Pre-Print Version of:
James Evans and Andrew Karvonen. 2011. Living laboratories for sustainability: exploring the politics and epistemology of urban transition, In *Cities and Low Carbon Transitions*, ed. Harriet Bulkeley, Vanesa Castán Broto, Mike Hodson, and Simon Marvin, 126-141, London: Routledge.

Living Laboratories for Sustainability: Exploring the Politics and Epistemology of Urban Transition

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INTRODUCTION

Creating a more sustainable society is increasingly an urban challenge (Pincetl 2010). Upwards of fifty percent of the world's population currently dwells in cities, and this figure is forecast to rise dramatically over the coming decades (Grimm et al. 2008). Cities both concentrate the activities that produce carbon emissions, and suffer disproportionately from their negative impacts such as air pollution, temperature increases, water shortages, and increased flooding. Given this, cities are increasingly being looked to as sites to develop long-lasting solutions to climate change (Hodson and Marvin 2007).

This chapter focuses on the use of 'living laboratories' to drive innovation in sustainable urban development. The types of spaces designated as living laboratories are highly variable, from a single plot of underdeveloped land to a degraded waterway, from a clogged transportation corridor to a completely new city. Further, a wide variety of organisations – notably universities, government bodies, and private companies – are using the term in an unapologetically boosterish manner to develop and market their own approaches to sustainability. Their enthusiasm is underpinned by two assumptions. First, living laboratories are real life experiments that promise to produce more *useful* knowledge and second, they are highly *visible* interventions with the purported ability to inspire rapid social and technical transformation. Taking a series of examples, we consider the epistemological and political implications of living laboratories, asking whether such experiments really do hold the potential seeds of change, as this literature suggests, or whether there are other motivations at work. The chapter concludes with a discussion of role of the living laboratories approach as a form of experimentation in relation to theories of transition and sustainable urban development.

LABORATORIES AND KNOWLEDGE GENERATION

The word 'laboratory' implies an epistemology; it is a way to know the world. Laboratory studies scholars have furnished well-known accounts concerning the exceptional qualities of laboratories as privileged spaces that channel and accentuate the power of science (e.g., Latour and Woolgar 1979, Knorr-Cetina 1981, Lynch 1985). Because they are purposefully separated from the lived world, they allow variables to be isolated and carefully manipulated in order to test hypotheses (Knorr-Cetina 1995). The material practices that take place in laboratories involve the enculturation of natural objects, breaking them down into constituents that can be examined under conditions dictated by the exacting demands of the experiment rather than the unpredictable whims of nature. In this sense, 'laboratories create enhanced environments where it becomes possible to see things not visible elsewhere' (Henke and Gieryn 2008: 362). Constructed through specific scientific practices, laboratories inscribe accounts of reality that can be repeated dependably, transforming the findings of an experiment in one place at one time into placeless facts that can be transported anywhere while remaining unchanged (Latour 1987).

The authority of laboratory knowledge depends upon this placelessness (Kohler 2002). As Henke and Gieryn (2008: 353) write, 'the laws of gravity worked the same everywhere; even if scientists in different locations disagreed for a time about the content of these laws, persuasive evidence and compelling theory would eventually rub out geographical differences in belief.' Part of this 'rubbing out' involves the generation of a social order to go alongside this new objective order, as the constructors (in the traditional account, scientists) are reconfigured around the new 'facts' (Knorr-Cetina 1995). Latour (1998) argues that this specific quality of laboratories allows them literally to 'raise the world' that we know into existence, remaking objects and subjects (facts and society) simultaneously.

But if the gold standard for natural scientists is knowledge produced in carefully isolated conditions, then how are we to understand 'living laboratories', which claim to produce laboratory ways of knowing in the notoriously messy real world? After all, it is precisely this messiness that, historically, has led scientists to denigrate field-based methods as vastly inferior to the control and explanatory power offered by laboratories. On this understanding, 'living laboratories' should be consigned to the epistemological trashcan; at best a contradiction in terms, and at worst a pathology of pseudo-scientific posturing. But the relationship between the lab and the field is often more permeable than the traditional account acknowledges; indeed, the very idea that the 'lab' can be separated from 'reality' has been widely critiqued (see Bowker 1994, Kulick and Kohler 1996, Henke 2000, Gieryn 2006). As such, the living laboratory approach offers promise for redefining what it means to experiment and innovate in the remaking of the world.

Kohler (2002) defines the lab-field dichotomy as a border zone in his historical account of US biological studies. He follows the attempts of successive researchers to reconcile the supposed superiority of lab methods with the necessity of working in the field, which classic problems like speciation, by their nature, required. Practices of place play a central role in his account. Early field biologists sought out places in which unusual circumstances had created natural experiments, allowing them to mimic the control of a lab. Charles Darwin famously called the Galapagos a living laboratory for the study of evolution because its unique geographical isolation replicated the variables of separation required to study speciation. But these studies largely failed in their efforts to empirically verify speciation, leading the pioneers of population biology in the 1920s and 1930s to turn this practice of place on its head. Rather than identifying special or unique settings to study nature's experiments unfolding, site selection was driven by the practicalities of collecting large amounts of data, which, in turn, privileged ease of access. The paradigmatic example is Raymond Lindeman's field study of Cedar Creek Bog in Minnesota, which yielded the trophic-dynamic theory of energy flow that forms the conceptual bedrock of modern ecology: ecosystems. Cedar Creek was chosen because of the ease with which data could be collected, allowing researchers to reveal the interworkings of its ecosystem dynamics inexpensively; it had a very simple species structure, and was shallow so could be cored to reveal species compositions over many years. Population biology managed to develop explanatory analyses from field studies by collecting an exhaustive amount of data, so that it became possible to identify and isolate variables and test causal links within. In this way, techniques of the field were developed to fit the rules of knowledge production as practiced in the lab.

LIVING LABORATORIES, INNOVATION AND TRANSITION

The concept of the 'living laboratory' blurs the distinctions between laboratory and field, inside and outside, controlled and uncontrolled experiment in a similar way to Kohler's population biologists, and his account has relevance to the way in which 'living laboratories' are being used to study sustainability today. The systems studies literature presents the living lab approach as a research methodology for sensing, testing, and refining complex solutions in real life contexts, which is user-driven and focused on generating innovation through public-private partnerships (Niitamo et al. 2006). The most prominent contemporary examples of living labs can be found in the field of commercial product development. CoreLabs, a coalition of high-profile Eureopean academic and private organisations, provides a typical definition of living labs as 'functional regions' where stakeholders (including firms, public agencies, universities, institutes and individuals) form a public-private-partnership to collaboratively create, prototype, validate and test new services, products and systems in real-life contexts. The phrase 'functional region' refers to cities, villages, rural areas, and industrial plants, thereby separating the living laboratory *in* the real world, if not *from* it. In a familiar refrain, the company goes on to state that living labs are superior to 'closed' labs 'in virtually all aspects' because they focus on user communities embedded within 'real life' (CoreLabs 2010).

Living labs are notable for their reliance on cutting-edge information and communication technologies (ICT) to realize innovation (e.g. Gregory et al. 2000, Frissen and van Lieshout 2004). In a widely cited paper, Cory et al. (1999: 193) describe the development of an 'Aware Home' as a living lab for the study of domestic activity. The purpose-built house was fitted with ultrasonic sensors, radio-frequency and video technologies, floor sensors and vision techniques, all of which feed data back to the domestic computer which responds to the needs of the inhabitants. Mirroring Kohler's field biologists of the early twentieth century, Cory et al. (1999: 191) describe the aware home as an 'authentic yet experimental setting' – a living lab that offers both the control of laboratory experimentation *and* the authenticity of real life. The access offered by the living lab allows ubiquitous computer-assisted learning to generate massive amounts of data from everyday activities. But the Aware Home takes the ease of access of Lindeman's bog to the next level, creating a bespoke space hardwired with monitoring equipment to capture live data. This commitment to total data capture runs through the literature, and is not confined to ICT monitoring. Multiple methods, ranging from creativity groups and social network logging to field trials and participatory design, are advocated as ways to collect data on all aspects of living labs.

Surprisingly, the centrality of the human user in the living labs approach unwittingly addresses a burgeoning critique from within the critical geography and Science and Technology Studies literature, which argues that sustainability transition is being framed in an overly technocentric way (see Brand 2005; Oudshoorn and Pinch 2005). By contrast, living labs emphasize the human dimensions of new technology uptake, arguing that it is users who ultimately determine the success or failure of innovations. Living labs thus validate products and services in collaborative, multi-contextual, empirical, real-world environments, integrating users and stakeholders in the activities of product and service development. The individual here is understood as multi-faceted and performing multiple roles, from user and customer to worker and maintainer (Kusiak 2007). Returning to Knorr-Cetina's language, the living lab approach interpolates technology into society at the most basic level, as co-evolving entities. It harnesses the power of the laboratory to generate new social conditions through commercial innovation.

The idea that innovation is the primary source of economic success has a long history (Schumpeter 1934), but studies of innovation have failed to achieve anything approaching a scientific insight into the process. Numerous disciplines have their own terminology to describe similar elements such as degree of novelty (incremental versus radical), types of innovation (products, systems, processes and services) and so forth, but two requirements tend to be widely accepted: first, innovation must create *new knowledge* (e.g. Brockman and Morgan 2003) and second, it must generate *commercial success* (e.g. Galanakis 2006). Procter and Gamble, the international consumer goods corporation, is a well known example of the success of this approach and a leader in research innovation. And they have realized significant gains since including stakeholders in their living lab activities, doubling their innovation success rate in two years with no increase in research and development expenditure (Kusiak 2007).

The commercial living lab approach is experimental in a colloquial sense; many small innovations can be trialled at a low level (i.e., let a thousand flowers bloom), which are then selected through an evolution of ideas. In this so-called 'innovation pyramid', competition and adaptation between products leads to the emergence of successful innovations (Utterback and Abernathy 1975). Geels' (2002) model of socio-technical transition relies on a similar evolutionary approach to understanding how isolated innovations, occurring in specialized or protected 'niches', either are, or are not, scaled up through wider adoption. Within Geels' framework, niches can force change at the regime level of wider governance if they are suitably successful, either by scaling up or multiplying and eventually coalescing. As Geels notes, 'while regimes usually generate incremental innovations, radical innovations are generated in *niches*' (ibid: 1260, emphasis original).

Living labs constitute classic niches for innovation in this sense, as arrangements 'built between actors to support the innovation in very specific time and space contexts' (Beveridge and Guy 2005: 675), that shelter it from wider political and economic pressures. That said, they differ from the classic examples offered by Geels in that they are *explicitly* experimental, rather than rationalized *post facto* as innovative. So, for example, the evolution of steam in the shipping industry and the developments in logistics that accompanied it were innovations (Geels, 2002), but not in the same way that a living lab sets out to explicitly *create* a niche in which experimentation can occur.

SUSTAINABLE URBAN INNOVATION AT UNIVERSITIES

Living labs are highly appealing to the wide range of actors involved in climate change mitigation and adaptation activities. Rooted in a specific place, they offer the immediate real-world relevance sought by policymakers; data-rich, they offer the promise of causal understanding and 'factual' knowledge that is the *sine non qua* for scientists; user-led in character, the innovations they generate have a greater likelihood of successful adoption, promising commercial rewards for the private sector. Further, the interdisciplinary approach of living labs lends itself to the academic challenge of urban climate adaptation, which Ravetz (2009) suggests requires innovation simultaneously in physical and social science, and a policy environment that increasingly speaks the language of demonstrations, experiments and pilot projects.

While the conventional commercial living laboratory model is not automatically associated with universities, living labs for sustainability frequently involve partnerships that include universities, the public sector and private companies. Living laboratories form part of the broader shift towards more pragmatic epistemologies that accompanies increasing pressure for universities to pursue research agendas that have relevance for society at large (Barnett 2000, Perry 2006). While notoriously hard to achieve in the urban environmental sphere (Evans 2006, Evans and Marvin 2006), an emphasis on demonstrable utility within academia more widely is set to continue, with the UK's forthcoming Research Excellence Framework requiring researchers to explicitly consider their impact on society (see Demeritt 2010). Table 1 includes a summary of four case studies of university-led living laboratories for sustainability that demonstrate four distinct approaches, each focusing on a different type of innovation, which, in turn, privileges different actors and forms of knowledge. In the following section, we tease out their central characteristics to inform the ensuing discussion about living labs and transition.

Table 1 Four University-Led Living Laboratory Approaches

	Masdar City	*North Desert Village*	*Oxford Road Corridor*	*Urban Landscape Lab*
Driver of innovation	Technological breakthrough	Scientific knowledge	Collaborative urban governance	Socio-material adaptation
Dominant disciplines	Engineering, business	Ecology, biology	Public policy, engineering, business	Landscape architecture, architecture, planning, urban design
Fabricated?	Yes	Yes	No	No
Types of data collected	Environmental and social use	Environmental and stakeholder preferences	Environmental	Stakeholder knowledge and opinions
ICT use	Heavy	Heavy	Selective	Low
Scale	Large	Medium	Large	Small
Commercial emphasis	High	Low	High	Low

Masdar City, United Arab Emirates

Masdar City is an ambitious project to construct a city of 50,000 residents 17 kilometres from Abu Dhabi in the United Arab Emirates. Designed by Foster & Partners as a model of sustainable urban development, it promises to be a zero-carbon, zero-waste city powered entirely by renewable energy (Masdar City 2010). The tagline for the project boasts that 'one day all cities will be like this' and Masdar CEO Dr Sultan Ahmed Al Jaber states, ‘Masdar City is a blueprint for cities around the world striving for sustainability, and a living laboratory to advance renewable energy solutions’ (quoted in Masdar 2010). Prosaically enough, the Arabic word 'Masdar' means 'source', and the strategic goal of the project is to generate ideas and knowledge to make Masdar City the model for sustainable urban development throughout the world. It is arguably the most enterprising form of living laboratory to tackle the issue of climate change and does so by forwarding technological development as key to a carbon-free future. Reflecting on the ambitious goals of the Masdar project, a journalist writes, ‘Abu Dhabians are betting that technology can dominate the climate, and, with almost limitless resources, they just might succeed’ (Hartman 2010).

The new university is a key aspect of this technopole of climate change innovation. The Masdar Institute of Science and Technology, unveiled in September 2009, was developed in collaboration with the Massachusetts Institute of Technology (MIT). By 2011, the institute will offer ten post-graduate science and engineering programs in renewable energy and sustainable technologies, and eventually it will be home to 600 graduate students and over 100 faculty to serve as a hub for public and private research institutes around the world. In addition to conducting traditional research and development on renewable energy technologies, the institute will be housed in a building that will be wired with an energy metering system to monitor energy consumption and be used by the faculty and students as a research tool (see Masdar 2010).

Masdar is a large-scale, technology-dominated approach to urban transition that seeks to develop commercially viable solutions to urban sustainability in a fabricated living laboratory. The laboratory concept has at least two meanings in Masdar City. First, the city itself is a testbed for a carbon-free lifestyle. A hybrid of vernacular Arabic and cutting-edge energy efficiency strategies are being incorporated to create a real-life city with a negligible impact on climate change. Second, the laboratory term refers to the development of a clean-tech sector, where the ‘aim is to become the silicon valley for clean, green and alternative energy’ with a high concentration of global and startup companies that will use the city as a base for an energy revolution (Masdar City 2010). Innovation here is fueled by technological breakthroughs and the increasing business opportunities offered by globalized energy markets.

North Desert Village, Arizona, USA

A second example of the university-led living laboratories approach is the North Desert Village in Phoenix, Arizona. Funded by the US National Science Foundation, the North Desert Village is a project within the Long-Term Ecological Research (LTER) program, the flagship environmental science research program in the US comprising 24 ecologically diverse sites, an annual direct budget of almost $20 million and approximately 1100 scientists and students. In 1997, the NSF added two metropolises (Phoenix and Baltimore) to their portfolio of sites, and both projects were granted second phase funding in 2004 (NSF 2002). The research teams in both cities adopted a large-scale ecosystems approach while also framing their cities as living laboratories (Grimm and Redman 2004). The Central Arizona-Phoenix LTER has realized this goal most explicitly by establishing an entire 'experimental suburb' to develop innovative urban ecological approaches.

Similar to Masdar, North Desert Village is entirely fabricated and is the first-ever experimental study of interactions between people and their ecological environment at the neighbourhood scale. One type of experiment involves the manipulation of vegetation types and irrigation methods to explore how landscape interactions affect human perception and behaviour. Residential landscapes at identical housing units in the village were installed in four different styles based on the different habitats found throughout the Phoenix area, ranging from a mixture of exotic water intensive vegetation and shade trees with turf grass maintained by flood irrigation (reproducing the classic and largely unsustainable suburban garden type) to native plants on granite substrate with no supplemental water whatsoever (reproducing the surrounding Sonoran Desert landscape).

Faithfully reproducing the mantra of living laboratories, the researchers claim that experimenting on humans in situ produces 'more accurate scientific models' which are better able to capture the complex and unpredictable feedback mechanisms between social and ecological systems that typifies urban areas (Cook et al. 2004: 467). The preferences of North Desert Village residents were used to design the area, and subsequently to inform ecological management decisions. This approach, dubbed 'adaptive experimentation', takes the user-centred approach of living laboratories to its logical conclusion, allowing users to adapt the experiment and alter its parameters from within. But however radical this methodology is, it is accompanied by a need to legitimize the North Desert Village as a scientific space. The experiment team does this through its description as a laboratory that incorporates 'most of the formal aspects of classic experimental design, including independence of study units, use of replicates, and controls' (ibid: 467). Their mode of adaptive experimentation turns the neighbourhood into a living laboratory, not by hardwiring science into the direct administration, design and planning of the urban landscape, but by assimilating these functions into the study itself (Evans 2009). Through this systems approach, nothing remains outside the lab. Unlike Masdar, the innovation is decidedly scientific in character, promising to integrate environmental monitoring and social preferences in a sustainable urban management system. Like Masdar, the North Desert Village experiment includes user preferences, but the interface between users and landscape is never direct – it is mediated though a data monitoring and policy/management interface system. As such, this living labi is defined by technocentric forms of user participation that fit within the ecological science model of the experimenters.

Oxford Road Corridor, Manchester, UK

Not all living laboratories are created anew. Manchester's Oxford Road Corridor is an example of how the living labs approach can be superimposed upon an existing urban area. Comprising 243 hectares, two universities, and five hospitals, the Oxford Road Corridor is frequently touted as the ‘backbone of the city’s knowledge economy’, involving 37,000 employees or 12% of the city centre's workforce with an estimated annual turnover of £3.2 billion (MSCP 2008: 2). In the mid-2000s, the public and private stakeholders along the corridor partnered with the Manchester City Council to create the Manchester City South Partnership (MSCP) whose mission is to improve the economic, environmental, and social aspects of the corridor, with the hope of generating spill-over benefits for the city, region, and the UK. The partnership is committed to spending an estimated £2.5 billion over the next two decades on economic development, cutting-edge communication networks, an integrated mass transportation plan, green infrastructure, and cultural growth. The University of Manchester wants to use the corridor, referred to by various actors as the ‘Green Laboratory’, 'Corridor Manchester' and 'Laboratory Manchester', to realize an affordable and resilient low carbon economy. Like Masdar, the university intends to use Greater Metropolitan Manchester as a ‘test bed’ for energy, communications and transportation technologies (Ravetz 2009: 8) with the corridor as the first major intervention. Both Masdar and the Oxford Road Corridor have a strong emphasis on commercially-driven innovation that will eventually recoup the costs of building and running these large, real-world experiments.

From an urban development perspective, the University is involved as a large property owner who will be directly affected by any changes to the corridor. But there are increasing calls from both inside and outside actors for the university to get involved as a research partner in the initiative. In 2009, the University of Manchester and the Manchester City Council signed a Memorandum of Understanding (MOU) to formally pursue climate change adaptation best practices methodologies for urban environments. One of the first partnerships of this MOU is the EcoCities project that will create a blueprint for climate adaptation in Greater Manchester by 2011 (see EcoCities 2010). And there are multiple ongoing and proposed research projects to monitor environmental parameters of the corridor (temperature, wind, air pollution, precipitation, etc.) using temporary and permanent monitoring climatic stations.

Like Masdar City, the living laboratory of the Oxford Road Corridor is firmly rooted in natural sciences and engineering, but the overarching emphasis here is not on technological innovation but rather on environmental policy and urban development. Innovation is achieved through new modes of governing the carbon flows in Greater Manchester under a rubric of ecological modernisation that promotes a win-win scenario between economic and environmental interests, an aim that fits in with Manchester's designation as a Low Carbon Economic Area as well as the City Council's Climate Change Action Plan (both unveiled in December 2009). The corridor serves as the pilot project for an overacrhing climate change agenda that will eventually shape the greater Manchester metropolitan region as a whole.

Urban Landscape Lab, New York, USA

A fourth example of a university-led living laboratory comes from the design disciplines, notably architecture, urban planning, urban design, and landscape architecture. Here, urban sustainability is frequently addressed through participatory design studios that focus on real-world issues. Such programs contribute to a larger trend of project-based education where university research is directed to concrete problems to fulfill the university's commitment to public service (see Bajgier et al. 1991, Pearson 2002, Moore and Karvonen 2008). An exemplar of this approach is the Urban Landscape Lab (ULL) at Columbia University’s Graduate School of Architecture, Planning, and Preservation in New York City. The laboratory is directed by Kate Orff and Janette Kim, two educators and designers, who lead an interdisciplinary, applied research group ‘dedicated to advancing dialogue and new design methodologies to effect positive change in urban ecosystems’ (ULL 2010). Their projects bring together a wide range of design and professional disciplines – architecture, landscape architecture, urban design, preservation, civil engineering, conservation biology, economics, climate, public health, and community-based advocacy – to work on traditional academic research and design studios as well as outreach activities that interpet 'cities as pedagogy' (Shields 2008: 714).

An example of a ULL project specifically directed at climate change adaptation is 'New Natures: Visualizing CarboNYC', a summer 2008 studio that visualized future scenarios for a self-sustaining New York City. The project examined settlement patterns at three different sites to understand how changing material conditions could be addressed with innovative urban design interventions. As such, living laboratory experiments are used to rework the relationship between urban residents and their material surroundings. The scale of these design interventions tends to be smaller due to time and personnel constraints, with site and neighbourhood scales being the most common focus. There is an explicit recognition that the city is not an economic engine, a disrupted ecosystem, or a policy conundrum, but rather a place of lived experience. And it is here, at the human scale, where sustainability interventions are considered to have the greatest impact.

Like the Oxford Road Corridor, the Urban Landscape Laboratory is not afforded a *tabula rasa* upon which new urban development strategy can be tested. Instead, the experimenters must contend with the existing fabric of the city that includes a whole host of physical, economic, cultural, and social relations. But while the Oxford Road Corridor focuses on top-down policy integration, to be achieved through collaborative urban planning and policy intermediaries, the ULL takes a bottom-up approach to socio-material adaptation of the urban environment by civic designers (e.g. Borasi and Zardini 2008). The living labs that have been fabricated (i.e. specially built) tend to be more comprehensively data-driven, with a higher reliance on ICT and a notion of their user community similar to that found in the living labs literature. This reflects the ease with which data monitoring equipment and protocols can be incorporated into an environment that has been specifically constructed. The Oxford Road Corridor and ULL are inevitably confronted with greater data collection difficulties as they attempt to establish living laboratories in already existing facets of the urban environment. This difficulty may explain their emphasis upon human agency as a driver of change, rather than the technical-expert solutions that drive fabricated labs.

TRANSITION AND THE POLITICS OF THE LIVING LABORATORY

In his study of the Clark Centre biotech lab at Stanford, Gieryn (2008: 797) argues that the lab itself is an 'experiment' in linking the production of scientific knowledge with economic interests, adopting a design aesthetic that mirrors the disembedded architecture of high capitalism associated more commonly with airports and art galleries. The living laboratory for sustainability consummates a similar union between truth and economy. The implication of Masdar City and North Desert Village is that if they are deemed successful, then the knowledge generated there has 'added value' and is, in some sense, *more* valid than knowledge produced either elsewhere or in 'traditional' scientific settings. Places like Masdar and the Oxford Road echo Henke and Gieryns' (2008: 365) observation that 'spaces for science are a powerful blend of material infrastructure and cultural iconography that lend credibility to knowledge claims.' As truth becomes synonymous with commercial success, it is embedded in the city as high profile living laboratories in no less material a way than monuments to economic success, such as skyscrapers.

For sustainable urban development, living laboratories exist as truth spots; visible arbiters of truth in their own right that have their own logic. They are symbols of power and hold the promise for improved urban futures but at the same time, they are not simply blueprints that can be 'rolled out' everywhere. Rather, it may be the container itself that has viral properties. Kohler (2008) suggests that labs display an exceptional weediness of character, which allows them to permeate life in multiple ways and contexts. In terms of their ubiquity and plasticity living labs may be part of the next stage of this dispersal. In his famous account of the pasteurisation of France, Latour (1988) describes how the proliferation of labs in universities, commercial research facilities, farms and processing factories changed procedures and material realities across the country, interpolating the microbe into French society as much as they did into the natural order. In this way, 'the world became colonised by 'extramural' laboratories (Knorr-Cetina 1995: 160), which were outside but under the aegis of the scientific sphere. The concept of extramural colonisation perfectly captures the process enacted by living labs, which explicitly endeavour to reproduce scientific ways of knowing in the real world. Further, the power of labs to interpolate seems more potent in relation to the applied scientific knowledge or techniques demanded by sustainability, whereby a range of users, builders, recorders and so forth are involved in the production of new knowledge. Living labs for sustainability interfere quite purposefully, harnessing the power of laboratories to remake society in accordance with new forms of knowledge.

Reflecting on Geels' framework of technological transition, living laboratories can be understood as a particular type of niche that explicitly incorporates knowledge production into decision-making. Geels' model is formal in the sense that the content of the niche is inconsequential; it simply describes how content spreads when successful, eventually being adopted more broadly in the governing regime. Living labs constitute a special kind of niche that is knowledge-driven, socially aware and *explicitly* experimental, qualities that are missing in Geels' framework (see Geels and Schott 2007 for a discussion). This self-awareness is crucial to the living laboratories approach because it opens up multiple avenues for, and a politics of, sustainable urban transition.

Living laboratories intentionally sidestep the tensions between bottom-up and top-down approaches to innovation in favor of lateral partnerships. On the one hand, this can be interpreted as a classic symptom of the post-political malaise affecting sustainability, where environmental catastrophe presents an opportunity for neo-liberal actors to wrest control of urban development from the government (see Swyngedouw 2007, 2009). On this understanding, climate change becomes a business opportunity for private interests to gain market share in the guise of helping society at large. Living laboratories aid and abet this appropriation by transforming the real world into a de facto research and development facility for capitalist modes of ecological modernisation. The post-political landscape that emerges is one of the city as a 'self-adapting' landscape, controlled by the market and governed by the integrated monitoring and management of feedback loops between social and physical processes, in which political choices are tamed and replaced by user patterns and preferences (Evans 2009).

On another reading, though, the living laboratory approach offers the potential for opening up climate mitigation and adaptation strategies to new strategies and ideas informed more democratic modes of governance that are socially inclusive and sensitive to local conditions (Evans et al. 2009). This is precisely the trajectory taken with the new World Urban Campaign launched by UN-Habitat in 2010 through its abandonment on the best 'best practices' approach of sustainable urban development in favor of a 'living practices' approach that is bottom-up, networked, and intended to champion the unique lived experiences of individuals in particular cities (Peirce 2010, see also Bulkeley 2006). From this perspective, living laboratories have the potential to act as intermediary spaces, positioned between technological possibilities and local contexts to 'manage' processes and governance of transitions (Hodson and Marvin 2009: 522) at the increasingly important levels of the city and region (e.g. Bulkeley and Betsill 2005, While et al. 2009). Here, climate change innovation emphasizes new modes of politics that challenge the conventional structural approaches that are top-down or bottom-up. Living laboratories are sites where 'fresh politics as yet unrecognized as such are emerging' (Latour 1998: 268), but precisely what form this politics will take is, as yet, up for grabs.

CONCLUSIONS

Kohler (2002: 214) notes how the idea of the natural laboratory formed a powerful part of field biologists' 'imaginative infrastructure' through which they understood the process of experimentation. Today, the rhetoric of living labs performs a similar function for those pursuing sustainable urban development. Hugely powerful yet poorly defined, living labs offer a set of alluring promises – as idea factories for generating relevant and usable knowledge, as 'test beds' for applying this knowledge in real world situations, and as places to form the 'blueprint' for climate change mitigation adaptation elsewhere. Living labs have *already* had a major impact, as cities and universities rush to establish their own bigger and better versions to compete with those that already exist. However, it is uncertain whether these niche experiments can be scaled up to generate widespread changes in the existing processes of urban development. This depends in large part on how the knowledge produced by through experiments is packaged and transferred to other locales. While all living labs express a desire to influence the wider world, the exact strategy or mechanism to scale up these activities is rarely outlined in detail; it is simply assumed that those successful innovative practices will somehow infiltrate and propagate, making these innovative practices the norm.

On the one hand, living labs (and experimentation in climate governance more widely) simply reproduce capitalism, seeking to 'tame' the messy realities of cities. On the other, the urban setting contains the seeds of many possible experiments that can resist this structural analysis – there is nothing about the urban condition that prefigures certain kinds of experiment. Indeed, explicit experimentation of the kind being practiced in living labs can accommodate a wide range of collaborative partnerships, and it is perhaps this new mode of knowledge generation, rather than the knowledge created therein, that makes living laboratories such an enticing concept for realizing improved urban futures.

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