This starts with a summary of the most recent projections from the UKCIP report (Jenkins et al 2009).

Summer, winter and annual mean changes by the 2080s (relative to a 1961–1990 baseline) under the Medium emissions scenario. Central estimates of change (those at the 50% probability level) followed, in brackets, by changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively). (UKCIP, 2010)

All areas of the UK warm, more so in summer than in winter. Changes in summer mean temperatures are greatest in parts of southern England (up to 4.2ºC (2.2 to 6.8ºC)) and least in the Scottish islands (just over 2.5ºC (1.2 to 4.1ºC)).

The biggest changes in precipitation in winter, increases up to +33% (+9 to +70%), will be likely along the western side of the UK. Decreases of a few percent (–11 to +7%) are seen over parts of the Scottish highlands. The biggest changes in precipitation in summer, down to about –40% (–65 to –6%), are seen in parts of the far south of England. Changes close to zero (–8 to +10%) are seen over parts of northern Scotland.

The Met Office Hadley Centre regional climate model projects reductions in winter mean snowfall of typically –65% to –80% over mountain areas and –80% to –95% elsewhere. We make no assessment of how the urban heat island effect may change. It is very unlikely that an abrupt change to the Atlantic Ocean Circulation *(Gulf Stream)* will occur this century.

The range of absolute sea level rise around the UK (before land movements are included) is projected to be between 12 and 76 cm for the period 1990–2095 for the Medium scenario. Taking vertical land movement into account gives slightly larger sea level rise projections relative to the land in the more southern parts of the UK where land is subsiding, and somewhat lower for the north. The land movements are typically between –10 and +10 cm over a century.

There follows a summary of main types of risk (also with a few opportunities), from the UK Climate Change Risk Assessment for the National Adaptation Plan (Defra, 2012):

Risks: Low water levels and reduced river flows leading to increased concentration of pollutants from agriculture, sewage and air pollution damaging freshwater habitats and other ecosystem services. Soil moisture deficits and erosion impacting biodiversity and soil carbon and increasing risk of wildfires. Increased prevalence of invasive non-native species, pests and pathogens impacting on animal, plant and human health provisioning services (such as fisheries) and biodiversity. Warmer rivers, lakes and seas impacting on biodiversity and the productivity and functioning of aquatic and marine ecosystems.

Flooding and coastal erosion impacting on key coastal habitats and other ecosystem services (including the extent of beaches and nature sites for tourism). Loss of climate space, with species unable to track climate change especially resulting from habitat fragmentation (due to cumulative impact of risks and policy decisions taken in other sectors). Possibility of algal blooms, ocean acidification and species range shifts impacting on marine habitats, species and ecosystem services. Changes in timing of seasonal events and migration patterns can result in mismatches between species such as predator-prey/host relationships.

Opportunities: Higher temperatures leading to increase in some provisioning services for example, agriculture and forestry (assuming that water availability is not a constraint). Increased habitat range for some generalist species e.g. warm water fish or southerly insects and plants.

Although the UK climate is relatively sheltered and benign compared to many, it's fair to say that many causal paths which are more indirect or inter-connected are hardly mentioned. For instance there may be profound effects on ground stability (Douglas, 2013); on the loss of species such as bees: or on the urban resilience to flood or drought (Lindley et al, 2006: White, 2013; Walsh et al, 2011). The recent Climate Change Risk Assessment (Defra, 2012) highlights that climate change impacts may manifest through sudden tipping points in extreme conditions, rather than smooth changes.

3.3.1 Climate change and social vulnerability

The physical impacts of climate change then cause further impacts or risk to social and economic systems. A generalisation would see the most poor and vulnerable communities in areas of highest risk and lowest resilience, before or after the extreme weather event. However, the reality is more complex, as shown by Lindley et al (2011). Figure 9 on the left shows a spatial mapping overlay of local risk from river or coastal flooding, combined with five key determinants of vulnerability. These include sensitivity to hazards in terms of age and health, enhanced exposure in the physical environment, ability to prepare, ability to respond, and ability to recover after the event. On this mapping, about 8% of neighbourhoods are in the most vulnerable category, most in urban centres adjacent to the coast, but also with large areas of the east of England, and other low-lying estuarial landscapes.

For heat vulnerability, as defined with similar determinants, the right hand part of Figure 9 shows a more urban focus (Lindley et al, 2011). London contains 40% of all neighbourhoods with high heat vulnerability. Other urban centres correlate closely with factors of deprivation, i.e. age, ill-health, housing conditions, education levels etc. However there are still pockets of vulnerability in coastal areas with high proportions of the elderly. (Note: England only is shown here: the full report also shows separate mappings for Scotland, Wales and Northern Ireland.)

These snapshots raise urgent questions for the future of cities and the urban ESS. Will the hazard and the social vulnerability to climate change increase or reduce? Is existing policy sufficient, and if not what more can be done?

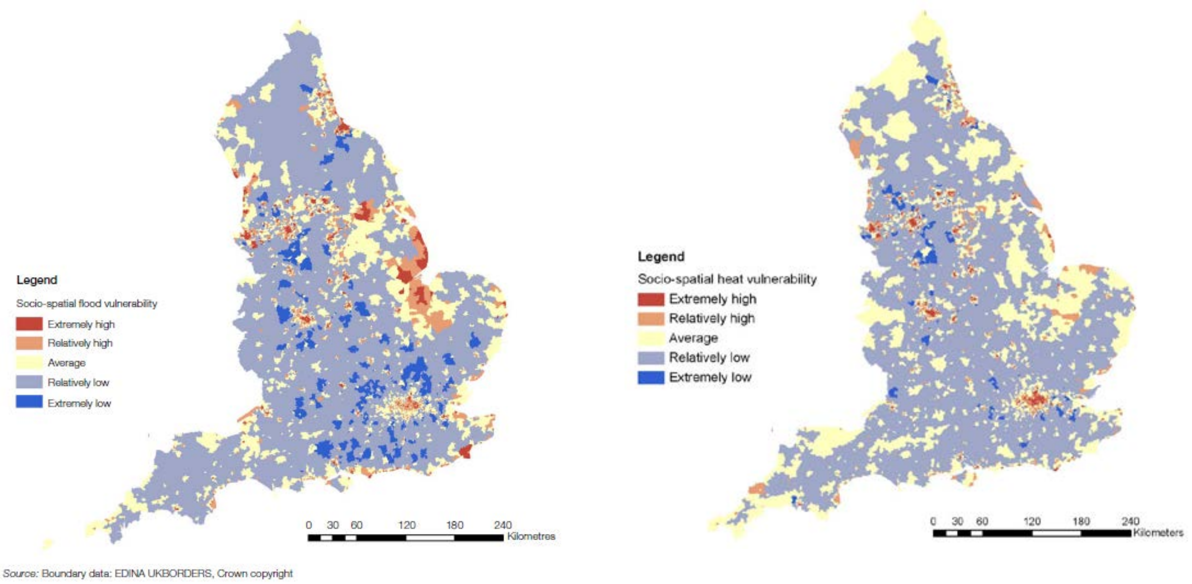
From the above, vulnerability to both flood and heat involves a combination of human and physical factors. Each includes urban form and design, building form and construction, social factors of dependency and deprivation, and institutional factors such as public services, utilities and emergency services. In response, urban greenspace and GBI can attenuate flooding or mitigate urban heat islands. Buildings can be located safely or designed for ambient cooling; social cohesion and mutual aid can be promoted; and public services can be managed for integration and participation. While many or all these might be assumed in an affluent suburb in a prosperous region, many parts of the UK at the moment see excluded and dependent communities, in poor housing conditions, with under-funded public services.

The implication of the climate change case is that the future of urban ESS (in terms of social resilience or vulnerability), is as much a question about society and governance, as it is about the physical form of cities and buildings.

Figure 9: Climate change and socio-spatial vulnerability

Socio-ecological vulnerability: flooding and heat wave risk (England data only), Lindley et al 2011.

Socio-spatial vulnerability to flood risk **Socio-spatial vulnerability to heat risk**



3.4 Thresholds and tipping points

In all futures studies it is essential to stretch common assumptions to the extremes, and to think 'outside of the box' on radical possibilities, where the future is not a simple continuation of the past. Below is a draft list for discussion, of potential 'wild cards' and tipping points (Table 8). A wild card is basically a 'high impact, low probability event': a tipping point is 'a process of discontinuous and at times disruptive change' (O'Riordan and Lenton, 2013). The wild cards shown here are based on an interactive digital library from the EU-funded project 'Inter-connecting Knowledge'[3]. The tipping points here are based on previous UK futures work from the EU Integrated Visions project (Van Asselt et al, 2005). The list below cannot be definitive, rather it aims to stimulate debate on the implications of wild cards and tipping points, positive, negative, local and global:

- social fragmentation tipping point - there may be urban riots, lock-downs, mass squatting and sudden migration of minority groups;
- technology innovation tipping point - it seems likely that digital technology (ICT) continues to drive social and economic change, but few can predict the results. One plausible outcome could be that urban communities become divided between the physical or virtual worlds;
- economic collapse tipping point - again it seems likely that economic globalisation accelerated by ICT, becomes increasingly unstable. A plausible systemic collapse of the

[3] wiwe.iknowfutures.eu

global financial system forces rapid moves towards more resilient local and urban economic systems;

- environment / climate change tipping point - some models envisage a possible acceleration of climate impacts, from the disruption to global circulation from arctic sea-ice melting. One plausible outcome is that the UK suffers a catastrophic series of storms, floods, droughts and heatwaves;
- environment / energy tipping point - a peak oil threshold event could combine with geo-political pressures, and strong climate mitigation policy, so that the current energy-intensive system comes to a halt. On a benign scenario this could result in rapid moves to self-sufficiency in energy, food and water. On a dystopian scenario there would be riots, martial law and the spread of pandemic disease;
- political / governance tipping points – it is quite plausible to envisage a total privatisation of all public services, combined with total ICT surveillance which enables total information recall and cost-recovery models;
- cultural / personal tipping points - there are already signs of the acceleration of mental illness, coupled with extreme lifestyle behaviour, both indoor and outdoor; and
- urban / spatial tipping points - even in the highly regulated UK we could see a flight from the cities with rapid counter-urbanisation of rural areas, alongside new kinds of informal and short life housing in trailer-parks, sparked by the deregulation of Green Belt and similar policies.

Table 9 takes these general directions and follows some of the implications for urban ESS in the different layers, 'within, around, through and for' the city. Some of these appear 'off the wall', and can be put into context by looking at patterns of change over the previous half century.

Table 9: Some possible wild cards / tipping points

	ESS '*Within*' the city (local and micro-scale ESS) (a)	**ESS '*Around*' the city (spatial dimensions of ESS) (b)**	**ESS '*Through*' the city (metabolic flows of ESS) (c)**	**ESS '*For*' the city: (ESS-related socio-economic systems) (d)**
Social, community	Many retreat to virtual lifestyles, of 'google glass' gaming headsets and intravenous drips.	Gated community enclaves are the norm; segregation of urban / suburban areas.	All local energy sources are now community owned with robotic self-maintenance.	Climate change causes massive migration to safer countries e.g. UK.
Technology, infrastruct	'Total smart-tech' runs the home and garden.	New leisure / theme / national parks based on total virtual reality.	New energy / water harvesting - large infrastructure becomes redundant.	New Zero-waste industrial ecology parks with distributed printing.
Economic, employment	Housing crisis grows; London gardens and roadsides are turned to temporary housing.	No-go zones of unemployment and deprivation, policed by G4S private militia.	Reuse / recycling is the biggest sector of enterprise and employment.	ESS-finance is big business, with market bubbles and crashes.
Environment, ecology	New eco-urban designs; vertical gardens, green roofs, domestic aquaculture.	Storm surge combines with major fluvial flooding in Thames with massive damage to London.	Fracking goes ahead in the UK; major protests with mass arrest of activists and community leaders.	Climate change accelerates; flood, storm, heat, drought sea level etc: food prices double and more.
Policy and institutions	First neighbourhood level 'autonomous zone'.	Outsourcing of local government is complete; online citizen forums advise G4S etc.	All urban infrastructure owned and run by foreign firms; retail prices double.	All public land is privatised OR private land is nationalised.
Cultural, ethical	Sustainability backlash growth in SUVs and extreme materialism.	Eco-cultural low-impact communities go back to the land.	Ethical climate change movement suddenly takes off, UK cities are in chaos.	First language / sentient exchange with other species.
Urban, spatial	Mass squatting by homeless on urban vacant land.	New floating cities in Thames Estuary / other flood zones.	UK's first off-grid zero-carbon/waste city is declared.	New city in Thames Estuary feeds London; 40 new garden cities across UK.

3.5 Future scenarios

3.5.1 Links with scenario structure

Scenarios are simply a 'structured conversation' about the uncertainties of the future, and a container for 'what-if' questions. The scenario structure in this study is based on the global standard of the IPCC, which is adapted to a simple urban / ecology axis. (The UK NEA scenarios were considered, but the 6-fold structure did not seem so suitable for exploring urban issues).

We start here with four scenarios, adapted from the IPCC socio-economic scenarios as in SRES (Special Report on Emissions Scenarios (IPCC, 2000), and also reflecting recent work on European spatial development (www.plurel.net). One benefit is a huge body of modelling and projections which has been carried out on these scenarios. They are arranged by two main axes:

- macro level top down dynamic OR micro level and bottom up dynamic; and
- private enterprise based values OR public collective responsibility type values.

The result is the 'opposite of a forecast'. Rather, it is a space of possibilities, which highlights the context for the interactions of the UK system of cities and their ESS:

- ***'global enterprise'*** – a world of rapid economic growth and technology innovation: ICT, nano-technology and bio-technology transform lifestyles and working patterns. Urban development sees more 'polycentric' networks of towns and cities;
- ***'local enterprise'*** - a world of self-reliance, local enterprise and communities. While population growth and technology innovation are slower, the effects of climate change come rapidly, with major disruption to cities and infrastructure;
- ***'global community'*** – a global approach to sustainable development. Energy and resource shortage begin to shape location choices and urban structures, and there is a return to larger cities and towns, while more remote rural areas decline; and
- ***'local community'*** – social groups retreat into enclaves, amid the fragmentation of society by generation, gender, ethnicity and special interests. Cities disperse as younger migrants dominate city centres, older natives move to gated enclaves, and peri-urban areas become 'peri-society'.

These context scenarios are summarised in the 2x2 matrix in Table 10.

Table 10: Context scenarios

Based on SRES (IPCC 1999) and PLUREL scenarios (Ravetz et al 2012)

Global / local ***Public / private***	***GLOBAL SCALE***	***LOCAL SCALE***
Enterprise dynamic **(private sector leads)**	Rapid economic growth, global population that peaks in mid-century, and the rapid spread of more efficient technologies. Information and communications technology (ICT), nano-technology and bio-technology, transform lifestyles and working patterns	A world of self-reliance and deregulation, local enterprise and local identities. While population growth and technology innovation are slower, the effects of climate change come rapidly, and there is major disruption to urban economies, services and infrastructure
Community dynamic (public sector leads)	This is driven by a global approach to sustainable development, led by governments, with just a few sacrifices on individual civil liberties and local enterprise. Energy and resource shortages begin to shape location choices and urban structures, together with climate change impacts	Many social groups retreat into urban or peri-urban enclaves, amid the fragmentation of society by generations, genders, ethnicity and special interests. The ethnic division of cities is driven by the increased in-migration of the working-age population.

3.5.2 Key axes and 'proto-scenarios' for urban ESS

Each of the above is relevant in some way to the cities theme: each represents profound uncertainties, rather than robust projections or forecasts. The next step is to identify two cross-cutting clusters of uncertainties, based on two themes, the 'urban' and the 'ecosystem':

- nature friendly versus nature averse - such as increases in outdoor living, contact and engagement with ecosystems: local and regional circular production: eco-friendly outdoor-focused low impact design of built environment, versus the opposite case;
- virtual lifestyles in controlled indoor environments - cities of hard surfaces and technological functionality, with global supply chains. However within this are counter

cases: e.g. where hi-technologies and ICT systems enable the greening of indoor environments, micro-climatic design, and urban food production etc;

- urban friendly versus urban averse – this includes concentration of the population in more compact urban areas, where urban quality of life increases. The compact city ideal might appear to reduce potential for GBI, but there are new possibilities in localised micro-scale greening as above, versus the opposite case; and
- counter-urbanisation and population of rural areas - urban areas become less desirable for the majority, due to social and economic factors. This could result in wasteful urban sprawl, or it might increase direct contact with ecosystems for the majority of people.

This space of possibilities is summarised in a 2x2 matrix in Table 11.

Table 11: Urban-ecosystem scenario combinations

'Urban' axis **'Nature' axis**	**Urban friendly** **(centralising dynamic)**	**Urban-averse** **(de-centralising dynamic)**
Nature-friendly **('Ecological' ways of thinking and management)**	**ECOLOGICAL URBANIST** (Freiburg model): (can be low or high-tech): the classic 'sustainable urban form' with dense, mixed use urban forms; greenspace is used and managed intensively: there are many layers of resilience to climate and other environmental hazards; urban ecosystems are oriented to improving social and cultural quality of life factors.	**ECOLOGICAL HINTERLAND** (Greater Stockholm model): many households relocate to peri-urban and rural areas, to be in closer contact with nature, and to produce food, energy, natural materials etc. Local economies are revitalised and better connected with local ecosystems, with alternative forms of ownership and management.
Nature-averse **('Technological' ways of thinking and management)**	**TECHNOLOGY URBANIST** (Singapore model): climate controlled sealed buildings are the norm, as environmental hazards and social divisions increase; food, water, energy etc come through hi-tech centralised systems. Urban greenspace which is not developed is generally privatised and carefully managed.	**TECHNOLOGY HINTERLAND** (Los Angeles / Dubai model): car-based land-extensive urban sprawl; many local ecosystems are destroyed or degraded, or, turned into private leisure / tourism such as golf. Food, energy, water etc are imported over large distances by privatised firms according to global markets.

Finally the 'socio-economic context' scenarios and the 'urban-ESS' proto-scenarios are brought together in a cross-alignment matrix, to identify the combined scenarios which are most plausible and most relevant, as set out in Table 12.

Table 12: morphological combinations for context / ESS scenarios

Context scenarios >> ESS scenarios: vv	'Global enterprise' (A1)	'Local enterprise' (A2)	'Global community' (B1)	'Local community' (B2)
Ecological urbanist	*(partial alignment)*		*(partial alignment)*	**ALIGNED**
Ecological hinterland		**ALIGNED**	*(partial alignment)*	*(partial alignment)*
Technology urbanist	*(partial alignment)*	*(partial alignment)*	**ALIGNED**	
Technology hinterland	**ALIGNED**	*(partial alignment)*		*(partial alignment)*

3.5.3 Combined scenarios for urban ESS

With a workable combination of external and internal scenario types, we can set out a scenario framework for urban ESS in the UK (summarised below in Table 13, with a visualisation in Figure 10). The brackets (as in A1), refer to the corresponding codes used by the SRES scenarios. *(Note: italics in the following section shows abbreviated format.)*

'Technology hinterland' / 'Global enterprise' (A1)

Cities in the UK could spread and merge across the affluent growth areas of the southeast and southwest, while those in other regions stagnate. The booming economy is highly globalised, while society fragments into enclaves of rich and poor. Climate change brings storms, heatwaves and droughts, and most people retreat inside sealed air-conditioned houses and workplaces. However, the new markets in 'ecological services' such as rivers and forests add to GDP. Characteristics include:

- *fragmented society and growing tensions - high population growth, global hi-tech supply chains, rapid ICT innovation, private firms, global labour market, high economic growth;*
- *ESS degradation and pollution - rapid climate change, corporate-driven governance, global level material growth, winner-takes-all culture for ESS;*
- *car-based urban sprawl with sealed buildings - counter-urbanisation, airports and other hubs are over-used with major pollution, urban heat island effects, derelict and under-used land and resources are widespread, due to sprawl and pollution.*

'Ecological hinterland' / 'local enterprise' (A2)

In this scenario the UK goes more local, after exiting the EU, and there is increased devolution for city-regions, alongside Scotland, Wales and Northern Ireland. Economic growth and technology innovation is slower, depending on local entrepreneurs: government is largely privatised and public services now depend on local philanthropists. Climate change brings storms, floods and droughts, and the effects are magnified as there is little capacity to respond. Other ecological assets are privatised, with rapid spread of security fences around rivers, forests and mountains. Characteristics include:

- *privatised society - retro social models, medium population growth, local low-technology supply chains, stable ICT, private firms and local labour markets, medium economic growth;*
- *exploitation and privatisation of ESS - rapid climate change with deregulated controls, corporate driven governance, at local level, material growth, winner-takes-all culture;*
- *localised rural development - low-tech eco buildings, sprawl and suburbanisation, growing air and water pollution pressure from deregulation and privatisation, and derelict and under-used land and resources from deregulation and market gaps.*

'Technology urbanist' / 'Global community' (B1)

Current trends towards a 'managerial society' continue and become ever more globalised, enabled by advanced ICT in all aspects of public services and economic activity. Climate change starts to be managed at the global level (i.e. the acceleration in emissions is slowed), climate impacts hit the UK, but a well-funded governance system can respond for all sections of the population. Cities are contained and managed, and become ever more 'smart', not only in ICT but in public services, local economies and social enterprises. Local ESS are also in smart management, so that rivers and forests are freely accessible while payment / investment systems ensure conservation. Characteristics include:

- *strong governance system aims for equality and integration - low population growth, global hi-technology supply chains, rapid ICT innovation, social enterprise, global activities, medium economic growth;*
- *conservation of ESS and public access - moderate climate change, public and civil governance at global level, socio-cultural growth, ecological stewardship; and*
- *intensive large scale urban form with sealed buildings - re-urbanisation, large compact cities generate pressure and vulnerability of infrastructure, derelict and under-used land and resources in hinterland, due to planning gaps.*

'Ecological urbanist' / 'Local community' (B2)

The fourth scenario suggests a possible outcome of the sustainability vision – small, low-impact, zero carbon, circular economy communities, largely self-sufficient in basic resources. There's also a possible downside, which sees a fragmentation into self-seeking enclaves, where the wealth-poverty gap widens and where trade and exchange becomes very difficult. Climate change brings floods, droughts, heatwaves and sea-level rise, but the general response is to seek local protection and resilience in social and low-tech solutions. New communities form in both the inner cities and the peri-urban landscape. Urban ESS are now a priority, but there are tensions between the needs of small communities and the larger towns and cities. Characteristics include:

- *enclave society - aims for local self-determination, medium population growth, local low-technology supply chains, stable ICT, social enterprise, local activities, low economic growth;*
- *conservation of ESS with privatisation - moderate climate change, public and civil governance at the local level, socio-cultural growth, ecological stewardship; and*
- *intensive small scale urban form, with low-tech eco-buildings - de-centralisation, pressures locally contained in enclaves, derelict and under-used land and resources in the hinterland, due to social fragmentation.*

Figure 10 below provides a simple visualisation of typical urban forms in each scenario. In A1 there are huge private mansions serviced by invisible workers. In scenario A2, governance is not enough to prevent widespread flooding and other events. Scenario B1 shows a more ‘urbanist’ model with high density diverse neighbourhoods, somewhat like a northern European city. Meanwhile, scenario B2 shows a slightly dystopian outcome of sustainable communities with rather high walls and fences.

Figure 10: Urban ecosystems scenario visuals

Urban systems: context scenarios. Based on PLUREL (2011) and on IPCC ‘SRES’ 2001.
Image © Joe Ravetz

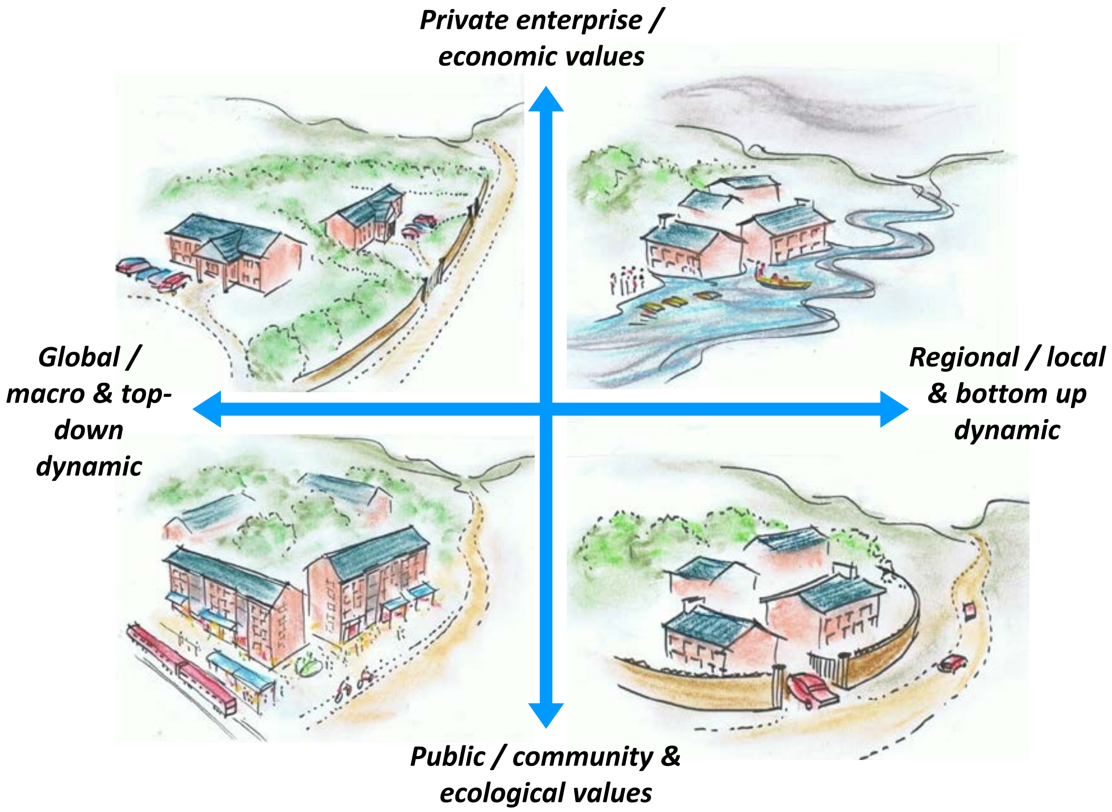


Table 13: Combined scenarios for urban ESS

	'Technology hinterland' ***'Global enterprise'*** ***A1***	***'Ecological hinterland'*** ***'Local enterprise'*** ***A2***	***'Technology urbanist'*** ***'Global community'*** ***B1***	***'Ecological urbanist'*** ***'Local community'*** ***B2***
Social, community	Fragmented society, growing tensions. High population growth.	Privatised society, retro social models: Medium population growth.	Managed society: aims for equality and integration. Low population growth.	Enclave society. Aims for local self-determination. Medium population growth.
Technology, infrastructure	Global hi-tech supply chains. Rapid ICT innovation.	Local low-tech supply chains. ICT stable.	Global hi-tech supply chains. Rapid ICT innovation.	Local low-tech supply chains. ICT stable.
Economic, employment	Private firms, global labour market. High economic growth.	Private firms, local labour market. Medium growth.	Social enterprise, global activities. Medium growth.	Social enterprise, local activities. Low economic growth.
Environment, resources	ESS degradation and pollution. Rapid climate change.	Exploitation and privatisation of ESS. Rapid climate change.	Conservation of ESS and public access. Moderate climate change.	Conservation of ESS with privatisation. Moderate climate change.
Policy and institutions	Corporate-driven governance at global level.	Corporate driven governance at local level.	Public and civil governance at global level.	Public and civil governance at local level.
Cultural, ethical	Material growth, winner-takes-all culture for ESS.	Material growth, winner-takes-all culture.	Socio-cultural growth, ecological stewardship.	Socio-cultural growth, ecological stewardship.
Urban, spatial	Car-based urban sprawl, with sealed buildings. Counter-urbanisation.	Localised rural development with low-tech buildings. Sprawl and sub-urbanisation.	Intensive large scale urban form with sealed buildings. Re-urbanisation.	Intensive small scale urban form, with low-tech eco-buildings. De-centralisation.
INTER-CONNECTIONS: ESS pressures and vulnerabilities in land and resources	Airports and other hubs are over-used with major pollution, urban heat island etc.	Growing air and water pollution pressure from deregulation and privatisation.	Large compact cities generate pressure and vulnerability of infrastructure.	Pressures locally contained in enclaves.
INTER-CONNECTIONS: ESS opportunities in gaps and under-used land and resources.	Derelict and under-used land/resources widespread, due to sprawl and pollution.	Derelict and under-used land/resources, from deregulation and market gaps.	Derelict and under-used land/resources in hinterland, due to planning gaps.	Derelict and under-used land/resources in hinterland, due to social fragmentation.

4. Transitions and synergy mapping

Here we explore responses to the uncertainties of the future. First, some common 'critical perspectives' on ESS: then some topical 'transitions' for urban-ESS, as sense-making and orientation. Third we explore the 'synergistic thinking' for collaboration and strategy.

4.1 Challenges and dilemmas

4.1.1 Critical perspectives: complexity, learning, valuation

Behind the green image of urban ESS lie many kinds of controversies, dilemmas, 'wicked problems', 'spaces of resistance' and conflict between social, cultural, economic or political values (Rittel and Webber, 1973). For example, tree-lined London squares are closed to the public, alienated youths start fires in the woods, urban canals become dumping grounds, and even the greenest cities and towns in the UK disperse their climate burdens onto other countries and other generations.

This calls for critical thinking on the 'services' concept. While being a useful way into the human system / ecosystem relationship, it risks fitting the systems, which are highly complex on both sides, into a simplistic functional scheme (Vadrot, 2014). This applies especially to the economic valuation of ecosystems, which is often problematic. For example, the NEA study of urban ESS gives rather precise figures for monetary values of urban trees, with no indication of uncertainty or confidence (Davies et al, 2011 p389). An urban political ecology perspective sees economic valuation as the beginning of a process of 'financialisation'. This arguably favours a capitalist elite at the expense of the excluded and vulnerable, whether or not it is intentional (Heynen et al, 2006). However there is a counter case that valuation should lead to open debate about values of both tangible and intangible ESS (Bateman et al, 2011).

A complexity perspective seems essential in dealing with urban-ESS interactions. This involves looking at urban ESS not just as items but as processes of social learning and co-evolution (Rodela et al 2012). For example the farming community 'learns' how to gain produce from the land, landowners 'learn' how to manage farmers, agri-food industries 'learn' which products to sell, and so on. In this way, knowledge is not only a technical thing but also an enabler of action. For social learning to transform 'knowledge into action', it must consider normative and critical aspects of institutions, power and ideology (Wynne, 2006). This suggests that more learning-oriented governance could work better with multiple ESS values, in processes of valuation or evaluation (Ravetz, 2015). Again this is in the spirit of the Ecosystems Approach, which in practice may be hindered by the lack of an Urban Systems Approach (see recommendations in Chapter 6).

4.1.2 Critical perspectives: social and environmental justice

A major challenge to the urban ESS concept is the privatisation and enclosure of land. This is visible in city centres and regeneration areas (Minton, 2009), and also in peri-urban and rural areas, where it is estimated that 0.1% of the population are the owners of over 50% of the UK land area (Shoard, 1986: Cahill 2002). For example, the privatisation of playing fields, unmanaged green space and woodlands is of particular concern, with 10,000 sports pitches lost in two decades (DCMS, 2009). Meanwhile there are deeper shades of urban dysfunctions: alienation of the younger generation, fragmentation of public services, health impacts of austerity, harassment of welfare claimants, and crises in housing markets (Stuckler and Basu, 2013). All these and more are recognised in urban policy outlooks such as the EU ‘Cities of Tomorrow’, but the recommendations for policy responses often seem less than adequate (DG Regio, 2011).

‘Environmental justice’ and ‘environmental property rights’ are powerful drivers of change in governance, the corporate social responsibility of business, and changes in personal lifestyles (Westra, 2008). Questions of justice can dominate ESS-related controversies over, for example, the siting of power stations, landfill sites, nature reserves or waterfront regeneration. In each case there are conflicts between property rights, social responsibilities, market systems and democratic processes. Policies for ‘urban environmentalism’ can succeed only by smoothing over the conflicts and contradictions (Brand and Thomas, 2005).

The implication of this and more, is that urban ESS are focused not only on technical issues, but alsp on social, cultural and political challenges and dilemmas. It then follows that progress on enhancing or sustaining urban ESS is possible, only by bringing these challenges into the frame of public deliberation and participation (Baker and Eckerberg, 2014). This forms the backdrop to the exploration of ‘transitions and discourses’ below.

4.2 System transitions and discourses

Given the challenges of the future scenarios in the previous chapter, and the above dilemmas and contradictions, it seems clear that more than marginal adjustments will be needed to respond to wider goals. These can be framed as ‘transitions’: strategic and systemic restructuring of all relevant domains, economic, social, environmental, political and so on (Geels, 2005). For each transition possibly the most important component is that of discourse or narrative, i.e. a conceptual scheme for sense-making and orientation. The first point here is that there is no single discourse with all the answers; rather there is a range of alternatives, each one focused on a different set of social and political values and coalitions (Guy and Marvin, 2001). From another viewpoint these can be explored as ‘Success Scenarios’, i.e. plausible sets of actions and responses, which respond to a range of future challenges and uncertainties (Bezold, 2013).

So there follows a brief outline of the most common transitions relevant to the urban-ESS types. The summary, as in Table 14 below, maps out a tangle of overlapping concepts: transitions, discourses, aspirations and narratives. These are put in the form of ‘HEADLINES’ (and hence the capitalisation). Each one has a following, a literature, and some policy resonance. Some are short lived while others appear perennial. Many are argued to be impractical, with unforeseen costs or consequences, but the significance here is their wider role in ‘framing and reframing’, a process of making sense of challenges and dilemmas (Fischer, 2003).

Table 14: Transitions and 'headline' discourses in urban ESS

	ESS '*Within*' the city (local and micro-scale ESS) (a)	**ESS '*Around*' the city (spatial dimensions of ESS) (b)**	**ESS '*Through*' the city (metabolic flows of ESS) (c)**	**ESS '*For*' the city: (ESS-related socio-economic systems) (d)**
Social, community	LIVEABLE NEIGHBOURHOOD	LIVEABLE CITY INCLUSIVE CITY	RESILIENT CITY	THIRD AGE CITY
Technology, infrastructure	TRANSITION TOWN SMART COMMUNITIES	SMART / FUTURE CITY	TRANSITION TOWN SMART INFRASTRUCTURE	SMART / FUTURE CITY
Economic, employment	PROSPERITY CITY	INTEGRATED REGIONAL STRATEGY:	CIRCULAR ECONOMY RESILIENT CITY	KNOWLEDGE ECONOMY
Environment, ecology	OFF-GRID / CARBON NEUTRAL COMMUNITY	INCREDIBLE EDIBLE TOWN	LOW CARBON CITY ZERO-WASTE CITY	CLIMATE-PROOF CITY BIO-ECONOMY
Policy and institutions	COMMUNITY EMPOWERMENT	STRATEGIC GOVERNANCE	INTEGRATED PLANNING	STRATEGIC POLICY INTELLIGENCE
Cultural, ethical	INCLUSIVE COMMUNITY	CREATIVE CITY	ECOLOGICAL JUSTICE	MULTI-CULTURAL CITY
Urban, spatial	SUSTAINABLE COMMUNITY	SUSTAINABLE CITY-REGION	REGENERATIVE CITY SUSTAINABLE CITY	SMART SPECIALISATION

Social transitions start with the widely known 'demographic transition'. By 2040 around one third of the UK population is projected to be over 65 (ONS, 2011). This has wide implications for the discourse of a 'resilient community' based on mutual aid and social inclusion, for the liveability of neighbourhoods, and for the interactions between humans and urban-ESS. For instance, in a community with a majority of non-full-time workers, there is not only potential but also a practical need to enable cultivation, greenspace maintenance, and ecological activities of many kinds.

Technology transitions often centre on the 'smart cities / future cities' agenda, with ICT seen as the catalyst for technical efficiency, social participation and economic prosperity. There are underlying tensions between the aspiration for local energy or materials: and the efficiencies of scale and advanced technology, as for example in wind turbines.

Economic transitions. There is a universal aspiration for the knowledge based, innovative, competitive city or city-region. This is then matched with ecological concepts such as the circular economy, or the bio-economy. For city-region territories there is an aspiration for a more integrated form of development, i.e. where economic development can lead to social and environmental progress. The fuzzy concepts of 'prosperity' and 'well-being' also pervade such debates.

Environment / ecology transitions include the 'climate-proof city', bio-economy, low carbon city, zero-waste city, transition town and 'incredible-edible' town, off-grid community, and so on.

Many of these show concepts which are radical in technical terms, possibly non-viable in conventional economics, but which may thrive in the context of social and cultural change. For instance the 'Incredible-Edible'[4] concept of food autonomy is about social cohesion, health, education, ecology and community enterprise, as much as the quantities of food produced (see Ravetz and Warhurst, 2013). This overlaps with the cultural transitions of diversity, environmental justice and creative empowerment. To make it work involves policy and governance transitions, looking for combinations of strategic intelligence, entrepreneurial skill, pro-active participation and so on.

All these can then be played out as spatial transitions in the physical city or city-region, in terms of a sustainable city-region, integrated planning, sustainable neighbourhoods, or sustainable regeneration. Urban systems can be characterised as local, urban, regional, national or global in the reach of their hinterlands and supply chains. At present, the ideal of the autonomous, localised, off-grid community or 'circular economy' may seem non-viable or impractical from a techno-economic point of view. However, as a wider policy narrative and social aspiration, it can be powerful. Each of these variations is relevant to the urban-ESS pathways and opportunities to follow:

- autonomous or circular economy community or settlement that generates most of its direct water, energy and food from within or adjacent to its boundaries;
- local urban fringe and hinterland city where most water, energy, food and materials comes from a short distance;
- regional-national city system where most water, energy, food and materials, from wider supply chains; and
- globalised city system where most water, energy, food and materials, from global supply chains. This offers the prospect of technical efficiency, but at the cost of extended chains with energy and waste impacts, together with financial vulnerability at both ends of the chain.

4.3 Synergistic opportunities and co-evolutionary pathways

4.3.1 Ecosystems Approach and beyond

Here we look for some kind of synthesis and synergy: fitting the drivers and uncertainties of the future, with critical challenges and dilemmas, together with the discourses and transitions above. This of course is the aspiration of the Ecosystems Approach (Defra, 2007, but the risk is that inserting a model of holistic inter-dependent thinking into a system of linear 'silo' type governance, is likely to be problematic.

The method here draws on the Ecosystems Approach, and looks more widely in order to mobilise it. This draws on the author's current work on 'cognitive-collaborative-complex' ('C3') systems, with social learning and synergistic intelligence (Ravetz, 2012, 2013, 2014 and forthcoming; Cohen, 2012); a summary is in the Annex.

[4] www.incredible-edible-todmorden.co.uk

Evidently, each of the above urban-ESS transitions and discourses are highly **'inter-connected'**, between actors involved and factors to be managed. So, we need to follow where possible the underlying threads of inter-connection, and look for processes of learning and co-evolution, which can help steer inter-connected conflict **syndromes**, towards inter-connected collaboration and **synergies**. Two main types of inter-connection can be seen:

- inter-connection between **actors** (e.g. building collaboration, trust and synergy between public, private, civic, infrastructure, research and innovation, the household, etc.); and
- inter-connection between **factors** (e.g. coordination and integration between social, technical, economic, environmental, policy, cultural and urban systems).

Steering negative inter-connections towards the positive depends on **'co-evolution'** or social learning on the workings of new systems. We can identify at least three frames or layers of co-evolution and/or social learning:

- **'linear'** type co-evolution **-** for direct interventions in mechanical type situations;
- **'entrepreneurial'** type co-evolution **-** for responses which are based on competitive and extractive types of enterprise; and
- **'synergistic'** type co-evolution **-** in response to more complex multi-valent problems which call for collaborative learning, social deliberation and collective intelligence.

The application of these fundamentals is summarised here in Table 15. This shows on the left hand side a typical linear policy response, based on the assumption that the problems and solutions are those of a typical mechanical system (conceptually). In the middle is the entrepreneurial-type response, based on a materialistic extractive 'winner takes all' model. On the right hand side of Table 15, we see the beginnings of a 'synergistic' response, which aims towards a step-change in the cognitive collaboration and collective intelligence.

This co-evolutionary thinking can then be visualised as a general progression from 'linear' to 'synergistic' (from left towards right on Table 15).

In the **social domain**, we look towards multi-sector ESS stakeholder partnerships, which help towards the goals of social inclusion, empowerment and participation. In the **technology domain** we look for technical solutions which are not only smart but 'wise', in the sense they are more self-organising and self-regenerating, mutually owned at the community scale, integrated between supply and demand, learning from change and feedback, and have a near-zero impact on the life cycle. Such integrated approaches also look towards, for instance, more synergistic food chains, which combine social, ecological, cultural and economic values.

In the **economic domain**, there is a transition from ecosystems as mono-functional 'services', to something more like 'relationships', based on multi-functional value generation. This then enables the 'circular economy' to develop, involving not only a circular flow of materials and recycling, but also a circular flow of regenerative finance, business value generation, and social value in the community.

In the **ecological domain** we again we look beyond ecosystems 'services' as rather deterministic one-way flows, and towards ecosystem 'relationships', based on more holistic social-ecological value generation models and collaborative partnerships. This then promotes more multi-functional, multi-valent, multi-level ESS relationships with users, households, communities or stewards of all kinds.

In the **governance domain**, achieving intelligent and synergistic systems requires a similar level of intelligence in governance, with the capacity to work with complex communities, cultures, asset values, and ESS relationships. In turn we look for cultural and ethical transitions, to enable a more collaborative model of bio-economy and circular economy, where eco-investment and low-impact lifestyles are the norm.

These and similar pathways are deliberately aspirational, but not unrealistic. In fact, the signs of such co-evolution are already widespread, and the seeds of future possibilities are there if we know how to nurture them. The results are there to be seen in practical and creative innovations, in urban ESS, climate adaptation, community empowerment and so on, as shown in the examples in the next chapter (Circle-21, 2014).

Table 15: Co-evolutionary and synergistic pathways

Domains	LINEAR '1.0' CO-EVOLUTION	EXTRACTIVE '2.0' CO-EVOLUTION	SYNERGISTIC '3.0' CO-EVOLUTION
Social, community	Social functions of urban-ESS in leisure, health etc, are fixed, prescriptive, segregated.	Social structures based on hierarchy and competition; urban-ESS focused on property and exclusion.	Multi-sector urban-ESS partnerships, stewardship models; urban-ESS integral to public health and education.
Technology, infrastructure	Technological systems are mono-functional; fixed regulations; hard flood defence; supply-side energy policy.	Technology is a commodity of finance and enterprise; energy from fracking / fossil / nuclear; hi-tech and GMO based food chains.	Technology systems are multi-functional and empowering for all; decentralised renewable energy; food from diverse low-impact sources; 'wise' citizen-based flood resilience.
Economic, employment	Business and finance models are single issue, materialist, extractive and monopolistic.	Neo-liberal model of proxy markets and 'payment for ESS'; privatisation and cost-recovery models.	From 'services' to 'relationships' based on multi-function value generation; circular economy based on circular material flow, finance, enterprise, social value.
Environment, ecology	Techno-centric urban-ESS management; system design as mono-functional, exclusive, externalising.	Urban-ESS managed for maximum return for investors; functional value model for entrepreneurs.	Multi-functional, multi-valent, multi-level, inclusive urban-ESS relationships, with all users and stakeholders. GBI chains and networks with multiple roles for habitats, production, adaptation and leisure.
Policy and institutions	Policy systems based on hierarchy, alienation, expropriation.	Rational management approach to urban-ESS policy, with incentives in competition.	Intelligent governance for urban-ESS management and investment; participative, capacity building, diverse, non-hierarchical: focused on public goods and commons.
Cultural, ethical	Cultural patterns based on linear view of society which dominates nature; alienation is reinforced.	Cultural patterns based on extractive society which sees nature as investment and enterprise.	Culture of diversity and collaboration for bio-economy, multi-species, eco-investment, eco-lifestyles.
Urban, spatial	Spatial zoning and urban design is mono-functional, based on top-down objectives; segregation of ESS into types and functions.	Spatial and urban patterns based on property investment and enterprise; privatisation and cost-recovery from assets.	Urban design for multi-functional ESS; greenspace and GBI throughout built environment; social, economic, ecological value generation in small and large spaces.

5. Policies and pathway mapping

This chapter steers back towards tangible solutions: responses to opportunities and problems, and the implementation questions of who does what, how and when. The first target is public policy, but with a wider view on other sectors.

5.1 Implications for policy and governance

5.1.1 Broad goals for policy

The first question here is – what are the goals for urban ESS policy? The question of goals or targets is far from simple or self-evident, and beyond a purely technical-economic analysis. Definitions for sustainability, indicators and targets fill many libraries. Local targets are dependent on global systems, but these are hugely complex and inter-dependent.

This study would in principle start with the accepted 'Bruntland' concept of sustainable development (WCED, 1987). It would recognise the inter-connections of social, technical, economic, environmental, political and cultural domains. It would also allow for the uncertainties of future scenarios, build on the multiplicity of urban-ESS discourses and transitions, and look for synergistic opportunities and the pathways which can help realise them. The 'goals' would therefore be less abstract concepts, and more based on the realities and opportunities of the situation. In practice, however, this would call for a full scale foresight deliberation, and in the current modest study, we can only point to the scope of all this.

Overall there is a two-way logic of cause and effect, with two broad questions:

1. how to enable ESS, to sustain cities (and/or urban systems); and
2. how to enable cities (and/or urban systems), to sustain their ESS.

Again we keep in mind that policy and governance is rarely simple, and there are opportunities not only in the 'substance', but also in the 'process' of policy and governance. Applying the above to each of the four ESS domains, we can sketch the broad principles:

- goals for ESS **within** the city - sustain local ESS to meet the needs of the city (environmental / social / economic) and sustain the city to meet the needs of the ESS;
- goals for ESS **around** the city - sustain ESS in each location, and the interactions between them, so that the whole city can meet the above sustainability goals (at local, city-region, national and global levels);
- goals for ESS **through** the city - sustain the ESS flows to meet the needs of the city, and sustain the city for sustainable ESS flows (at local, city-region, national and global levels); and
- goals for ESS **for** the city - promote ecological principles and practice in all sectors, (industrial ecology, social ecology, political ecology, ecological design etc) to enable the above goals.

We can illustrate this with a typical river running through a typical city. For the first goal ('within' the city), services such as flood control are to be 'sustained' so the river should not rise too far. At the same time the city should play its part through planning and building design. For the second goal ('around'), the city starts from the reality that the river and the city have many interdependent parts in space and time, so the goals apply to the whole river and whole city, as well as their parts.

The third goal (ESS flows 'through' the city) concerns the wider systems of supply and demand. Water flows through the city as a result of land-use and catchment management, while the city can play its part in water efficiency and behaviour change. Lastly, the fourth goal (ESS 'for' the city) looks at how the river-city ESS relationships can be sustained through practices such as industrial ecology, political ecology, ecological design and others.

5.1.2 Challenges for policy and governance

Many policies now pay at least some attention to ecosystem services concepts. The most topical in the UK is the 'ecosystems approach' (Defra 2012), reflected at the international level with the UN Convention on Biodiversity (United Nations, 1992). However, most inherited policy initiatives still focus on single services, often overlooking the whole and interdependent ecosystems that provide these benefits. Even for policies and policy concepts which directly respond to urban-ESS, many challenges remain:

- how can urban-environmental regulation incorporate the systemic and inter-connected emphasis of the ESS and ecosystems approach?
- as more of the urban-environmental systems are globalised, how can ESS thinking better support national or local level environmental policy responses?
- How can we apply methods, such as impact assessment, valuation or systems modelling, in this highly inter-connected concept of ESS (see the example at the end of this chapter) (Ravetz, 2015: George, 2013).

Over the last decade, the EU, Defra (and its predecessor Departments), the Environment Agency and others have already taken on the ***principles*** of ESS in many areas, such as the EU Water Framework Directive, EU Soils Directive, UK Soils Strategy, and the Defra (2007) *Action Plan for embedding an ecosystem approach* (Defra, 2007 and 2013; Everard and Ravetz, 2009). However, in ***practice,*** it is arguably very difficult to achieve this within current policy 'silos', due to many factors:

- each silo, both within and between organisations, operates to its own targets, budgets and performance measures, and competes for priority and funding (e.g. the Environment Agency, Natural England, Forestry Commission, etc. and the various functionally-oriented departments within them), in addition to gaps or barriers between Defra and other departments such as Communities, Business, Health or Transport;
- many providers and users of ESS are in the private sector (water supply, agricultural production, etc.) and are driven by different incentives, which are also poorly aligned with ESS thinking or wider public benefits; and
- there are practical conflicts and trade-offs, often with no clear and rational way to resolve them: e.g. local housing targets versus preservation of floodplains.

5.1.3 The Ecosystems Approach

This emerged in the 1990s from the understanding of natural systems as complex, systemic, and inter-connected. For example, "The Ecosystems Approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way"[5]. In the UK it appears on many policy documents from Defra and its partners: "The Ecosystem Approach is a holistic and inclusive approach to looking after the natural environment. It includes 'valuing nature's services: understanding how nature works: and involving people'[6]. There is a policy-makers' practical version as in the Defra guidance (2007 and 2013), in contrast to a complexity approach which builds on the concepts of resilience and panarchy (Waltner-Toews et al, 2009; Folke et al, 2002).

Overall, the discussion in this study suggests that, to achieve the Ecosystems Approach in cities (where the majority of the population is situated), an **Urban Systems Approach** is needed – one which is equally systemic and inter-connected, co-evolutionary, participative and so on (Ernstsson et al, 2010; Ravetz, 2014; Cohen, 2012). Otherwise there is a risk that the aspirations of the Ecosystems Approach come up against the hard reality of cities as places of competition and hierarchy, social exclusion and division, waste and exploitation. And from the 'silo' challenges above, it might appear that policy is part of the problem as much as the solution – and so calls for a **Governance Systems Approach**. And because government is so inter-connected with markets, we need an **Economic Systems Approach** and so on. The 'transitions' and the 'pathways' above point towards a systems approach in all of these domains and others. However, this is often aspiration with little backup, hence the high rate of failure in social innovations such as 'transition towns'.

Overall, this study shows that the Ecosystems Approach can provide a model for other domains to build on. So the recommendation in Chapter 6 is for an extended foresight-type policy learning program to enable progress in this direction.

5.1.4 Economic policy directions

One topical direction is to recognise and value economic markets for ESS. For example, established carbon trading markets and emerging 'Payment for Ecosystem Services' approaches to water catchment management could, in principle, be extended to other ecosystem services, assuming these are suitable for marketisation (Defra, 2013). Possible measures include:

- reforming the system of subsidies to sectors responsible for significant production or loss of ESS (e.g. agriculture and energy generation) to reflect the production of multiple ecosystem services and not single outputs such as food and fibre production;
- developing markets for a wider range of ESS (e.g. carbon, water services, nutrient recycling, or disease regulation);
- other economic measures include tax reform to influence sectors which impact on ESS (e.g. road transport, waste generation); and
- meanwhile, there are many variations on levies, charges, hypothecated taxes or cost-recovery mechanisms for various forms of subsidy or market support.

Market pressures pose several risks. Firstly, tangible and trade-able ESS can easily dominate intangible and more complex systems effects. Secondly, markets can easily encourage speculation, short-termism, inflation and gaming, as seen with the near demise of the EU

[5] (Convention on Biological Diversity as on www.cbd.int/ecosystem)
[6] (Ecosystems Knowledge Network as on http://ecosystemsknowledge.net/about/background).

Emissions Trading Scheme (Lohman, 2006). Should the ecosystem markets become mainstream institutions, there would be a call for a regulatory authority to manage such issues.

In the urban sphere, it is clear that policies for greening and sustainability are rarely, if ever, value-neutral and progressive; the urban ESS agenda can easily become an instrument for power and competition as with any other (Brand with Thomas, 2005; Kaika, 2005). And so if the more complex and systemic goals above are to be realised, a new kind of politics and governance is called for (Hajer, 2003; Healey, 1997; Cohen, 2012).

5.1.5 Spatial policy directions

In principle, spatial planning is the first governance channel for place-based ESS. In practice, the complexities of the UK system, as well as the many gaps between urban and environmental governance systems, and the typical disconnection from public investment powers, mean there is a long way to go. The scope of the forward agenda is expressed by Goodstadt (2014):

> *"Spatial planning has the potential to be an effective instrument for the management of ecosystems, for example, by increasing housing density, no longer exporting waste to surrounding areas, decreasing flood risk or by providing green space for exercise and carbon sequestration. There are also examples of an ecosystem approach being embedded in spatial planning (e.g. green infrastructure frameworks). But if these benefits are to be secured more widely, there is a need to overcome the challenges in terms of governance, the nature of decision making and methodology discussed above which provides the context for planning decisions. This requires the acquisition of new skills and a change in the culture in spatial planning, without creating added burdens to already overstrained professional resources. It is considered that this would be assisted through the development and promotion of toolkits which help planners address several key questions with consistency and efficiently, and to avoid everyone trying to 'reinvent the wheel".*

5.1.6 Community participation and stakeholder policy directions

In practice both environmental and urban policy systems are far from neutral and objective: they are dependent on the contribution and participation of a wider community, whether geographical, sectoral, departmental and/or scientific. There has been a long running development of 'participatory and deliberative techniques to support the monetary and non-monetary valuation of ecosystem services', as in the Defra report of that name (Fish et al, 2011). In both environmental and urban participation there are typical broad assumptions made about 'the citizen' and 'the community', so it's useful to review just how many roles are played here (Ravetz, 1999 and 2009a):

- citizens as 'polluted' - the text book case, where the public is the receptor of environmental pollution, and subject to various degrees of risk and hazard;
- citizens as 'polluters' - where the public or local business is the cause of pollution, through activities such as dog fouling, fly-tipping or the use of household chemicals;
- citizens as 'participants', in environmental reporting and monitoring, enabled by new technologies, they may be active advocates or campaigners;
- citizens as 'stakeholders' - as neighbours or investors in environmental assets, where physical qualities are part of social and economic development;
- citizens as 'users' - active enjoyment of environmental assets, through activities such as fishing, walking or other forms of leisure;

- citizens as ‘beneficiaries’ or consumers of ESS, receiving food or materials directly, or other supporting services indirectly; and
- citizens as ‘activists or hack-tivists’, campaigning for environmental protection and/or justice, often in conflict with mainstream policy, and now using new technologies.

There could be more, but the main point is that a combined ‘Urban-Ecosystems Approach’ would aim to foster a diversity of roles and relations between many parts of many communities: a relational and collaborative planning approach (Healey, 1997).

5.2 Policy pathways

The next step is to test the potential policy responses in each of the alternative scenarios. The combination of these scenarios then becomes a policy ‘Pathway Mapping’ or ‘Success Scenario’, which is future-proofed against a range of pressures and uncertainties, as far as they can be anticipated (Bezold, 2009). Similar questions were asked in the NEA Follow On program (Haines-Young et al, 2014). Again, this would ideally call for a full foresight-type program: so here the summary results are shown just to illustrate some likely directions, as in Table 16.

Policy pathways for the **Technology Hinterland** focus on responses to the ‘big business’ regime and discourse of this scenario. There will be an agenda of rebuilding communities out of atomised consumer deserts in social and economic terms; urban sprawl would be revitalised and restructured with new nodes and hubs. For the urban ESS of energy, water and food, each controlled by global corporate firms, there would be potential for new business models and social enterprises, which enhance ESS alongside financial value-added. The concepts of public realm and environmental justice, and stewardship beyond profit-driven extraction, will need to be reconstructed. It is possible that some of the new advanced digital, nano-technologies and bio-technologies could be useful as the components for a new system of urban-ESS management.

Policy pathways for the **Ecological Hinterland** scenario would focus on re-inventing systems of collective decision-making (i.e. governance) in this free-market localist future, possibly the closest to current UK trends (at the time of writing). Some of this re-invention would come through the mobilisation of a wider civil society community to take on some of the functions of governance. Opportunities might exist in working alongside markets for privatised ESS, such as rivers, forests or heritage landscapes, and morphing ‘free’ markets towards social value exchange systems. Policy challenges would include the coordination and integration of larger scale systems (such as national or international power grids), and redistribution from richer to poorer cities or regions. A third challenge would exist in translating non-market and intangible assets of bio-diversity and ‘regulating’ or ‘supporting’ types of ESS into market terms, either by proxies, shadow markets, social quotas, or contingent cost/value recovery, and so on.

For the **Technology Urbanist** scenario, there’s a rather different kind of challenge: how to enhance a policy system which may be part of the problem. This highly coordinated and technologically advanced ‘big state’ may be quite efficient at managing urban ESS in a technical sense, but it risks losing touch with citizens and communities. So a policy agenda here would look for ways of re-humanising the over-managed urban ESS, with spaces for enterprise and creative improvisation. It would look for bottom-up feedback and participation to enhance centralised decision-making: and respond to vulnerability to capture of a globalised smart city model. This scenario sees compact low carbon cities as the norm, but opportunities then arise for the peri-urban and rural areas to have more holistic ESS schemes in food, energy, water or biodiversity. This would also aim to build capacity for corporatist technocrats to engage with local communities and minority interests, to re-invest in creative enterprises, minority groups and radical cultures. Policies would aim to diversify from the technically smart compact city, towards more diverse and flexible spatial structures, where vacant / under-used space is a key to community enterprise and social innovation.

Policy pathways for the **Ecological Urbanist** scenario could be faced with a ‘moment of truth’, in a full-scale sustainability agenda, with ecological zero-carbon communities all around. So we could explore the contradictions which might emerge in this ‘green dream’, and the implications for policy. It seems likely that autonomous self-organising communities might result in island mentalities and widening gaps of rich and poor, so policies would look at rebuilding of wider multi-cultural networks and exchanges between the enclaves. They would look at how to balance technology systems between centralized versus autonomous infrastructure, and how to link local economic value to wider urban-regional level supply chains. There are questions over how local ESS and wider catchments, zones, systems and trade routes would be coordinated. This could involve new ways of capturing and generating value in wider strategic collaborations at different scales. It could also aim to reconnect urban neighbourhoods or peri-urban settlements with wider urban systems, and explore the potential of in-between ESS functions between communities.

Overall, each of these scenarios shows a different context for governance, and so the range of policy responses is wide. Some are seeking to reinvent governance for urban ESS, while others are looking to manage or enhance the existing system. Some are building bridges between markets and the state, and others are looking for new ways of decision-making, allocation and investment of ESS and social value. The final implications for policy pathways, and suggestions for a governance agenda, are in the next section.

Table 16: Pathways and 'success scenarios'

Scenarios>> **IPCC-SRES label**	***Technology hinterland*** **A1**	***Ecological hinterland*** **A2**	***Technology urbanist*** **B1**	***Ecological urbanist*** **B2**
Social, community	Revitalising mono-functional commuter settlements; new 'shareable' social economy models.	Diversification of exclusive inward looking communities; social housing and facilities.	Re-humanising the globalised managed communities; new spaces for enterprise and improvisation.	Rebuilding of wider multi-cultural networks and exchanges between the social enclaves.
Technology, infrastructure	Smart tech innovation for lower impact energy, water, waste etc.	Strategic level infrastructure to improve fragmented systems.	Look for bottom-up feedback and participation to enhance centralised systems.	Technology systems balance between central VS autonomous.
Economic, employment	finance / business models in multi-lateral ESS partnerships; new enterprises in bio-economy.	Re-investment and redistribution, for wider socio-ecological enterprise and prosperity.	Respond to vulnerabilities of global smart compact city; explore opportunities outside city systems.	Link local economic value to wider urban-regional level enterprise and supply chains
Environment, ecology	Value generation and proxy markets in local ESS and integrated systems.	Respond to high local pollution and waste levels with negotiated regulation.	Promote active community participation in local environments and ESS.	Link between local ESS and wider catchments, zones, trade routes etc.
Policy, governance, institutions	Reinventing public goods and policy, to counter elite / corporate expropriation.	Revitalising stagnant localities: governance for investment, coordination, redistribution.	Capacity building for corporatist technocrats to engage with local communities and minority interests.	Look for value generation in wider strategic collaborations and partnerships.
Cultural, ethical	Re-vitalising a culture of ESS justice, based on global and local commons.	Re-circulation of cultural ESS values from economic to other domains.	Re-invest in creative enterprises, minority groups and radical bottom-up cultures.	Rebuild cultural diversity in ESS relations at different scales and locations.
Urban, spatial development	Reconnecting urban sprawl and its isolated car-dependent communities.	Integrated development pathways for mono-functional settlements.	Diversify from compact city with smart systems, towards more diverse and flexible spatial structure.	Reconnect enclaves and neighbourhoods with wider urban system.
INTER-CONNECTIONS: vacant, derelict, contested spaces	Focus on leftovers of urban sprawl, as new value generator resources.	Focus on local land and ESS as potential for integrated value generation.	Promote vacant / under-used space as key to creative enterprise and social innovation.	Focus on spaces in-between functions and communities, as new value generators.

5.2.1 Synergies of actors and stakeholders

The next step in the policy Pathway Mapping would apply the broad success scenarios back to the actors and stakeholders to be involved. At this point we only sketch an outline of an agenda for each type of actor, as in Table 17.

Table 17: Actor-strategy mapping

ACTOR TYPES>>	Public sector	Private sector	Infra-structure	Civil sector	Households	Research / innovation
Social, community	New forms of community governance.	Social value and return on investment metrics	Engagement with ESS users and stakeholders	Multi-valent community partnership models	Demographic changes for young and old, promote new networks	Understand and mobilize multi-socio-ecological values
Technology, infrastructure	Big date for public policy; identifies public value generation.	New financial models to enable integrated systems.	Developers of technical solutions.	Social tech for civil intelligence and lobbying.	Citizen science, digital monitoring and management.	Citizen science, digital monitoring and management.
Economic, employment	Payment for ESS as generator of employment and enterprise.	Re-circulatory investment by and for the community.	Multi-value generation via integrated systems.	Social innovation for enterprise and activity.	New household economics to mobilise property assets.	Innovation in finance and business models.
Environment, ecology	New forms of ESS stewardship and partnership.	New enterprise models for managing the commons.	Ecological design for infrastructure.	Socio-ecological innovation for food, energy, resilience.	Multi-functional land use for social value generation.	Multi-functional land use for social value generation.
Policy and institutions	Policy innovation to respond to complex problems.	Public-private-community partnerships.	Governance-utility firm partnerships.	Public-private-community partnerships.	New governance engagement and institutional models.	Understand and mobilise new institutional models.
Cultural, ethical	Re-connect public sector with the public.	CSR and ethical investment as value generators.	Ecological cultures for demand-supply management.	Ecological culture for empowerment, inclusion etc.	New potential in social tech, media, lifestyles.	Understand and mobilise new cultures and psychologies.
Urban, spatial	Neighbourho-od and multi-level governance.	Micro-enterprises for community regeneration.	Decentralised and self-managed locally.	Community level social / cultural enterprise.	New potential in local activities, values, lifestyles.	Understand and mobilise new spatial forms and patterns.
INTER-CONNECTIONS: hot and cold	Dynamic governance to respond to growth / decline.	Re-distributive long term investment, link growth and decline.	Re-distributive long term investment, link growth and decline.	Multi-level civil society for challenge of city-region integration.	Lifestyles and aspirations for balancing growth and decline, areas and communities.	Understand and mobilise sustainable settlement forms and systems.

5.3 Enabling and capacity building

As each of the scenarios above is equally probable (i.e. constructed with that criteria), a future-proof policy approach would aim at a 'no-regrets' combination. As above, this would strengthen governance where needed in some places while adapting it in others. This extends governance into the market for some ESS, while inventing new forms of decision-making in other ESS. While the scenarios are simple caricatures, reality is generally a more complex and nuanced mix. The governance agenda or policy pathway will therefore be more like a portfolio or toolkit, to be used as needed, together with the capacity and skill to use it.

In the background there are major challenges in understanding, working with and sustaining / enhancing urban ESS, both locally and globally. From this brief review, some of the enabling components of a governance toolkit or policy pathway begin to emerge:

- **science and the evidence base** build up the intelligence and analytical capacity based on whole systems, not just their parts. This involves both technical data and a wider, more participative mode of evidence-building, where lay experts, communities and citizens are also part of a co-evolutionary system of distributed knowledge and social learning. This takes traditional models of scientific knowledge into a wider field of citizen science, radical science and post-normal science (Funtowicz and Ravetz, 1999);
- **capacity-building in governance -** this suggests a cross-cutting 'strategic policy intelligence' program which provides active links between the typical silos of sectoral and organisational divisions. This should aim to mobilise and improve capacities and resources within policy institutions, with the skills, evidence base, analysis and modeling functions. The concept of 'anticipatory governance' looks at how to extend foresight principles throughout all types of policy processes, in particular linking technically-informed futures knowledge with a creative and participative socio-cultural approach (Hajer, 2011).
- **linking regulation with markets** - this is a controversial question. Some argue that new methods of valuation, investment or trading are essential for most urban ESS, while for others, a more responsive and joined-up mode of regulation should be based on inter-dependency of functions and performances. A sharper understanding is needed of how best to deal with each type of ESS, as part of a fully inter-dependent whole. This study recommends that market measures such as Payment for Ecosystem Services can be valuable in certain situations, where the system inter-connections and bounds of uncertainty / confidence are fully transparent and deliberative (see the case study in the next section);
- **participation and networking** - we need to bring together each of the organisations involved in all branches of urban ESS; possibly to reform institutional arrangements overall. Other public agencies, the private sector, the civic sector and NGOs, research and technology, and even culture and media have major roles to play. This will contribute to extended monitoring, deliberative decision-making, and including citizens and the community as active participants in ESS-related decisions which are embedded in society from macro to micro scales (see the Netherlands case study below); and
- **global–local linkages** - an extended global foresight-type intelligence base and policy coordination unit is proposed in order to track global trends, pressures, implications for UK ecosystems, and implications for regulator organisations. This would take the work of the Millennium Ecosystem Assessment forward into policy, and strengthen the linkages between the local, city-region, national, EU and global scales.

Overall, the urban ESS agenda represents a paradigm shift, rather than a marginal adjustment of pre-existing models of monitoring and regulating. The Ecosystems Approach sums up one side of the agenda for governance and management: an Urban Systems Approach is called for to realise the opportunities.

5.4 Case studies

To demonstrate the wide ranging discussion above, here we look at two case studies: one from the UK and one from the Netherlands.

5.4.1 Case Study: Mayesbrook Climate Change Park Project, London

Source: http://ecosystemsknowledge.net/resources/examples/mayesbrook

> "This is the largest river restoration project in London and the flagship project for the London Rivers Action Plan. Mayesbrook Park is situated in the London Borough of Barking and Dagenham, east London, one of the twenty most deprived boroughs in the UK. The 48 hectare park, one of the largest in east London, used to be mostly short mown grass and lacking amenities, was used little by people.
>
> "The project attracted £1.4m of funding for Phase 1, which includes the river restoration, floodplain excavation and landscaping elements of the master plan. Robert Oates sees the secret of this success in designing a river corridor project at the landscape scale with multiple benefits that help all partners to achieve their business objectives. The master plan was developed in consultation with local communities. The partnership also developed the idea of linking the improvements in park and river to climate change adaptation – Mayesbrook Park was developed as the first Climate Change Park in the UK.
>
> "An ecosystems approach to the project was a major factor in the success of the project, as it demonstrated the environmental, social and economic benefits of the planned improvements. An Ecosystem Services Assessment conducted by Dr Mark Everard from the Environment Agency in cooperation with Queen Mary University of London, quantified the benefits from the proposed work. The report shows benefits worth up to seven times the estimated £4 million cost of the whole scheme; a fact that proved to be very useful in convincing funders to contribute to the Project." The report is available on: http://ekn.defra.gov.uk/resources/examples/mayesbrook/"

This ecosystems services valuation is one of the first of its kind in the UK, and a pathfinder in that regard (Everard et al, 2011). However it raises some major questions (see table 18) which show a summary of the estimated ESS benefits in relation to the totals. Nearly two thirds of the total cost 'benefit' is in 'recreation and tourism', and another 30% is due to property value uplift in the surrounding area. The problem is that the 'regulatory services' of climate, flood, soil erosion, nutrients and habitats, together make up less than 5% of the total. This implies is that a policy-maker could look at the components of the total benefit, and decide quite rationally to replace the park with an indoor leisure centre (similar thinking was demonstrated by the 'Anti-Roskill Commission' cost benefit analysis, which 'proved' that the third London airport should be sited in Hyde Park: see Hall, 1980).

This is not to negate the concept of ESS valuation as such; rather we should explore the possibility of more 'synergistic' approaches, which might better serve the goals of enhancing and sustaining urban ESS (Ravetz, 2015b and forthcoming). This is all work in progress, but we can point in some useful directions for ESS valuation / evaluation (based on the 'synergistic mapping and design' approach as summarised in the Annex):

- map the combined linkages of urban systems / eco-systems, with multiple inter-connections, which can be framed as 'capabilities and affordances'. For example, the park and watercourse might be essential to a certain quality of life which gives local people the capability of outdoor experience for general qualities and for particular activities such as pets, children, sport, etc. This also includes a wider range of uses and users, as above.

- map the multiple values and inter-connections. This would look systematically at values in the context of domains such as the STEEPCU (social, technical, economic, ecological, political, cultural, urban), together with each of the main inter-connections (e.g. socio-technical, cultural-economic, political-ecological, and so on);
- explore the 'future-proofing' of the above, with a systematic review of drivers and outcomes of potential change;
- explore the 'co-evolution-proofing' of the above, with a systematic review of the potential for synergistic learning and collaboration. For example, as in the introduction, a 'zero-sum' problem can be transformed into a 'win-win' opportunity with a completely different valuation; and
- shift from 'valuation' models (which tend to assume clear and tangible concepts of value) towards 'evaluation' models (focused on deliberation around multiple forms of value, for multiple actors, with multiple justifications).

Table 18: Summary of ESS benefits in the Mayesbrook Park project

(figures drawn from Everard et al, 2011).

est. figures in £1000	per year	40 year lifetime @3-3.5%	proportion of total
REGULATORY SERVICES			
climate regulation	13	279	1.0%
flood risk	10	214	0.8%
Erosion	5	107	0.4%
nutrient cycle	21	450	1.7%
habitat	10	214	0.8%
CULTURAL SERVICES			
recreation and tourism	815	17476	65.6%
education	5	107	0.4%
Sub-total ESS	879	18848	70.7%
Sub-total property uplift (@ 100 year life)		7800	29.3%
TOTAL BENEFIT		**26648**	**100.0%**
(excludes uncosted benefits of air quality and microclimate)			

5.4.2 Case Study: Green Allure in Nijmegen, Netherlands

Source: www.circle-era.euinp4/home.html

> "In its effort to 'green' the city the Dutch city of Nijmegen improves living conditions for its citizens, promotes the city as a shopping area, and improves ecological conditions. One of the measures in Nijmegen is the building of climbing wires for plants to be grown by the municipality in five streets in the inner city. With this simple scheme even narrow streets can be greened and provide a little support in keeping the houses and the surrounding areas cooler. Side walk gardens are a second measure which was met with great enthusiasm of the local people. The idea is as simple as it is effective. A row of tiles is removed from the sidewalk and plants are planted in the open soil. The excess tiles are used to fence off the garden. Side walk gardens are open to everyone living in Nijmegen and no permission is needed. The only rule is that about 1.2 metres of space is to left for pedestrians. Thanks to enthusiastic citizens beautiful tiny gardens can give the wall an attractive, green appearance."
>
> "A third measure is the creation of a vertical green wall that has been placed on a building the municipality rents in the city centre. One of the walls of the building is now completely covered with plants. A structure with shelves is attached to one of the walls in which plant boxes with a vertical grid of about two metres high are situated. This grid is now completely overgrown with ivy. The last project is the conversion of a parking lot into a little park. The involvement of the local population from the planning face onwards and their inclusion in deciding about the final design of the park however, led to a quick acceptance."

This provides a useful reality check that urban ESS is not all about grand strategy and foresight studies. In fact there are many simple, low cost actions with great benefits in the micro-scale urban environment. Success here seems to depend on 'conversations' with householders, in older or younger social groups, who are then enabled to self-organise the planting and maintenance of ESS. This example comes from the Circle-21 collection, one of the most creative collections of climate adaptation examples now available (Circle-21, 2014).

6. Synthesis and recommendations

This chapter draws the case together: first with an overview of the inter-connections: then by international comparisons: lastly with recommendations for research and policy.

6.1 Synthesis and inter-connections

This study has looked at the interactions between urban systems and ecosystems and the 'services' they provide. On the urban side we took a multi-scale approach, from individual buildings and neighbourhoods, looking at fringes and peri-urban areas, right up to the UK system of cities (however that is defined). On the 'ecosystems' side, we followed the established types of 'services' ('socio-cultural, provisioning, regulating and supporting'), which we structure around more tangible features: ecosystems **within** the city; ecosystems **through** the city; ecosystems **around** the city; and ecosystems **for** the city.

We used a 25-50 year time horizon, although given the uncertainties of even 5-year projections this horizon is purely for illustration. We follow the general Foresight approach, which works with the uncertainty and complexity of both present and future, and explores creative and strategic responses for a wider community.

This study is also a demonstration of the Synergy Foresight method, which has been developed for similar problems. As far as possible, the method uses a matrix toolkit which provides a structured and systematic approach to complexity. This includes the 'landscape mapping' of current conditions, 'change mapping' of the dynamics and alternative scenarios, 'synergy mapping' which looks at transitions and opportunities for collaboration, and 'pathway / road-mapping' for practical action in the face of uncertainty. Overall these provide a structured and systematic 'future-proofing' of a complex present with an uncertain future, and a 'co-evolution-proofing' of opportunities which emerge through social learning and collaboration.

The overview of findings is summarised in the Executive Summary. Here we provide some comments on the inter-connections of one theme to another, with some examples.

6.1.1 Inter-connections and examples

Firstly we can take an overview of some of the most significant opportunities for linkages and inter-connections, between social, technical, economic and environmental domains.

Linking urbanisation dynamics with ecological opportunities (see Table 7):

- urban intensification may bring new opportunities for ESS if it encourages greening in urban features or layers not previously on the agenda (for example, the New York 'High Line'[7]:).
- with urban shrinkage and obsolescence, new spaces emerge for urban ESS, including country parks, wildlife and education centres e.g. Reddish Vale Country Park[8];

[7] www.thehighline.org
[8] www.reddishvalecountrypark.com

- counter-urbanisation or peri-urbanisation can enable social innovation and new partnerships e.g. the Incredible Edible;
- re-urbanisation and regeneration can enable large scale greening e.g. the Birmingham Nature Improvement Area[9]; and
- new urban developments can and should be designed around ESS and GBI, for instance the award winning proposal[10].

Linking climate change pressure to adaptation and urban opportunities:

- areas and communities with vulnerability to flooding will have incentives to use the Ecosystems Approach to enable flood defence, attenuation, mitigation, and social and political resilience e.g. in the WAVE Community Woodland project in Somerset[11]; and
- areas and communities with vulnerability to heat waves or drought could innovate in micro-climatic cooling and shading and water harvesting, together with social and political resilience e.g. the Tamera Water Retention Landscape[12].

From economic restructuring and re-valuation, to socio-ecological opportunities:

- sectors and communities facing loss or risk to their livelihoods could seize the opportunities for socio-ecological activities, such as food and forestry cultivation, garden and landscape maintenance, animal and wildlife conservation, climate change adaptation, etc. An example is the Southern Ontario Food System project[13];
- where ecological assets at risk of market failures (e.g. public common land, and street trees), we could look for new kinds of social market exchange, investment, and socio-ecological value generation.

From technology transitions to governance opportunities:

- the digital/ social network transition may have the effect of displacing many people from their physical environment. It also has the potential to re-connect, through socio-ecological enterprise, community mutual aid and so on. An example is the Tellus Toolkit and the participative GIS approach[14];
- the digital potential for forest protection can work at a global scale, as linked to the REDD scheme by Global Forest Watch[15]; and
- new concepts of citizen science, using big data, distributed processing and open innovation could unlock new potential for understanding complex systems.
- all these add up to new concepts of governance, not only conventional regulation, but also a model of governance by empowerment mobilisation, and enabling of opportunities.

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[9] www.wildlifetrusts.org/node/3195
[10] www.policyexchange.org.uk/wolfsonprize/item/wolfson-economics-prize-2014
[11] http://climatesouthwest.org/library/Case_Study_PDFs/WAVEupdatespring2011.pdf
[12] www.tamera.org
[13] www.greenbelt.ca/dollars_and_sense_opportunities_2015
[14] www.tellus-toolkit.com
[15] www.globalforestwatch.org

From socio-political innovations to ecological opportunities:

- by reframing the overall concept of a megacity such as London, new opportunities in urban ESS can emerge rapidly[16]; and
- In parallel are new roles and structures in socio-ecological enterprise, such as community stewards, citizen monitors, circular economy entrepreneurs and so on.

Finally, we set out some inter-connecting risks and vulnerabilities, and possible negative tipping points:

- climate change in the next 50 years could produce a hostile outdoor environment, with massive ecological destruction caused by flooding, storms, drought and heat waves. The majority of urban dwellers would survive within sealed and air-conditioned houses and cars, global climate change would cause instability and price rises in food and energy, and the vulnerable and dependent would be left to fend for themselves in urban no-go areas; and
- urban growth in the next 50 years could develop in a highly destructive pattern, with deregulation of green belts, national parks and other policies. There could also be investment and public service withdrawal from low-income areas, collapse of public transport and housing economics, corporate expropriation of energy water and food systems, and international isolation and possible break-up of the UK. This could have a highly destructive impact on ecosystems and the urban patterns which support them.

We could continue to explore more inter-connections, but the main message becomes clear:

- the changing system of cities and the UK urban systems bring new kinds of risks and vulnerabilities in urban ESS, but also many kinds opportunities and spaces for innovation;
- the system uncertainties are too great to allow robust projections or forecasts; and
- so the question of what the future holds – whether the negative vulnerabilities, or the positive opportunities – depends on the capacity for resilience, creative collaboration and social learning of all actors at all levels.

6.2 International context

The global patterns of urbanisation are by now well-known. At present, 3.3 billion people live in urban centres across the globe. By 2030 this number is predicted to reach five billion, with 95 percent of this growth in developing countries (UN Habitat, 2004). While mega-cities dominate the agenda, overall growth in centres of 10 million or more inhabitants is expected to level out; over the next 10 years, cities of less than 500,000 will account for half of all urban growth.

The implications are many and would deserve a separate study. Here we just point to four themes: (a) urban development trends; (b) global ecological zones and urban location; (c) new forms of urbanisation; and (d) emerging science-policy-business agendas. Each of these shows implications for UK urban systems and ecosystems, either directly or indirectly.

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[16] www.nationalparkcity.london/proposal

6.2.1 Urban development and types

On current trends, the proportion of slums and/or informal settlements could increase to over half of the world's urban population by 2030 (Neuwirth, 2005). The form of urban agglomerations is also changing: the former hard edges of urban built form are shifting to a more fragmented and diffused pattern (Angel, Sheppard and Civco, 2005). So it is quite probable that the majority of the world's urban dwellers will be in quasi-temporary shacks, lacking fixed systems such as water, sanitation and electricity, in a peri-urban sprawl between rural and urban (Webster and Lai 2004).

Behind the trends, we can look at the 'world urban system', with implications for urban ESS. There is much study of the urban hierarchy, with countless league tables for size, GDP, competitiveness and so on. At the top are the 'alpha' global cities including London, New York and Tokyo, based on global connections in finance, business, professions, media and cultural power, and 'cognitive capital' (Sassen, 1994; Scott, 2000). This kind of ranking is different to that of pure size, where the megacities of Africa and Asia are rapidly overtaking older cities such as London. More relevant to urban ESS is the national development profile, which correlates closely with the urban environmental transition above (McGranahan, 2006):

- characteristics within lower income countries – there is often rapid and/or unplanned urban growth, combined with rural out-migration. There is a focus on primary production, with close connections to urban-rural ESS and physical resources, often with negative local effects on air, water and sanitation, ground and soil quality;
- characteristics within middle income (industrialising) – there is more rapid urban growth, with some areas of decline and restructuring, with regional demands on water, energy, minerals etc. In terms of production there is a towards secondary and advanced industrial sectors, with expanding urban infrastructure. Again, there are negative local effects on air, water, ground and soil quality, however growth in prosperity can (potentially) enable cleaner production and rising standards for workers and consumers;
- characteristics within higher income countries - as seen in the UK, there is generally slower urban growth and/or decline and restructuring, with complex patterns of counter-urbanisation and re-urbanisation. In terms of production, the shift to tertiary services, knowledge based occupations and intensive consumption activities, brings new kinds of ESS interactions. Environmental impacts and hazards are generally displaced to other parts of the world or, in the case of climate change, future generations.

However these categories are changing very rapidly. The trajectory from pre-industrial to post-industrial cities, which in the UK took several hundred years, is accelerated into a very few years in the new megacities of Asia, Africa and Latin America.

6.2.2 Global urban-ecological interactions

One starting point is the study of global ecological zones and urban locations, with implications for ESS distribution, trends, risks and opportunities. Here the primary reference point is the MEA (Millennium Ecosystems Assessment, 2004, Chapter 27 on Urban Systems):

- coastal zones – around the world these are the primary zones of urbanisation, with a quarter of the world's population; two thirds of the population in the coastal zone is urban. At the same time, the coastal zone cities and megacities are generally the most vulnerable to natural hazards and climate change-induced hazards, with storms, flooding, earthquakes, sea-level rise and land instability. Coastal megacities in developing countries also tend to have lower incomes and levels of development, with low capacity in governance and civil institutions;
- 'cultivated' zones contain a total urban population of nearly 2 billion people;
- 'dryland' zones with an urban population of nearly 1 billion are particularly vulnerable to climate change heat and drought, with growing water shortages and soil erosion;
- forest and inland water locations are more vulnerable to fluvial flooding, landslips, forest fires and other hazards; and
- mountain locations are vulnerable to many environmental problems, including air and water quality.

In each of these zones there are complex interactions between urban, peri-urban and rural areas, in terms of migration and labour, agriculture and forestry, energy and water and so on. In many cases rapid urbanisation is changing or disrupting these interactions, while throwing up new opportunities and resources, for example for peri-urban agriculture for local markets.

Recent modelling studies have explored in detail global patterns of urbanisation, and their impacts on biodiversity (Seto et al, 2012; Güneralp et al, 2013: Gomez-Baggethun et al, 2013). The overall outlook is challenging: "Urban land-cover change threatens biodiversity and affects ecosystem productivity through loss of habitat, biomass, and carbon storage…. If current trends in population density continue and all areas with high probabilities of urban expansion undergo change, then by 2030, urban land cover will increase by 1.2 million km^2, nearly tripling the global urban land area circa 2000. This increase would result in considerable loss of habitats in key biodiversity hotspots… Although urbanisation is often considered a local issue, the aggregate global impacts of projected urban expansion will require significant policy changes to affect future growth trajectories to minimise global biodiversity and vegetation carbon losses." (Seto et al, 2012).

6.2.3 Cities, urbanisation and climate change

Global urbanisation and its impacts overlap with the urban climate change agenda, as per the synthesis of Revi et al (2014) for the IPCC AR5 Working Group II (Impacts, Adaptation and Vulnerability) in Chapter 8 on Urban Areas. From the summary:

> *"Urban climate adaptation can build resilience and enable sustainable development. Action in urban centers is essential to successful global climate change adaptation. Much of key and emerging global climate risks are concentrated in urban areas. Cities are composed of complex inter-dependent systems that can be leveraged to support climate change adaptation via effective city governments supported by cooperative multilevel governance. Urban adaptation action that delivers mitigation co-benefits is a powerful, resource-efficient*

means to address climate change and to realize sustainable development goals. Urban climate change risks, vulnerabilities, and impacts are increasing across the world in urban centers of all sizes, economic conditions, and site characteristics. Urban climate adaptation provides opportunities for both incremental and transformative development. Implementing effective urban adaptation is possible and can be accelerated."

Urban areas and the processes of urbanisation are also a major part of the agenda for mitigation of climate change emissions, as per the SPM (Summary for Policy Makers) of the IPCC AR5 Working Group III:

"Urbanisation is a global trend and is associated with increases in income, and higher urban incomes are correlated with higher consumption of energy and GHG emissions. The next two decades present a window of opportunity for mitigation in urban areas, as a large portion of the world's urban areas will be developed during this period. Mitigation options in urban areas vary by urbanisation trajectories and are expected to be most effective when policy instruments are bundled. The largest mitigation opportunities with respect to human settlements are in rapidly urbanising areas where urban form and infrastructure are not locked in, but where there are often limited governance, technical, financial, and institutional capacities. Thousands of cities are undertaking climate action plans, but their aggregate impact on urban emissions is uncertain. Successful implementation of urban‐scale climate change mitigation strategies can provide co-benefits".

These global perspectives highlight some major differences with the UK situation. There are typically fast growing cities with inadequate infrastructure, finance and governance systems, and often located in zones at high risk of climate impact and/or natural disaster. However the overall conclusions and recommendations of the global assessments show many similarities with the UK situation. They include integrated planning and responsive governance with policy 'bundles', community engagement and empowerment, and unlocking finance and new business models for resilient infrastructure.

6.2.4 New forms of urbanisation and ecosystem services:

At present there is no single 'global urban foresight', so we can only use current projections and innovations too anticipate the risks and opportunities ahead.

There is high certainty on continuing income growth from lower to higher levels of development and infrastructure. On current trends there would be continuing displacement of environment impact and resource levels, from the local-regional level to the global level. However the possibility of reverse development is very real. This includes the experience of the former USSR republics, rapid industrial fallout and shrinkage as seen in Detroit or Leipzig, or geo-political conflict which destroys major urban areas, as seen in the Middle East. Ironically such de-development can be favourable to ecosystems which colonise vacant or derelict land, and new forms of habitat in empty and decaying buildings.

In contrast some new urban types are emerging with major implications for urban ESS. A techo-economic development agenda sees a new generation of decentralised edge cities, the *aerotropolis* model, and the carceral-enclave urbanism of 'post-metropolis' (Soja, 2001; Kasarda and Lindsay, 2011). Extreme cases are seen in cities such as Dubai or Qatar, systems of migrants and urban spectacles, where hostile climates are overcome with massive energy and technology inputs (Krane, 2009; Ravetz, 2013). The role of urban ESS is then very different to the norm: highly contained and dependent on artificial structures and micro-climates.

Another track sees an intentional sustainability and ESS agenda, which can take the form of 'smart', digital, integrated forms of energy, water and other infrastructure, as seen critically in Masdar or Songdo (Cugurullo, 2013). There is a parallel but opposite direction towards a low-tech, decentralised, communitarian kind of vision, as seen in the international movements for ecological Green Belts and for urban agriculture.

6.2.5 New science-policy agenda

More recently there is a surge in international studies and policy initiatives on urban vulnerability, urban resilience and low-carbon transitions. Various current themes include:

- the urban dimension of climate change impacts, mitigation and adaptation policies (IPCC, 2014, Chapter 27: Urban Systems). There is a focus on the most vulnerable case, the developing country coastal megacities, as in the Land-Ocean Interaction in the Coastal Zone project. Cities around the world are now assessed for physical risk and resilience, alongside business competitiveness (Swiss Re, 2014);
- Rockefeller 100 Resilient Cities program, with a background report (Ove Arup and Partners International, 2014). This proposes that every city have 'resilience officers', with various kinds of support and capacity building;
- low-carbon and resource efficient urban systems are a growing agenda, but there is a realisation that such a shift is more than a simple task: it calls for new levels of policy intelligence and business / civil society engagement. One approach is framed as 'urban resource flows and the governance of infrastructure transitions' as in the City-Level Decoupling initiative (UNEP, 2014);
- new angles on the peri-urban and rural-urban system, with new integrated models and policy agenda. This was explored in the EU project PLUREL and in practice by the Green Belt movement[17]. There has been huge growth in experimentation on Chinese garden cities and the 'circular economy' (Junde and Zaide, *1996);*
- urban agriculture is one of the most interesting global trends, raising many questions on the paradigm of industrialised food chains, use of urban space, support for social enterprise and community mutual aid, and so on. This is promoted by the FAO 'food in cities' network, the UN Habitat 'Urban Gateway' and so on (Pretty, 2002; Nettle 2014); and
- innovations on the economy-ecology interface, with the international TEEB initiative (TEEB, 2010). International scientific networks include the UGEC (Urbanisation and Global Environmental Change) which coordinates global studies on that axis;
- creative and innovative responses to urban climate adaptation, ecosystems and social and political ecology, with an international perspective across Europe, OECD and the developing world (Circle-21, 2014)

Each of these and many more can be explored and critiqued. The significance here is that they each offer new insights and new examples of the urban ESS agenda. With such international comparisons we can respond to the question - what can the UK contribute to, or benefit from, the experience of other parts of the world?

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[17] www.greenbelt.org

6.2.6 UK-global exchanges

The UK, as the world's first industrial system, is arguably one of the first post-industrial systems bringing both opportunities and risks. Countries such as China, which is facing rapid urbanisation and environmental disruption, might look to the UK for some insight on future development challenges and the practice of urban planning in a mature service-sector consumer society. The counter-case is where some features of the UK system of cities resemble in some ways very different systems overseas. These include the UK housing crisis which calls for radical approaches to urban space and social inclusion, and the infrastructure gap which calls for rapid and effective decision-making and investment. In particular, the changing and innovative nature of the urban-ESS interactions call for a learning with overseas experience in areas such as urban food, low impact energy and water systems, neighbourhood greenspace and so on.

6.3 Recommendations

Finally we put up some general recommendations, as set out by the four urban ESS domains. These recommendations are firstly aimed at policy-makers, but would also involve business, NGOs and all parts of the community.

1. Urban ESS within the city: This is the basic portfolio of urban ESS, in a generalised urban situation:

a) **socio-cultural services -** promote integrated multi-functional urban ESS in leisure, sport, education, culture, social services and community enterprise;

b) **provisioning services -** promote ESS provision of water, energy, materials, food, construction materials and waste assimilation (at the local level wherever possible);

c) **regulating services -** promote urban ESS for climate control, environmental health, pest and disease regulation, and management of flooding, environmental health, and air and water quality; and

d) **supporting services -** promote the underpinning ESS of primary production, photosynthesis, nutrient cycles, soil, water, biodiversity.

2. Urban ESS around the city. These are typical applications of the above in different location types around the wider city-region:

a) **city centres -** there are ESS opportunities for high-density / high traffic areas, e.g. micro-climatic public space, green walls and nature corridors;

b) **inner city areas -** there are ESS solutions for older housing areas, with novel building solutions, community enterprise and temporary landuses;

c) **industrial areas** – there are ESS opportunities for integrated industrial symbiosis and green-grey infrastructure;

d) **suburban areas** – ESS opportunities include gardens, permeable surfaces, low carbon housing, neighbourhood recycling, low impact transport;

e) **urban fringe areas -** ESS opportunities exist in multi-functional landuse, integrated eco-enterprise, community stewardship of river corridors, together with woodlands, wetlands and other habitats;

f) **peri-urban areas** – there are ESS opportunities in smaller settlements with low impact and autonomous systems of food, waste, energy, biomass and forestry products; and
g) **overall city-region area**: promote strategic integrated planning across the space, to enable sustainable ESS management in a coordinated 'spatial ecology'.

3. Urban ESS through the city: infrastructures of energy, water, waste etc (as detailed in the Foresight paper on 'Urban Metabolism':

a) promote sustainable integrated systems for urban **energy and carbon cycles**;
b) promote sustainable integrated systems for **material and resource flows**, with waste re-use and recycling in a circular economy;
c) promote sustainable integrated systems for **urban food provision** and agricultural activity for the city;
d) promote industrial innovation for **integrated eco-urban infrastructure**, linking energy, water, food, waste, materials, and pollution control; and
e) promote **digital systems** for monitoring and modeling, social media, geo-location analysis, citizen science and community participation.

4. Urban ESS for the city: a wider scope, to include all kinds of human activity with potential to follow ecological principles and applications:

a) promote the **social ecology** approach: collaborative and informal social and community enterprise, co-creation and related activity in working with ESS;
b) promote the **industrial ecology** approach: ecological engineering for integrated eco-urban systems (energy, water, food, waste, materials, pollution adsorption);
c) promote the **political ecology** approach: synergies in city-region level health, education, social care and other public services, for integrated benefits in urban ESS;
d) promote **ecological finance**, valuations and markets, which enable investment and enterprise models in urban ESS;
e) promote **cultural ecology** with creative arts, leisure, sport, education, gardens and adventure playgrounds; and
f) promote **spatial ecology** principles for the **UK System of Cities**: planning for inter-regional transfers, urban growth in vulnerable or resilient locations, strategic ESS management.

5. Urban ESS and the Ecosystems Approach: general resources and capacities:

a) strengthen the technical evidence for the Ecosystems Approach, through big data analytics, remote sensing, integrated systems modelling, and open spatial data systems;
b) strengthen the social capacity for the Ecosystems Approach, through civil society mobilisation, citizen participation, social media and networking;
c) strengthen the governance capacity for the Ecosystems Approach, with deliberative, inclusive, participative, and strategic processes of decision-making;

d) strengthen the ‘strategic policy intelligence’ which combines the above, in a national-local scale continuous foresight and capacity building program; and

e) strengthen the Urban Systems Approach to complex interconnected cities and settlements, in technical, social, economic and governance domains, in combination with the Ecosystems Approach.

7. Annex

7.1 Abbreviations

BAU	‘business as usual’ scenarios
CAP	Common Agricultural Policy
CSR	corporate social responsibility
CURE	Centre for Urban Resilience and Energy (Formerly, Centre for Urban and Regional Ecology)
DA	Devolved Administration of the UK, i.e. Wales, Scotland, Northern Ireland
DCLG	Department of Communities and Local Government
Defra	Department of Environment, Food and Rural Affairs
EA	Environment Agency
EEA	European Environment Agency
ESS	Ecosystem Services
EU	European Union
EC	European Commission
GBI	Green and Blue Infrastructure
GDP	Gross Domestic Product
ICT	information and communications technology
IPCC	Inter-Governmental Panel on the Scientific Assessment of Climate Change
MEA	Millennium Ecosystems Assessment
NEA	National Ecosystems Assessment
NHS	National Health Service
OECD	Organisation for Economic Cooperation and Development
SEA	strategic environmental assessment
WFD	EU Water Framework Directive
WWF	World Wildlife Fund
UNEP	United Nations Environment Program

7.2 Background tables

Table 19: Background: Ecosystem services in relation to spatial urban systems

Based on full listing of generic ESS, from the Millennium Assessment (UNEP, 2005).

	UPSTREAM ISSUES	URBAN AREA ISSUES	DOWNSTREAM ISSUES
PROVISIONING SERVICES			
Fresh water	Water resources and catchment management	Water conservation	Urban waste water treatment and discharges
Food (crops, fruit, fish etc.)	Food supply chains and city-region hinterland	Potential urban cultivation: lifestyles and diets GBI integration	Food waste, packaging, climate impacts
Fibre and fuel (timber, wool etc.)	Forest product chains and city-region hinterland	Building design and construction	Construction and other waste
Genetic resources (used for crop/stock breeding and biotechnology)		Urban species and habitats; animal-human relations	
Biochemicals, natural medicines, pharmaceuticals		Potential for local cultivation	
Ornamental resources (shells, flowers etc.)		Potential for local cultivation	
REGULATORY SERVICES			
Air quality regulation	Regional scale air pollution and air quality management	Urban air pollution; traffic / industry	Downwind pollution from urban areas
Climate regulation (local temperature/rainfall, greenhouse gas sequestration etc.)	Global climate change impacts	Urban micro-climate, UHI; role of GBI	Urban climate emissions
Water regulation (timing and scale of run-off, flooding etc.)	Upstream catchment management	Urban SUDS and local flood management; groundwater levels	Downstream water management risks
Natural hazard regulation (storm protection)		Urban resilience to storm and hazard	
Pest regulation	Organic and ICM farming reduces chemical pollution	Urban GBI and biodiversity reduces chemical use	
Disease regulation		Urban GBI and biodiversity for resilience	
Erosion regulation	Upstream catchment management	Urban SUDS and flood management	Downstream flood risks
Water purification and waste treatment	Water resources and catchment management	Water conservation	Waste water treatment and discharges
Pollination		Urban GBI and biodiversity corridors	

	UPSTREAM ISSUES	URBAN AREA ISSUES	DOWNSTREAM ISSUES
CULTURAL SERVICES			
Cultural heritage	Cultural heritage can drive urban development	Urban greenspace and GBI as heritage	Urban activity can impact on cultural heritage etc
Recreation and tourism	Leisure landscapes can drive urban development	Urban greenspace and GBI as recreation	Urban expansion into rural leisure
Aesthetic value		Urban greenspace and GBI as aesthetic value	
Spiritual and religious value		Urban greenspace and GBI as spiritual value	
Social relations (such as fishing, grazing or cropping communities)		Urban structure can support social structures (positive or negative)	
SUPPORTING SERVICES			
Soil formation	Soil fertility can enable urban development	Urban soils are often degraded but can be renewed	impacts of urban activity may enable or destroy soils
Primary production		Urban micro-cycle in primary production	Urban pollution may impact
Nutrient cycling		Urban micro-cycle in nutrients	Urban pollution may impact
Water recycling	Water cycle changes may impact on cities	Urban micro-cycle in water	Large urban areas may impact on water cycle
Photosynthesis (production of atmospheric oxygen)		Local effects in urban air quality	Urban pollution may impact
Provision of habitat	Upstream habitat may improve ESS for cities	Local urban habitat and biodiversity	impacts of urban activity may enable or destroy habitats downstream

Table 20: Background: the role of urban parks, gardens and forests in cities through time

Adapted from Douglas and Ravetz (2011)

Urban Development	Leading Actors	Types of garden	Main forms of park	Main urban forest functions
Ancient cities	Rulers and elites	Palace and villa private gardens	Limited public gardens (e.g. in Athens)	Hunting grounds (Persia, Assyria); parts of palace gardens (Rome)
Mediaeval city (political, religious)	Nobility	Gardens in monasteries and large private residences; gardens and horticulture within city walls	Private parks around palaces	Hunting, subsistence
Mercantilist and Renaissance City	Nobility and bourgeoisie	Private gardens behind larger urban houses; much vegetable growing	Botanic gardens linked to medical schools	Recreation, prestige, production (for a few)
European Industrial City	Local governments, industrialists	Private gardens for the wealthy, intense peri-urban horticulture	Parks for people	Recreation (for all)
Tropical Colonial City	Colonial officers	Private gardens for the wealthy (colonial elite)	Formal parks, Botanic gardens	Nature conservation
North American city	Democratic city planners	Gardens in urban squares as “symbols of nature”	Nature in cities; Pleasure grounds	Provision for areas of trees in early city designs
Traditional east Asian cities	Emperors and rulers	Formal symbolic palace gardens	Parks in palace grounds: later opened to public	Glades of trees in palace grounds; sacred forests near temples/monasteries
Early twentieth century cities	National and local governments	Garden city suburbs; street tree planting, sprawl greenspaces	Open space systems; multi-purpose facilities; sports grounds	Bird sanctuary and tree protection orders;
Late twentieth century cities (1970-2000)	National and local governments; civil society organisations	Domestic gardens, municipal gardens; allotments, urban farms in parks	Rejuvenation of old formal parks; nature reserves, natural areas; sports and recreation	Recreation, nature conservation, environment, landscape, production
Post 2000 cities	National, regional and local governments	Renewal of interest in local and home food production in affluent societies	Promotion of biodiversity and green infrastructure planning and management	Health benefits and ecosystem services emphasised; multi-functional uses promoted
Tropical cities in emerging economies	National and Municipal Governments	Small domestic gardens, high use of plant pots; informal use of land for urban agriculture especially by poor	Formal parks as national symbols; others as pleasure grounds including lakes	Protected forests on urban periphery, or significant topographic features, including coastal mangrove reserves

Table 21: The ecosystem functions of different types of urban greenspace

Adapted from Douglas and Ravetz (2010)

Ecosystem service functions	Regional Parks, green grids, greenways	Street trees	Communal and neighbour-hood open spaces	Gardens	Green roofs	Sustainable urban drainage systems	Wetlands	River corridors
Food: Crops	Urban food production		Allotments and urban faming possible	Family food production	Potential for vegetable cultivation			Urban vegetable plots
Livestock	Managed grazing possible			Raising chickens and rabbits for food		Managed grazing possible		Managed grazing possible
Fishing (capture)							Can include recreational fishing ponds	Angling a major participant sport
Aquaculture	Ponds can be incorporated					Ponds could be used for fish	Potential if water quality good	Flood basins could be used
Wild plant and animal food sources	Harvesting of wild fruits and green plants	Provide food for birds					Potential for raising water birds (e.g ducks)	
Fibre: Timber	Managed urban forests						Possible use of willows and similar wetland trees	
Wood fuel	Coppicing provides wood for cooking							
Genetic Resources	Preservation of species lost from farmland	Possible to have diverse species	Wildlife reserves can harbour rare species	Often high biodiversity	Possible to have diverse species	Possible to have diverse species	Wildlife reserves can harbour rare species	Diverse habitats encourage many species
Biochemicals			Can promote preservation of traditional medicinal plants	Can promote preservation of traditional medicinal plants				Potential for varies biochemical production
Freshwater	Water					May reduce pollution	Help to cleanse water and delay runoff	Storage and conveyance of water, interaction with groundwater

Ecosystem service functions	Regional Parks, green grids, greenways	Street trees	Communal and neighbour-hood open spaces	Gardens	Green roofs	Sustainable urban drainage systems	Wetlands	River corridors
Air quality	Reduces heat island effect, removes some pollutants	Reduces heat island effect, removes some pollutants	Reduces heat island effect, removes some pollutants	Reduces heat island effect, removes some pollutants	Reduces heat island effect, removes some pollutants	Reduces heat island effect,	Reduces heat island effect,	Reduces heat island effect,
Climate	Absorbs CO_2	Absorbs CO_2	Absorbs CO_2	Absorbs CO_2	Absorbs CO_2; reduced heat loss to atmosphere	Plants absorb CO_2	Plants absorb CO_2	Plants absorb CO_2
Water regulation	Help reduce some flood flows			Aids infiltration to groundwater	Reduces rainwater discharge	Reduce storm water peak flows	May act as flood detention ponds	Can include flood detention ponds
Erosion regulation	Good ground cover reduces erosion risk		Good ground cover reduces erosion risk			Reduce gullying and channel erosion, retain sediment	Retain sediment	Restoration can stabilise channels
Water purification and waste treatment						Helps in cleaning water flowing to streams or groundwater	Can be highly effective in removing pollutants	Can incorporate wetlands
Disease regulation	Removal of forest vegetation can lead to spread of leptospirosis in tropics			Plant diseases can be introduced by importation of exotic species			Risk of dengue fever in tropical cities if drainage blocked	
Pest regulation	Opportunities for natural enemies to provide pest control							
Pollination	Possibility of reducing decline in pollinators							Diverse habitats favour pollinators
Natural hazard regulation	Helps to reduce geophysical hazards, protecting hillsides, coastlines, and river banks							Significant flood management role, especially peak runoff storage

Ecosystem service functions	Regional Parks, green grids, greenways	Street trees	Communal and neighbour-hood open spaces	Gardens	Green roofs	Sustainable urban drainage systems	Wetlands	River corridors
Spiritual and religious values	Possibility of maintaining sacred groves							
Aesthetic values					Improves appearance of buildings			High quality river scenery
Human health benefits	Mental and physical benefits	Mental and physical benefits	Mental and physical benefits	Mental and physical benefits	Mental and physical benefits	Mental and physical benefits	Mental and physical benefits	Mental and physical benefits
Social relations	Group re creational activities		Group re creational activities	Family activities				Group re creational activities
Cultural Heritage	May include historic woodland		May include historic buildings					May include historic bridges and other structures
Recreation and ecotourism	Passive recreation		Can include sports grounds	Gardening as a relaxing hobby				Water recreation possible
Soil formation	Renewal of soil nutrients				May develop a soil			
Photosynthesis	Effective							
Primary production	Produces wood and plant matter							Growth of aquatic and floodplain plants
Nutrient Cycling	Usually maintained: depends on harvesting							
Water cycling	Maintains natural water cycle							Important for conveyance, storage, infiltration and evapotransp-iration

7.3 Methods: Synergy Foresight and Matrix tool

This study has adopted a method which has been developed for systematic analysis and synthesis in wide-scale foresight and future-oriented studies: the '**Synergy Foresight'** method. This helps in working with complex inter-connected problems (a.k.a. 'wicked' or 'post-normal' problems), which involve not only 'linear' systems, but 'cognitive' human systems of learning, collaboration and shared intelligence (Ravetz 2013, 2014 and forthcoming).

Understanding climate change, for example, combines earth systems science with social, technology, ecology, economics, politics and cultural issues, with many inter-connections between global and local levels. Urban ecosystems are also highly complex and inter-connected. For each the main feature is that they involve not only technical systems but human cognition, learning, collaboration, social intelligence and so on. How to work with such problems?

We have developed a framework - '**synergistic mapping and design' -** to enable systematic thinking, for problems / solutions which revolve around creative synergy and social intelligence. This helps to manage a Foresight type exercise, in the form of the **'Synergy Foresight'** method. It begins with drawing the problem, with the main inter-connections, with as much detail as needed (it can work well on a flipchart). Then it works through a four-stage cycle with questions to be addressed:

1. **scoping / landscape mapping -** questions include ' what is our problem?', 'who and what is involved?', 'how does the system work?' and 'what are the inter-connections?';
2. **scenario / change mapping –** questions include 'what are the drivers of change, trends and alternatives?';
3. **synergy / idea mapping –** questions include 'what are the most creative synergies and opportunities?'; and
4. **strategy / pathway / road-mapping –** questions include 'which direction should we follow?' 'what can we do next, how and with whom?'

Going around several times with this 4-stage cycle, we can explore different layers of systems change, and the co-evolution or 'emergence' of new patterns. These can take up to 3 types of change:

1. ***1.0: linear change in*** 'functional systems' - responding to direct short term change (with an image of a large and complex *machine*);
2. ***2.0: adaptive change in*** 'complex adaptive systems' - evolving with longer term changes and transitions (an image of *biology- wilderness or garden*); and
3. ***3.0: synergistic change in*** 'intelligent adaptive systems' - these are shaped by human qualities such as thinking, learning, questioning, strategy, self-awareness, intelligence (an image of a *human situation)*.

The third model of change – the '3.0' synergistic change - helps to understand many kinds of human system, where there are both technical and cognitive dimensions, and where there is potential for creative synergy / collaboration, or social learning / intelligence. For example:

- ***urban 3.0 -*** a self-organising, responsive city or region, which provides livelihoods for all, takes responsibility for its ecological effects, and builds a just and equitable society;
- ***ecology 3.0 -*** ways of organising energy, food, resources and ecosystems, which mobilise human intelligence for increased added value combined with lower impact;
- ***economy 3.0*** - systems of livelihood, production, finance and overall prosperity, which include social and ecological values, responsive to global limits, creative and resilient, self-organising and stabilizing; and
- ***governance 3.0*** - structures for participative decision-making and collective resource management, with citizen empowerment via collaboration, based on social learning and intelligence.

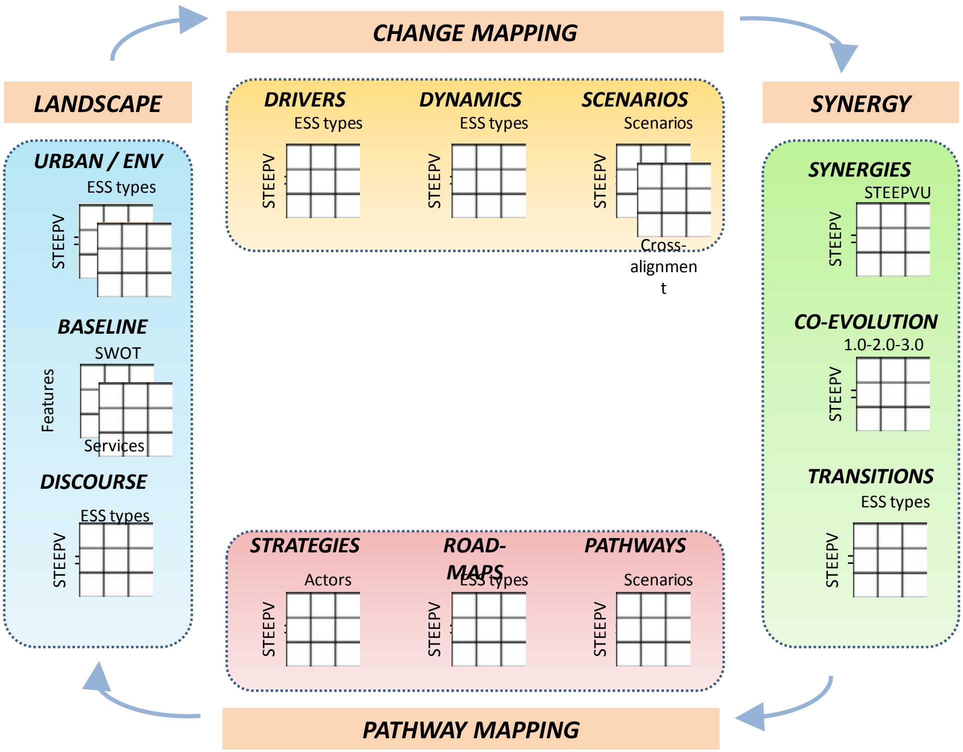
In the context of this study, experience shows that understanding and working with urban ESS is more than a '1.0' linear type of mechanical cause and effect, and more than a '2.0' extractive type of jungle where winners take all. The Ecosystems Approach and similar, involve a more '3.0' synergistic model and way of thinking. This model helps to understand how social, technical, economic, ecological, political, cultural and urban systems are each interconnected: and how the social learning, creative synergy and shared intelligence of all actors, is the key to progress. This agenda is explored at length in *'Urban 3.0: creative synergy and social intelligence'* (Ravetz, forthcoming).

7.3.1 Synergy Matrix toolkit

There are different techniques for working on the details in the 4-stage Synergy Foresight, depending on the kind of study, level of detail, audience, etc. This Foresight study followed a more analytical technique, the **Synergy Matrix** toolkit (other options include flow-charts, network analysis, visualisations etc). The **Synergy Matrix** toolkit provides a flexible set of templates for each of the 4 stages: it enables a structured exploration and analysis of what often starts with a complex wide-open set of uncertainties. The generic knowledge flow structure, to be adapted to suit different projects, is outlined in Figure 11 below. This works as follows:

- **landscape mapping -** the matrices will map the 2-way combinations between multiple sets, including 'domains' (STEEPC etc), the 'actors or sectors' (e.g. NACE etc), the 'types or 'layers' (e.g. 4 layers of urban ESS), or any other root classification which is relevant to the problem;
- **change mapping -** the matrices take the most relevant of the landscape mapping combinations, and explore drivers of change, dynamics of change, and possible outcomes of change (i.e. scenarios);
- **synergy mapping -** the matrices take the most relevant of the change mapping combinations, and explore the 'transitions / discourses', and the 'co-evolution synergies' with different models of change; and
- **pathway / road-mapping -** the matrices take the most relevant of the change mapping and synergy mapping combinations, and identify a set of combined pathways which are 'future-proofed' and 'co-evolution-proofed': these can then be translated to strategic 'road-mapping' with objectives, resources, actors, and processes.

Figure 11: Synergy Matrix toolkit



8. Bibliography

Resources

Online data sources

- The MAGIC website provides geographic information about the natural environment – (GB only) www.magic.gov.uk/About_MAGIC.htm
- The GRABS project platform based at Manchester is a best practice in interactive spatial data, see www.grabs-eu.org
- The RTPI Map of England, as on www.rtpi.org.uk/knowledge/policy/map-for-england/
- The PLUREL ('Peri-urban Land Use Relationships') online X-plorer provides European data with spatial analysis and scenario modeling: available at www.plurel.net
- The EEA (European Environment Agency) also offers online spatial thematic mapping, as on www.eea.eu

Policy resources

- UK NEA (National Ecosystems Assessment) [online] Available at: http://uknea.unep-wcmc.org/EcosystemAssessmentConcepts/tabid/98/Default.aspx
- Natural England, Geodiversity [online] Available at: www.naturalengland.org.uk/ourwork/conservation/geodiversity/default.aspx
- The Economics of Ecosystems and Biodiversity: A global initiative focused on drawing attention to the economic benefits of biodiversity including the growing cost of biodiversity loss and ecosystem degradation. www.teebweb.org
- Ecosystems Knowledge Network: A resource for anyone wanting to share knowledge or learn about the practical benefits of the Ecosystems Approach.
- Valuing ecosystem services is one of the Ecosystem Knowledge Network's learning themes. http://ecosystemsknowledge.net
- Valuing Nature Network: An interdisciplinary network for valuing biodiversity, ecosystem services and natural resource use. www.valuing-nature.net
- EVRITM – The Environmental Valuation Reference Inventory TM. www.evri.ca/english/default.htm.

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GS/15/34