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Reflections on disruptive energy innovation in urban retrofitting: Methodology, practice and policy

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ABSTRACT

Retrofitting cities provides major challenges for decision-makers and planners seeking to provide strategic management of urban transitions. Recognising the implications of disruptive innovations for the urban energy sector is key to understanding how transition management can be operationalised. This also requires an integrated urban foresight approach to engage with city stakeholders in exploring the construction of socio-technical urban retrofit processes across a variety of scales and domains

1. The challenge of urban retrofit

We live in an urban age. A majority of the world's population (3.9b or 54%) lives in cities and this is set to grow to 66% by 2050 [1]. On the one hand, this urban growth provides us with huge opportunities, because cities can act as centres of knowledge and innovation, enterprise and jobs, and as the focus for creating economies of scale in rolling out new technologies. However, this can also provide us with big challenges, because as urbanisation continues rapidly it creates more greenhouse gas emissions, depletes resources, consumes more energy and can create socio-economic polarisation. Although 'cities' are only explicitly mentioned twice in the 2015 Paris Agreement on climate change, the agreement did give a strong mandate to the global buildings and construction sector to help keep global warming below 2 °C, and to limit the increase even further to 1.5 °C. Moreover, cities are implicitly seen as a strong focus for mitigation and adaptation activities to tackle climate change impacts [2].

An important challenge is to be able to develop the knowledge, capacity and power for public bodies, businesses and other users in urban areas, particularly in the developed world, to systemically retrofit built environment and city infrastructure to respond to climate change, resource depletion and socio-environmental problems [3,4].

Indeed, over the last decade, the drive to 'retrofit' existing buildings and the built environment in response to the long-term challenges of climate change and resource constraints has gained increased discussion and debate [5–8]. In the UK, the Climate Change Act and related 80% emissions reduction target for 2050 have focused considerable attention on the impact of the built environment in cities on greenhouse gas emissions. In the UK therefore, there is a strong focus on retrofitting existing buildings and infrastructure. Because building stock turnover in the UK is relatively sluggish, only about 1–2% of total building stock each year can be defined as 'new build' [9,43], and approximately 70% of total 2010 building stock is expected to still be standing in 2050 [10].

The concept of 'retrofitting' has the literal meaning of 'adding (a component or accessory) to something that did not have it when manufactured' (Oxford English Dictionary), but the term has also often also been used synonymously in the built environment with terms such as 'refurbishment' or 'conversion' [3]. At a city-scale, however, retrofit is seen as more comprehensive and wider in scope. For example, 'sustainable urban retrofitting' can be seen as the directed alteration of the fabric, forms or systems that comprise the built environment to improve water, energy and waste efficiencies [11].

Research on retrofitting in the built environment has traditionally focused on either individual buildings (or building components), or neighbourhood or district level, as opposed to city scale. However, we often think of this kind of large-scale transforming change in relation to 'what' is needed, and 'how' it can be implemented, without thinking about the way in which to address both together [7,8,12,13].

In this sense cities should not be seen as a 'blank canvas'. To implement the systematic change required, we need to consider cities as they exist today: as a complex mix of homes and businesses, and the product of many hundreds of years of evolution and growth. We also need to recognise that cities can become "locked" into patterns of resource use that can no longer be justified, and to also respect their social, environmental and economic sustainability [14,4].

This means having a primary focus on understanding 'disruptive

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innovations' at city level, and combining this understanding within an urban transition framework. In this article, we define what is meant by disruptive energy innovation. We then explore how an integrated urban foresight methodology can help us explore the socio-technical construction of such urban retrofit processes across multiple scales and domains. We conclude with a discussion of the practice and policy implications of this research perspective.

2. Disruptive energy innovations: definition and examples

In the field of 'Technological Innovation Systems' [15] innovations can be classified according to whether they are 'incremental', 'radical' or 'disruptive'.

Firstly, incremental innovations emerge from discoveries which happen in 'existing technology paradigms', but which do not affect them to any large extent [16] for example, in a wind turbine lengthening the blades to increase efficiency [17]. In contrast, a 'radical', or 'transformative' technology involves many more alterations to how things happen, and requires new knowledge which may not necessarily be 'disruptive' (for example, fuel injection for a car engine). On the other hand, a 'disruptive' technology involves new knowledge to produce a way of doing something differently, but does not require a substantial change in regime (for example, using biofuels instead of petrol would disrupt markets and business models based on existing petroleum, but would tend to have a lower impact on social practices (i.e. driving)) [17–19].

'Disruptive technology' is also used as a term in 'Disruptive Innovation Theory' (DIT) to describe a technological innovation that suddenly affects existing technologies or markets [19,20]. Christensen [21] also distinguishes 'disruptive' technologies from 'sustaining' (or 'incremental') technologies. For example, 'sustaining' innovations in a core market result in an improved product which provides improved quality at a lower price, in contrast to 'disruptive' technologies, which occur more at the margins of markets which are already established.

Examples of disruptive technologies which could be considered to be part of the 'energy retrofit domain' include: (i) light emitting diode (LED lighting) as a replacement for incandescent lighting, and (ii) phase change materials (which have a high heat of fusion and latent heat properties) for energy storage and production [15]. Although these represent 'technological breakthroughs', they do not necessarily require wholesale regime change for them to succeed, and so can be seen as disruptive rather than radical.

Nonetheless, disruptive technologies can also impact on business models through increased competition in the utilities market [22,23,15]. For example, utility profits may be reduced in markets with high prices, where, for example, new technologies, such as renewables, can impact on electricity prices. However, disruptive technologies are by their nature hard to foresee and quite rare, and so they may be difficult to identify using conventional futures techniques [24,15]. Therefore, we need to develop combined (or 'hybrid') methodologies which can also provide clearer identification of innovations which are unpredictable and uncertain.

3. Theoretical perspectives: an integrated urban foresight methodology

Urban retrofitting is complex and large-scale ponding [25]. Responding to the challenges and complexities of urban retrofitting at scale therefore means integrating the 'what' (for example, technical knowledge, targets, technology choices, costs) with the "how" of implementation (for example, institutional capacity, public engagement, and governance). Currently, there is still too much of a dichotomy between the "what" and "how" questions, which is characterised by fragmentation of disciplines; absence of suitable governance systems; and a failure in learning, and cross-transfer of that learning [26,3,13,4].

Urban retrofit transitions can be seen as complex, co-evolutionary, and characterised by non-linear processes which draw upon a range of actors, and focus on different levels and dimensions over time, and this also draws form ideas and concepts anchored in systems, evolutionary and complexity theories [27–29,4].

Building upon these theoretical concepts, (and often focusing on case studies of energy, transport and food, for example), the multi-level perspective (MLP) has emerged as an important conceptual model for understanding large-scale socio-technical systems dynamics and change set against the interrelationship between niche, regime and landscape ('micro', 'meso', and 'macro') processes [30,31,7,8].

Urban retrofitting in the context of MLP can be seen as an interlocking system of innovation challenges, with a primary emphasis on [15–17][1]:

- Multi-scalar transitions: for example, building, neighbourhood, community, and city scales (i.e. 'integration across scales');
- Integrative perspectives on systems innovation over the long-term, which operate across sectors and levels. Here the concept of socio-technical regime is used to identify particular urban retrofit 'regimes' (for example, housing, urban infrastructure and land-use regimes [7,8]);
- The identification of sustaining and disruptive retrofit technologies which are important in understanding changes in the regime and niches brought about by technological innovation [15];
- Understanding retrofit as a 'co-evolutionary' and 'sociotechnical' process of change [7,8,32].

The MLP can therefore be used to help conceptualise a stronger and more focused systemic approach, by avoiding 'piecemeal' and fragmented approaches to the problem. Drawing on 'transition management' frameworks, and theories related to the 'performative' roles of visions and expectations, MLP offers a powerful set of tools (for example, 'backcasting' and 'visioning' processes) for understanding future social and technical change (see for example, [7,8,3,4]).

4. Methods for identifying disruptive energy innovations in urban retrofitting

Previous research in urban retrofit has shown that two key techniques can be used to identify sustaining and disruptive technologies [15]. These comprised: (i) participatory backcasting; and (ii) roadmapping. These were linked with a wider set of urban foresight methods (see Fig. 1), which included a commissioned series of 'foresight'-based expert reviews authored by international experts.

The research described in this short perspective (see [15] for further details) draws on key findings on disruptive technologies from Workshops II and III, national UK roadmaps and online survey work to help further identify sustaining and disruptive technologies. This process is described in detail in Eames et al. [7,8] and Dixon et al. [3,15].

The research adopted a participatory backcasting approach to develop a set of socio-technical transition urban retrofit scenarios which included the following:

- 'compact city' of intensive and efficient urban living
- 'smart networked city' hub within a networked, competitive society, and
- 'self-reliant green city' in harmony with nature.

Using these visions as a backdrop, and then linking the work with the other methods outlined in Fig. 1, the research was able to identify and distinguish sustaining and disruptive technologies across different scales, and to ultimately set these within the socio-technical context of

[1] See McGrail and Gaziulusoy [33] for an interesting comparison of EPSRC Retrofit 2050 and other urban transition research projects.