Energy Houses, Smart Grids and Lab Style Transitions

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Abstract:

Transitioning to a low carbon society involves the systemic transformation of socio-material environments, and yet there are few precursors upon which to base action. Accordingly, a range of methodologies have begun to emerge across the public and corporate sectors that are explicitly designed to test innovative low carbon solutions. This paper focuses on living labs, which are designated spaces capable of hosting real world experiments in built design and sustainable technologies. Living labs represent a niche approach to innovation that seeks to monitor various infrastructure experiments and learn from them. As real world experiments it is assumed they will yield knowledge that can be easily applied to wider contexts, and yet they are themselves embedded in very specific geographical and political contexts. This paper explores the experimental arrangements through which these lab spaces engage 'the real world', and how the generation of transferable and up-scalable knowledge is shaped by the political and social context in which testing take place.

Introduction – the experiment and the lab

"The laboratory is the place where things that are uncommon and unproven are tested: a learning process by definition."

- Paolo Soleri (2002) *What If?* Chapter 5

Living labs represent an increasingly popular strategy to expedite low carbon transitions. Constituting a form of experimental governance, whereby urban stakeholders experiment with new technologies and approaches to address the challenges of climate change (Bulkeley and Castan-Broto, 2012; Evans, 2011), living labs are distinctive in staging formal experiments that can be scientifically monitored and learnt from. Living labs for low carbon research are emerging all over the world, from individual buildings like the Queens Building for energy research in Leicester, to the European Network of Living Labs, which encompasses over 300 cities (Tecnalia, 2012).

These places, and they are very much 'places', hold strong appeal for politicians, funding bodies, university vice chancellors, companies and the public alike. The idea of the laboratory confers scientific legitimacy upon both the practices and knowledge outputs associated with it. This is important in terms of the potential to scale up; single cases of successful change are important, but the rigour of the controlled experiment promises the kind of generalisable knowledge upon which wider transitions depend. Relevance is conferred by the 'living' part of the equation. Materialising solutions in physical places that can be seen and touched provides a powerful tonic to the declensionist narratives that dominate much of the public environmental debate. Adopting a register more akin to the Human Genome Project, living labs position themselves as the places where the DNA of sustainability is being discovered; anticipatory beacons of the low carbon future from whence transition will emanate.

In their rhetoric at least then, living labs promise a new form of research infrastructure capable of producing, communicating and appropriating effective forms of knowledge to drive the technical and social infrastructure transitions upon which economic growth and carbon reduction depend (Hodson and Marvin, 2009a). The following paper explores the practices through which living labs are established and the types of experiments that they make possible in order to better grasp how they might contribute to wider low carbon transitions. Drawing on Laboratory Studies to contribute to debates in the Geography of Sustainable Transitions, the paper explores living labs as a kind of niche in which experiments are both structured by their wider network of relations and structure their ability to drive change.

Niches, experiments and the geography of transition

Living labs are emerging in numerous cities around the world as a strategy for local governments to partner with public and private property owners to reduce carbon emissions while simultaneously stimulating economic growth. In the spirit of mode 2 science (Gibbons et al. 1994), living labs are designed to facilitate physical interventions in the form of applied experiments that can be closely monitored and used to change policy or practice. They tend to be clearly defined geographical and/or institutional spaces with the capacity to collect large amounts of data that can be analysed to identify causal links between experimental interventions and outcomes (Evans and Karvonen, 2011). Universities see living labs as vehicles to establish critical mass and profile in terms of energy research, and give public and commercial organizations access to free or heavily match-funded research capacity and testing facilities (Evans and Karvonen, 2013). Such research infrastructures play an important discursive role in allowing cities and universities to position themselves as leaders in low carbon innovation and major players in regional economic development (Benneworth et al 2013; Koenig and Evans, 2013; Trencher et al. 2013).

Living labs represent a specific type of niche, or protected environment, in which innovations emerge and are tested (Geels 2002). Niches form incubation rooms where unique combinations of expertise and resources are available that provide the seeds for change, protecting radical innovations that may be commercially unviable at first from wider economic forces (Kemp et al. 2001). The Multi-Level Perspective (MLP) model of technological transition suggests niches break-out to effect regime change as they become more economically competitive than the incumbent technologies, prompting wider transition. That said, many existing studies of low carbon experiments suggests that incremental learning through developing, testing and introducing new technologies and services tends not occur in any meaningful way as more often than not technology is simply ‘dropped’ in to a place, tested and then removed without any meaningful participation of the public or decision-makers (Hodson and Marvin, 2009b; Karvonen at al., 2013). A distinction is made in the literature between ‘fit and conform’ experiments that simply reproduce regime inertia and ‘stretch and transform’ experiments that prompt change, with the observation that the former are far more common in practice than the latter as niche experiments often become captured by dominant actors and interests (Smith & Raven, 2012).

These more critical accounts underpin a broader concern that the Multi-Level Perspective model over-simplifies the exact processes by which niche experiments influence the wider world. For example, economic competitiveness itself is determined by a series of broader social and political factors, from institutional learning and regulatory change to political and public opinion which the

MLP approach does not fully account for (Truffer & Coenen 2012; Lawhon & Murphy, 2012). Talking about the processes through which niche experiments generate wider impact, Brown and Vergragt (2008, 110) argue that 'little systemic study has been done on defining the learning processes in experiments, monitoring them, assessing their societal impacts, or examining the conditions under which learning does (or does not) occur, and by what mechanisms.'

Transition management is a model of governance that relies on a cycle of problem structuring, visioning, experimentation, policy development, implementation and adaptation (Kemp et al., 2007) to drive change; a continuous feedback loop of experimentation that allows novelty to emerge (Broto & Bulkeley, 2013). Seen in this way, the ability of niche innovation to stretch and transform depends upon pushing the rules of experimentation (Coenen et al 2010). This observation draws attention to the way in which experiments are framed in niches so as to enable the emergence of novelty. Talking about this process in the biological sciences, Rheinberger (1997; 134) states that surprises are 'made to happen through the inner workings of the experimental machinery for making the future', as the hypothetical basis of the experimental test opens up more than one possible outcome. Experimental logic controls variables to allow the emergence of underdetermined 'epistemic things' that were previously unknown in such a way that allows the experimenter to be open to surprises but at the same time to 'control the surprising event as a basis for learning' (Gross, 2010; 29).

Viewing niches as labs allows the question of how innovations break out to effect regime change to be viewed slightly differently. While a perceived lack of 'socio-spatial embeddedness, scale and power' (Truffer & Coenen 2012) in the MLP has prompted a turn to Geography (Coenen and Truffer, 2012; Hargreaves et al., 2013), laboratory studies offers a sophisticated relational view of the laboratory as a network of wider relations including staff, materials, professional networks, funding, ideas and ideologies. As a network the lab represents a 'form of innovation, where scientific research increasingly erases the received institutional boundaries between science and society' (Gross and Krohn, 2005; 76). Seen in this way, experiments are structured by their wider context, networked into the regime if you will, rather than being somehow spatially separate and temporally successive in impact. Such a relational view of the niche is currently advocated by some transition scholars (Geels, 2011), with Smith & Raven (2012) identifying 'expansions in supportive socio-technical networks' as critical in supporting break-out. Similarly, Smith et al. (2010) have highlighted the need to understand how the functional socio-technical spaces of niche, regime and landscape relate to other dimensions of space, such as territorial, administrative and communicative spaces. Considering space puts an analytical premium on how actors' power depends on their relationships and connections within networks across a range of scales; in other words, it suggests that the territorial embeddedness of niche experiments underpins the multi-scalarity of sustainability transitions (Coenen & Truffer 2012).

While their emphasis on formalized knowledge production distinguishes living labs from broader conceptualisations of niches, they have something potentially interesting to tell us about the way in which experimental networks structure relations between specific places and wider transition. The remainder of the paper presents the preliminary analysis of two living labs based in the UK; the Salford Energy House in the North West and the Durham Smart Grid in the North East, that focus on facilitating low carbon infrastructural transitions. In doing so the paper seeks to address the practices through which living labs are established and the types of experiments that they make possible. The cases are not intended to be exhaustive or representative, but paradigmatic and contrasting examples of labs that are explicitly aiming to foster broader infrastructure transitions though experimentation. In that sustainability transitions are what Geels and Schot (2007) term 'purposive transitions', the explicit focus of these two lab spaces on knowledge generation makes them inherently interesting.

The Energy House and the Smart Grid

In 2010 the European Regional Development Fund awarded Salford University a grant to build a brand new 1930s terraced house inside their old physics laboratory, with the goal of developing and testing energy saving technology. Intended to be an accurate replica of the dominant type of 'hard to heat' housing stock in the UK, the house was built by local builders inside a fully controllable Heating Ventilation and Air Conditioning chamber that allows temperature, precipitation and even wind to be precisely controlled (see Figure 1). A series of homely touches compound the innate strangeness of finding a fully functioning house in a hermetically sealed shed; a Lowry picture hangs on the living room wall while a bottle of red wine idles on a work surface in the corner of the kitchen. These human touches hint at the purpose of the Salford Energy House, which is to simulate 'real' life in a living laboratory, right down to the rhythms of fridge doors opening and shutting, pizzas going in the oven and toilets flushing.

The head engineer at Salford identified replication and control as the most significant achievements of the laboratory. In terms of how to achieve scientific legitimacy in a living context, the scientists involved highlighted the different technologies that could be used to control variables ranging from meteorological conditions to various types of appliances and use regimes in the house itself. In the case of the Salford Energy House it was the chamber in which the house was sealed that brought 'the science to the experiment'. The emphasis was very much on the laboratory rather than the house, which while visually striking was a relatively a cheap component within the more expensive laboratory, and which is eventually planned to be torn down and replaced with another housing type.

Often the Energy House was presented as a research infrastructure waiting for a user. It explicitly positions itself as a data producing test facility that stays away from analysis; as one member stated, they literally hand the data over 'on a memory stick'. The emphasis on testing was particularly strong, with demand from business far outweighing that from academics. The main technology being tested at the time of our visit was a smart flow control system that had been developed by British Gas to better control the water flow through a standard gas combi boiler in order to improve the efficiency of water heating. The instrumentation in the boiler and on the heating system generated hundreds of pieces of data every second on water flow, temperature and pressure, while the house enabled the researchers to test the piece of equipment under simulated conditions of a hypothetical four person family using it for periods ranging from days to months under different weather and seasonal conditions. As one researcher stated, 'many of the technologies [being tested here] are not our own technologies anyway, they're not things we want to test.... so really we are testing to see what the problems of the real world are rather than testing particular systems'. Again the emphasis here is on the power conferred by the ability to replicate real world conditions; it was the ability to perform more realistic tests that was identified as the main advantage of the Energy House. Novelty in this circumstance emerges in the form of problems surrounding the application of technologies.

Ironically, a year on from the Energy House opening, the most pressing challenge facing the engineers is how to automate human activities. While originally intended to be inhabited, the health and safety issues of living in a hermetically sealed chamber and the unpredictability of real human behaviour have meant their exclusion from the laboratory. Humans have been replaced by automated appliances and electric door openers so that everything can be set to a programmable schedule, from the frequency and duration of the toilet flush to the oven simulating the cooking of a pizza. This helps to ensure replicability, although the irony of removing the living component from a research facility that explicitly billed itself as a living lab was not lost on the researchers we met.

The Energy House brought the distinction between experimenting (as the discovery of something new) and testing (as the trialing of a discovery) into question. A lexicon of exceptionalism surrounded it based on claims that the site was special and unique as a research facility in offering this kind of controlled and yet realistic environment. Here lies another interesting tension, between the living lab as a generic analogue for any office building / terraced house / urban landscape, and its uniqueness as a site of knowledge production. The Energy House has been visited by numerous politicians and even a minister, warranting numerous mentions in the House of Commons as an exemplar of knowledge-driven low carbon innovation and economic growth. There is another gap here between the huge cost and hype of living labs and what is often a fairly unassuming reality. Even the Salford Energy House sits in an unassuming shed like building in a corner of a university campus, and once inside has no impressive control room or viewing area. The scientists can control all the functions remotely from a laptop or PC.

The Energy House avoids the legal and ethical ramifications of conducting research in the external world while offering a lab that is just as real. The importance of encouraging local technology clusters as part of the regional low carbon growth strategies was highlighted, although it was noted the uncertainties surrounding the level of interest there would be in this from private industry. As it turns out, most of the users of the lab were either PhD students or large corporate players like British Gas who were keen to gain access to a state of the art facility to test and refine pre-existing technology. In terms of specific impacts, the Energy House team made no attempts to understand how the knowledge that they produced was used or what it subsequently achieved, and this included the academic as well as the non-academic knowledge. There is no doubt that part of the challenge to traditional institutional roles and boundaries posed by this kind of research infrastructure is the requirement for more sustained engagement with the entire knowledge chain of which they are part in order to better understand the needs of external partners and their subsequent uses of the knowledge that they obtain.

The Durham Smart Grid is a more traditional looking scientific lab. Hidden in the corner of a 1960's science building that is mostly home to bulky items of unused aerodynamic testing kit that hark back to a pre-computer era, it would be entirely miss-able to the casual observer in a way that the Energy House is not. The lab itself is a small room encircled by cables that run across the walls, ducking down periodically to connect to a variety of machines. The cables run a 3 phase low voltage network that replicates the low level power distribution used by the National Grid, while the various machines that are connected to this micro-grid are emulators, which can be used to mimic wind and solar power sources. Wind power is notoriously 'lumpy', as power flow depends directly on wind speed which tends to be variable and greater at night, while solar power tends to be unreliable in the UK. Known amiably as 'windy boy' and 'sunny boy' (see Figure 2), these emulators turn data from actual wind and solar power sources into real volts that can then be fed into the network to simulate the effects of renewable energy sources on the actual energy grid. The smart grid also has an electric car charging point with a dock outside in the service road adjacent to the lab with a battery array to allow temporary storage of excess power for later discharge and its own power generator. The equipment used is all commercially available and any of the sources or loads can be plugged into any one of the three wires, just like a real network. The grid is fully instrumented to allow repeatable tests of wind and solar impact to generate new algorithms to manage power delivery on the grid more effectively.

The lab is also connected to a computer that allows data to be both fed into models and data from models to be tested in the lab in real time. On one wall four large LCD monitors display various circuit diagrams and graphs busily drawing themselves in real time. To add to the mind-bending complexity of the smart grid, data on low voltage, high voltage, wind speed, cable temperatures and so on is also monitored on a real world network near Darlington which can then also be fed into the computer for replication in the lab. A few similar labs exist, but few have analogue and computer models linked in real time. There is no clear start or end point to the Smart Grid; rather it is described as a loop. Unlike the Energy House, the smart grid has accreted incrementally, and various bits of equipment have been added over time when funds have become available. The goal of the Smart Grid was not to test commercial equipment but to develop more efficient energy management principles. Similarly, while the importance of simulating consumer behaviour was recognized, the lab was not doing so yet.

The close connections of the Smart Grid to energy companies meant that they were very much aware of how the knowledge that they produced was being used in the real world, with power companies deploying equipment and algorithms developed in the lab in Wales. The key to success in this lab identified by primary investigator and creator of the lab was 'having the right ideas to test', and this was in no small part due to his background in the power industry and connections to important power companies and the National Grid. While 'learning something new' was identified as the validation of success, there was an equally important recognition that the 'lab adds credibility to industry [partners] – they like real volts and amps'. Computer models allow scaling up but they don't model system behaviour on a real grid accurately as there are too many mathematical simplifications, especially when supply is very dynamic as is the case for renewable sources. Building an analogue power network to scale allows computer models to be validated before they are deployed on the real power network. This is seen as an important stage in convincing power companies to adopt the labs models, as there is limited opportunity to experiment on the real power network given the necessity of ensuring a continuous power supply to homes and businesses.

Viewed as networks the two labs are very different, being set up in different ways and reflecting the different groups of people involved. The Salford Energy House was created from a model of big match funding and a partnership between senior University leaders and local government based around stimulating regional green economic growth. The Durham Smart Grid was a smaller scale, research-led initiative led by a charismatic investigator who had actually left the power industry specifically because they would not back an experimental facility of this kind. It was built up piecemeal using small amounts of funding to enable the testing of a specific set of research questions, whereas the Energy House was built as a massive experimental facility to allow others to come in and use it for their own purposes. As such they are products of quite specific networks which have framed not only the kinds of experiments that can be conducted but the resulting pathways through which knowledge flows back out into the wider world. They are different styles of lab driven by networks of operators, funders and users. The next section explores the implications of this networked understanding of the experiment for sustainability transitions.

The politics of testing

The different styles of experimentation reflect the broader contexts in which the two labs operate, and structure their relationships with the wider world in different ways. Both the Energy House and the Smart Grid represent microcosms of their wider contexts – the Energy House is an analogue of the real world that houses domestic technology and works with familiar industrial players like British Gas, while the Smart Grid is a microscosm of the national grid operating again with domestic technologies and working with key industrial partners. Both labs materialize potentially different futures through the emergence of novelty that is situated in specific networks of actors. In this sense, the experiments are promissory visions that project technology through image, expectation, PR, framing, lobbying, legitimising, negotiating and 'outward oriented activities of representing, promoting and enrolling support' (Smith and Raven, 2012). Such visions and ambitions are central to the prospective of transitions management approaches (Hodson and Marvin, 2010; Smith et al., 2010), and form part of the way labs necessarily distinguish themselves geographically and politically and for PR purposes to demonstrate action.

This 'grammar of hype' (to use Fortun's (2013) memorable phrase) is an essential part of the experiment, but the symbolic importance of the lab is complemented by its existence as a truth spot whereby the material existence of the novelty adds to its weight (Gieryn, 2006). The four big screens in the Smart Grid showing power flows around the north east and in the lab itself are primarily window-dressing for visitors. Similarly, the pictures of the different network components are largely to help lay people understand the concept of emulators. The control room panel in the Smart Grid presents what visitors might 'expect' to find in this kind of lab and helps to make explicit the labs relations with the wider world through visualising flows and connections. While the control room is somewhat underwhelming in the Energy House, the wow factor of seeing a full sized terraced house inside a large shed performs the same epistemic work of exposing its experimental connections to the wider world. Visitors to the Smart Lab engage with the LCD display screens and information labels above the 'boys', whereas the visiting the Energy House involves a tour of the house like some 'scientific through the keyhole' experience. Of course the role of performance and audience in promulgating scientific discoveries forms the core insight of science studies, and here it is crucial in making the experimental network visible for different audiences and purposes (Smith and Raven, 2012). This performative element to knowledge production fulfils the need to sell to wider constituencies, from politicians and businesses to other academics and funding bodies.

Returning to the promissory nature of these lab spaces, the process of truth-making relies on a potential future use rather than the potential for falsification. In this sense, low carbon transitions reflect trends that have been explored more fully in relation to the life sciences, whereby large scale experimental infrastructures link science and capitalism more closely together through a utilitarian logic of success (Rajan 2013; Davies, 2010; Gieryn, 2008). The potential for world building here is conferred by condensing infrastructure into such malleable forms (Marvin, Pers. Comm.) that can then be tested in order to presuppose and produce epistemic things that then circulate through wider networks. There are parallels here with the Global Circulation Models of used to investigate climate change in the 1990s, but the difference in this case is that the Energy House and Smart Lab are analogue models of real infrastructure. Materialising these things actualises pathways to transition as they engage with the wider reality of the known world.

The emergence of more highly networked and expensive labs shifts the epistemology of knowledge making from the search for cause-effect to the production of a slew of statistical data derived from huge amounts of technical objects, out of which it is hoped that some statistically verifiable patterns might emerge. The Energy House very much conforms to this informatics style of large-scale statistical knowledge production, whereas the Smart Grid reflects its more scientific origins in providing the means to test a set of predetermined hypotheses. As experimental systems grow in size so increased investment is required to produce emergence and the places where such science can be done become more exclusive.

This brings us back to the question of exactly what the experimental apparatus of each lab promises. On one level, the Smart Grid can be viewed as a tool to defer investment in infrastructure, whose entire *raison d'etre* is to discover ways to use the grid more efficiently rather than increase capacity. The clue is in the name here – the Smart Grid implies a smart transition that avoids major reallocations of resource to achieve large-scale change. The Energy House is political in that it is a vessel that is more easily filled by large corporate actors interested in certain types of technological solutions. Framing transition in this way makes it more open to capture by dominant interests and presupposes the kinds of pathways to transition that it can establish.

The politics of lab style transitions rests upon their ability to test different futures in an experimentally constrained but socially embedded way then, but what does this mean for niches and transition more generally? If the concepts of transition and niche have an experimental disposition, it becomes important to explore the way experiments with different constituencies imply differing types of transition. The lab in this sense reduces ethical and political issues to questions of testing, so that it is not so much that reality is being tested as that testing is constitutive of what can be designated as real (Ronell, 2003; 665). In order to better understand political struggles over different low carbon futures, which constitute another aspect of transition that the MLP model has been criticized for neglecting, perhaps it is necessary to politicise the test itself. If, as Smith & Raven (2010) suggest, the political job of niche actors is to lobby for institutional reforms that embody their niche findings, then a closer examination of the web of relations of which niches are composed and the knowledge chains and pathways to transition that that confers might help to secure the deeper benefits of experimentation (Coenen et al 2010).

Conclusions: lab style transitions

In the knowledge society the idea of society as laboratory has come back to prominence. If the emergence of an experimental disposition is seen as a response to the uncertainty and insecurity of modern world, then it should perhaps not be surprising to find it being imbued with the power to drive change. Talking about Arcosanti, a city in Arizona that he founded in 1970, Italian architect Paolo Soleri suggested that its purpose was to function as an urban laboratory 'modestly nudging reality'' (2002, Chapter 6), and the overriding rationale given by those involved in the labs studied was that they were primarily test sites for new technologies and designs that would have the capacity to change the wider world. The connections through which the labs were constituted enabled them to test different futures in an experimentally constrained but socially and politically embedded way. The rhetoric of change was supported by a reality of experimental discovery, making the lab promissory in both a symbolic and material way. The experimental site operates as a territorialised network, whereby epistemic things were generated and translated, underpinning the durability and traction of different visions of transition. The opportunities afforded by taking a relational approach to experiments lies in better grasping the way in which relations are structured between the niche and regime. As Geels (2011) notes, 'these theories should be multi-dimensional, because it is unlikely that only one kind of causal factor or mechanism can explain entire transition processes.' It is here that ethnographic style methods might be useful in tracing the flows of things, people and ideas that accrete in the lab, but also the knowledge that is produced.

These arguments hint at the broader importance of the test to low carbon transitions. While the two labs studied here are not formally tied to transition pathways but rather hover in softer networks, test facilities like the Building Research Establishment in the UK generate results that are used as the basis for broader regulatory change. More widely the experiment of climate change, in which we are all participants, is elevating the status of the test to ever greater legitimacy as the basis for all manner of decisions. Living labs infer an experimental approach to city-building that reaches its apogee in the emergence of cities like Masdar that are actually designed as living labs. The urge to 'empiricise reality' (Gross and Krohn, 2005; 79) through the experimental test is an urge that inhabits the very notion of transition, and is one that could fruitfully be further unpacked.

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Figure 1: The Salford Energy House

Figure 2: 'Windy Boy' emulator, Durham Smart Grid