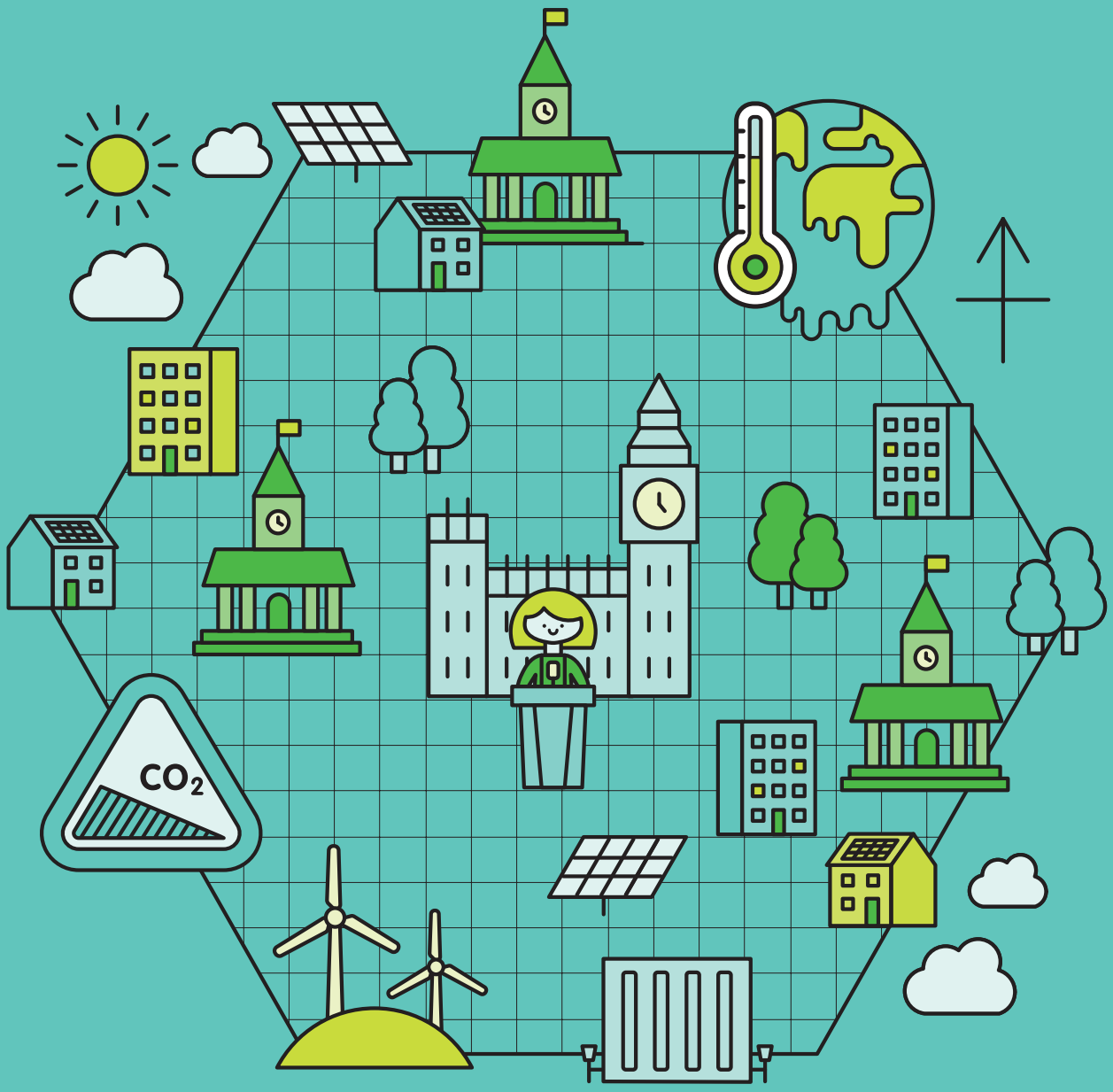

Local Area Energy Planning – A Scoping Study

Final Report

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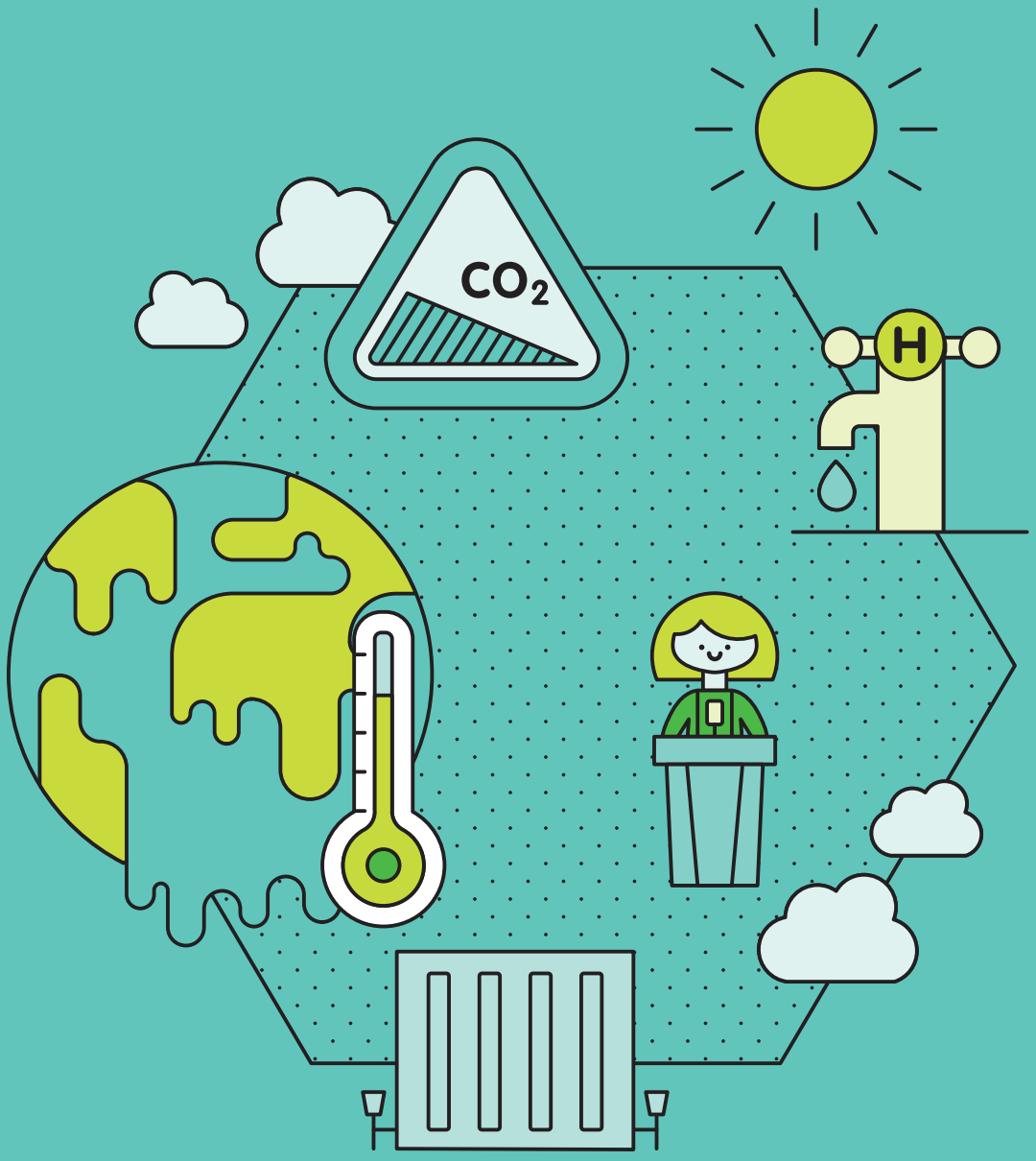
Contents

Project funded by the Energy Technologies Institute and Energy Systems Catapult, and delivered by researchers at Edinburgh University and Cardiff University. The report is jointly authored by Richard Cowell and Jan Webb.

Introduction



Minimising the risks of dangerous climate change is fundamental to future welfare. The UK has set legally binding carbon budgets intended to cut greenhouse gas emissions by 80% by 2050 (against 1990 levels), and is reviewing the implications of the 2015 Paris Agreement which seeks to limit average global temperature increase to 1.5C. The combustion of fossil fuels for energy is a major source of greenhouse gas emissions, and transition to low carbon and renewable energy is essential. Energy use in buildings, particularly for space and water heating, is the largest component of energy consumption, and accounts for around a third of total emissions. UK Government have recognised that reducing the need for heating, and developing low carbon supply, is a critical challenge, and is developing a longer-term policy framework (UK Government BEIS 2018).

However, the issue is an immensely challenging policy, governance and coordination question, with potentially high upfront financial, political and social costs. Unlike renewable and low carbon electricity, which is more susceptible to centralised solutions, low carbon heat is expected to require changes in appliances and networks in every building not currently heated by electricity; major investment in grid infrastructures, and retrofit of building stock to improve thermal performance. Every household and building owner is affected, including many low income households, and there are logistical problems relating to multi-occupancy buildings and ownership. Cost estimates vary widely (from circa £120-450 billion), and there is no straightforward replicable solution or obvious 'silver bullet'. Any new policy will need to set the direction for future energy sources and infrastructures, particularly in relation to gas and electricity networks, while recognising technical-economic and social uncertainties, including costs and distributional impacts, over a considerable period. Innovation and learning by doing in societal, technical and governance realms will be paramount.

In 2011 the ETI commenced its Smart Systems and Heat (SSH) programme to investigate and address some of these challenges. The programme was transferred to the Energy Systems Catapult (ESC) in November 2015, with ETI continuing as funder and client. The second phase of SSH, funded by BEIS and delivered by ESC, commenced in 2017 and concluded in 2019. The programme has three interconnected areas of work (ETI, 2019) resulting in significant data, market information and modelling tools in relation to the following:

- Domestic consumer preferences in relation to heating and hot water use
- Testing of new business models including the concept of 'heat as a service' using digital control systems in a living lab with 100 homes;
- Local Area Energy Planning (LAEP) pilots, using whole systems engineering models. In each of the three pilot local authorities (LAs) detailed evidence has been assembled to inform review of options for future heat infrastructures and building retrofit, and to create foundations for future planning and decisions on decarbonising heat;
- Operations and governance of the whole system.

It is the second of these work packages, addressing LAEP, which is the main focus of the study here. The SSH team have argued that local diversity of building stock, infrastructures, resources and geography makes some form of local level energy planning and implementation critical to a systematic, coherent and cost-effective transition to low carbon heat and low energy buildings across the UK. Their particular proposition is that a whole system perspective, using systems engineering tools, will be vital to optimising a transition to low carbon energy, because of the capacity of such tools to enable a structured, cost effective and dynamic approach to strategy. The whole systems engineering approach is conceived as a means to move away from familiar patterns of single vector (such as solar or heat network) local authority-led projects. Such projects do not generally take account of the complex system interactions across heat, power, transport and storage, which are implicated in a longer term planned energy transition. In 2013 the SSH team invited applications from LAs to work with them in testing and demonstration of LAEP, piloting the EnergyPath Networks (EPN) tool to support this whole energy systems planning. Three LAs were selected- Newcastle, Greater Manchester/Bury and Bridgend - and the process of engagement unfolded over five years, involving other parties such as DNOs as necessary.

Towards the closing stages of the pilots in late 2017, questions had begun to arise about the potential wider take-up of the LAEP research, the scope for scaling up, whether it had delivered in the way intended, and whether the technical-economic dimensions of the research could have been – or could yet be – better integrated with the social and political context in which LAs operate. Surrounding this specific issue are wider questions concerning the prospects, resources and responsibilities for mainstreaming of any local clean energy planning, including the role of local authorities. This wider context is important, given that one cannot conceptualise a planning support tool without a clear conception of planning (Coucelis 2005).

This scoping study was commissioned to examine these questions. It was charged with using social science insights to facilitate learning from the LAEP experience, first for immediate use by ETI/ESC and LAs, and second to examine the scope for more comprehensive investigation of the future prospects of local energy planning. The aim is to inform debate about capacity building and capabilities for next steps in planning and implementing the transition to low carbon heat. It focused on what can be learned from the Bridgend, Greater Manchester/Bury and Newcastle LAEP pilots. Throughout, a particular concern has been to understand the role and effects of technical innovations to support decision making in local energy planning activities; in this case, the SSH

whole system planning and design tool, EnergyPath Networks (EPN), which is intended to enable exploration of optimised least-cost local energy system designs that meet stipulated sustainability and security targets. In our account we use 'Local Area Energy Planning' (LAEP) to refer to the specific processes and outcomes of this part of the SSH programme, and 'local energy planning' as a more general term to describe wider locality-based strategy-making.

Our research has provided insights into many aspects of the LAEP pilots and the interrelations between the actors involved across local and other governmental arenas. Findings have been reported in detail in two earlier reports. In this our final report, we organise our overarching findings into four distinctive, but inter-related themes fundamental to planning and implementing future heat systems for a low carbon economy and society:

- Problem framing: Structuring the Problem of Local Area Energy Planning for Future Heat Systems
- The engagement process: local councils as 'civic scientists'
- Making knowledge: what is useful knowledge for local energy planning?
- Making plans: different conceptions of local planning for energy

Across each theme, our research identifies potential lessons about the factors shaping progress and crucial dimensions of the heat decarbonisation problem. In addition to this, the research has a scoping function, using the results to inform future research questions about the social and technical elements implicated in mainstreaming local energy planning, where local and regional governments may be key actors. Our conclusions and recommendations in this respect are given in the final section.

What We Did

We began by exploring the history and dynamics of the SSH Programme, from inception of the LAEP project through to the time of writing (March 2019), focusing on the Local Area Energy Planning pilots, the perceptions of those actors centrally involved, and framings of the problem, the relevant goals and their evolution (Rein and Schön 1996). The first phase of the research comprised documentary analysis and discussions with eight members of the SSH team. The second phase examined the experiences of the three local authorities, using documentary records and discussions with key participants in the Greater Manchester Combined Authority (GMCA) and Bury (3 interviews), Bridgend (5 interviews) and Newcastle (5 interviews). The third phase explored the role and experiences of UK and devolved governments in the LAEP component of the SSH programme through discussions with officials in UK BEIS (4 interviews) and Welsh Government (2 interviews).

Each stage included considering the interactions between the SSH team, the LAs and actors from supra-local levels of government in development and testing of, and interactions with, the EPN whole systems model, and tracing lines of actual or prospective use.

Our Conceptual Approach

ETI documents setting the context for our study (ETI 2017a) characterised it in terms of analysing 'gaps' between the 'technical activity' of developing the EPN tool and applying it to local energy system modelling - as an essentially technical-economic engineering task - and the social and political dynamics of take up and use in some form of local energy planning. Our research does indeed highlight problems with, and negotiations about, take up and use, but conceptually we have resisted the idea that 'social and political perspectives' are separable from the technical.

A socio-technical approach

We see analytical advantages in socio-technical approaches, drawing especially on actor-network theory (ANT) (Callon et al 2009; Latour 2005). The theory treats the agency required for innovation in science and technology not as a property of individuals, but as distributed across a social and technical network, which comprises multiple people differentiated by formal roles and specialist knowledge; technical devices including contracts, regulations and systems engineering models; and material artefacts such as buildings, gas pipes and turbines. The capacities of the resulting actor networks are not pre-fixed, but conditioned by their particular hybrid of social, physical and technical constituents (Callon and Caliskan, 2010), and constrained by history, including power struggles, incumbent infrastructures and institutional systems. The pipes, wires and artefacts of our current energy systems, in this sense, represent material legacies of the outcomes of earlier contests (Star, 1999), and form the medium for contemporary negotiations (Coutard and Rutherford, 2010). In the UK energy system, the current gas grid and home heating system is an example of such material legacies and their impacts on current scenarios for low carbon heat innovation (Pearson and Arapostathis, 2017). Developing insights into innovation for local energy planning hence requires analysis of interactions across, and interdependencies between, social *and* technical actors and their diverse settings (from laboratories to households), specialist knowledges, values and objectives.

By tracing the making of knowledge in practice, ANT is also helpful in showing that whether knowledge takes hold, or becomes persuasive, is not simply a result of its 'factual' status (i.e. the accuracy with which 'reality' is represented), but is also a result of the varied willingness and capacity of actors to utilise that knowledge in decisions (Latour 1986). Certainly, the qualities of the knowledge produced are likely to affect such processes, but even these qualities are not purely technical; they embody assumptions about parameters, weightings and formats (e.g. spatial scale, resolution, infrastructures, and building types) which may be evaluated differently by the relevant parties, influencing the perceived credibility of the knowledge, or the providers. Viewed in this way, the development and fate of new knowledge can be shown to be highly context-dependent.

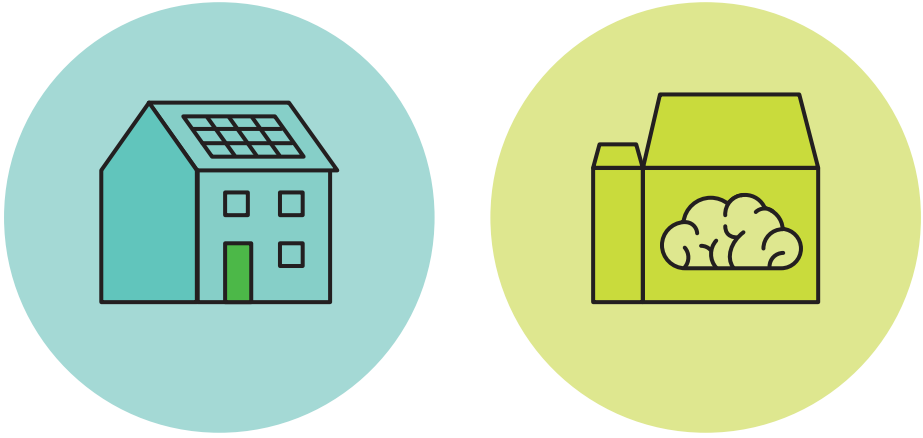
"...conceptually we have resisted the idea that 'social and political perspectives' are separable from the technical."

The problems make a difference

As an extension of these perspectives, our research has affirmed the importance of recognising how 'the problem' – its contours and the issues at stake – makes a difference to the outcomes (Marres 2007), including apparent problems in knowledge take-up. Decarbonising heat is a problem arising from the necessity to mitigate climate change, but most options lie outside the sphere of 'tried and tested' solutions. To use the language of transitions theory, it is a situation where the dominant 'socio-technical regime' for energy provision – combining social practices, politics, incumbent businesses, technologies and economic science – exhibits high stability (Geels 2002, Unruh 2000) and makes it hard for certain niche innovations to gain traction. As our interviewees noted, it is a situation in which it is challenging to construct 'no regrets' strategies from which many householders would be obviously better off (or indifferent), compared to extant gas-based central heating systems. The work of comparing technological alternatives is also value-laden, and subject to constantly shifting knowledge around technical performance and cost. Together these elements create a situation in which political champions and economic interests – as typical change agents - are slow to emerge, which reproduces the sense of intractability. Again, one can see how the technological, social and political dimensions of the problem are intertwined.

Unpacking 'knowledge use'

This leads to the third and final point about our approach – knowledge use. As researchers have noted (Rich 1997, 15), 'use' in relation to knowledge 'is not an all-encompassing concept', but comes in different forms with an array of explanatory models behind them (Owens and Rayner 1999). To a large extent, concerns about the so far limited integration of the LAEP work into local energy planning practice seem to have been framed by models of use that Rich (1997) would categorise as 'influence', indicating that knowledge has contributed to a decision; and 'impact', where information has been received, understood, leading to clear concrete policy action. The underlying assumption is that knowledge use is (or should be) 'linear rational' i.e. that the overt content of knowledge is what influences decisions (Owens et al 2004). With such concepts of use providing benchmarks, knowledge use 'fails' should direct impact or influence not arise.



Wrapping round this perspective are questions raised by different contributors to our research about the potential for commercial exploitation of the LAEP resources. This relates back to the ETI's modus operandi which entailed working closely with commercial members, as discussed below. It is situated more widely in the notion that LAEP and any constituent systems engineering models like EPN are exploitable assets, and so need protection by Intellectual Property (IP) rights.

The intentionally sought types of knowledge and applications associated with the LAEP pilots are however a subset of types of 'knowledge use': other types have been clearly visible in this study and these have relevance to the wider heat decarbonisation problem. Knowledge can be used symbolically, for political purposes, to help rationalise decisions already made on other grounds (Flyvbjerg 1998). Here the technical quality of the research (or the researchers) may still help to create authority and legitimacy, reducing the risk of challenge. Knowledge can also be used in the sense that it informs wider debate and contributes to learning over a longer period (Owens and Rayner 1999). Even if a piece of knowledge lacks immediate impact, it may nevertheless contribute over time – with other factors –to a focusing of priorities, a re-framing of the issues at hand, and the gradual displacement of the *status quo ex ante*. Such discursive, learning roles may be conflictual, episodic, punctuated by 'failures' and feel uncomfortable to those involved but nevertheless be highly relevant when dealing with 'wicked' problems (Rittel and Webber 1973) that lack consensus. Questions thus arise as to what forms of knowledge are most useful for fostering such learning. These different concepts of knowledge and 'use' also point to different models for local energy planning.

Our Analysis

Theme 1 Problem framing: Structuring the Problem of Local Area Energy Planning for Future Heat Systems

One of the challenges has been to understand more precisely how different actors view what might be involved in 'the problem' of local energy planning for low carbon heat and why, and indeed whether some form of local planning is (or is not) needed in order to enable decarbonisation. The complexity of the problem, and the different interests involved, mean that it is framed in divergent ways. Different parties have only partially overlapping perspectives on the planning problem and its potential solutions, and these perspectives are also evolving as the extent of the heat challenge comes into focus.

The original SSH definition of the LAEP problem, and decisions informing development of particular systems engineering tools, are located in the Energy Technologies Institute (ETI) programme commencing in 2011. The programme was primarily designed to 'build the foundations for a market-led approach to decarbonise heat across the UK' (ESC 2017b, p.10) with an emphasis on innovation for scalable and replicable commercial solutions. This approach structured the encounters between the SSH team, LA officials and Welsh and UK Governments around the LAEP pilots and use of the EPN tool to inform whole systems thinking.

The ETI set out to develop a knowledge base to inform low carbon heat strategy at a point where this complex field of strategic innovation was only beginning to be debated. The ETI was itself an innovative concept for UK energy system decarbonisation; it was established as a Public-Private Partnership between government and industry leaders, who would theoretically be able to gain market advantage from early innovation. The ETI invested heavily in leading-edge energy systems modelling capability, notably through its Energy System Modelling Environment (ESME), and sought commercial advantage from that investment. Work on systems modelling for the future of heat in the domestic sector was a major, but logical, next step. UK government was developing the 2012 Heat Strategy (DECC 2012), but had no established policy or well-rehearsed scenarios. The earlier all-electric vision for the future of heat was beginning to be questioned as its logistics and potential costs were emerging. The anatomy of heat decarbonisation in the UK - in relation to user preferences, technical options, network infrastructures, energy sources, governance and regulation, decision pathways, costs and their distribution, risks and responsibilities - was hence only vaguely defined and strewn with ambiguities. There were no obvious UK or international business leaders for energy efficiency and heat in buildings.

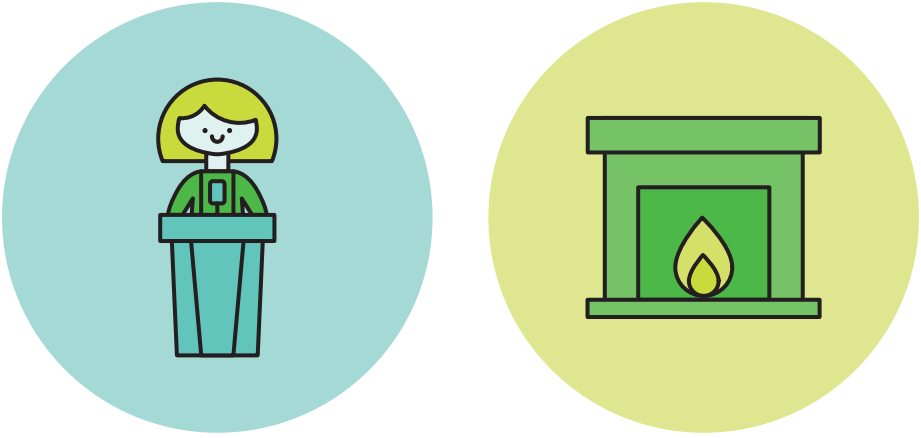
Rather than commissioning and contracting with such a business leader, as it had done in other areas, the ETI therefore had to structure a programme, specify the tools and build an in-house team to manage and deliver the work. Hitachi joined as associate member; the company had a strategic interest in SSH as a demonstrator programme that would stimulate a market in Europe. This led to new boundaries within the ETI, associated with the risk of the new member gaining undue access to earlier phases of commercial knowledge. SSH was located on a different site, and managed by the Board as a separate sphere of innovation.

The ETI, with UK Government as one representative on the Board, set out a number of propositions about the problem and methods for solution. The problem definition encompassed awareness of the likely enabling role of LAs in local planning, as well as a central orientation to the main users of heat: the circa 27 million UK households, the majority of whom use gas central heating. A core part of the SSH programme linked these issues together through the concept of a technical-economic whole systems cost optimisation model to inform and support long-term local strategies for decarbonising heat in the domestic sector. This problem definition derived significantly from the ETI's historical investment in energy scenario modelling capabilities through ESME, and the drive to protect and extend the value of such assets. The EPN tool was envisaged as being one among a number of tools in a local planning process structured around productive dialogue and periodic review. It is distinct from the Energy Path Operations (EPO) simulation tool which is used to provide operational simulation and related evidence for new market arrangements and business models in the context of the physical energy system.

EPN is described by ETI/ESC as follows:

Extract from D4 *Modelling Local Energy System Designs with EnergyPath Networks, SSH1, p.8-9*

EPN incorporates choices associated with buildings (heating systems and efficiency measures), networks (electricity, district heating and gas; including repurposing for hydrogen), and distributed energy and storage. The model was designed to provide an independent and internally consistent framework for creating an evidence base to inform local area energy planning, whilst facilitating close collaboration with all of the key stakeholders (Local Authority, electricity and gas Distribution Network Operators (DNOs), heat network developers and so on). The analysis is based on a detailed spatial representation of each local area, which helps to reflect the relationship between buildings and the networks that serve them and determine the associated costs and benefits of modelled pathways. It uses a least cost optimisation process to develop potential future decarbonisation pathways, which allows for a wide set of options and trade-offs for the local area to be explored. The optimisation simultaneously covers buildings, distributed generation/storage and network options across multiple energy vectors and timescales (i.e. 10-year steps to 2050). It incorporates a Monte Carlo mode of operation to incorporate a wide range of uncertainty in the value of future inputs (e.g. the costs of different heating systems or commodity prices).



Such complex systems models are usually developed in a laboratory setting before testing *in vivo*, and this applied to EPN. Detailed technical specification also preceded significant engagement with LAs, and insights into their priorities, regulatory frameworks, resources and capabilities. In our scoping research, terms such as 'purist', 'advanced', 'academic', 'science not policy' and 'lab-based' have been used by officials to characterise their understanding of EPN. The physical separation between lab and field was accompanied for the LAs by the perceived ETI commercial confidentiality context and boundary-setting commitment to protection of IP. Both of these factors sowed the seeds for potential dislocation between problem framings, and the sites of knowledge production and knowledge use.

The ETI's overall approach to IP has been bespoke, dependent on the type of work funded. In the case of the SSH Programme, and specifically the LAEP work, the ETI sought to invest in the creation of IP and capabilities that could be used first in the initial three pilot studies. These could then be taken forward by the ESC and the sector more widely into the later stages of work on the SSH Programme to support decarbonisation of heat and local energy systems. Unlike other ETI technology development projects, there was no expectation that the ETI investment would create any commercial return. At the end of the Programme the IP created was assigned to the ESC for their use and development and, where appropriate, sharing and further development. This strategy was consistent with the ESC goal to generate impact from its assets and capabilities. All parties who shared data, strategic plans and insights as part of the development of the Local Area Energy Plans also had expectations around the sharing of their material. In some cases they were happy for this to be shared publicly, in others it was considered sensitive or valuable, and the ESC team developing the plans had to negotiate a path through these expectations. Uncertainties and questions about the commercial context of the LAEP pilots seem however to have created a sense of premature closure of options for more exploratory, collaborative, boundary-spanning and improvisational forms of knowledge creation with a variety of parties. For a number of respondents, this level of closure was not their usual experience of engaging in research.

From other socio-technical studies, we know that all expert models embed particular assumptions, exemplified in EPN in relation to the concept of cost-optimality and its calculability, though such assumptions are often 'black boxed'. These derive ultimately from the core values of the relevant society, such as priorities of economic growth, markets, financial costs and benefits, and materialism in contemporary consumer societies. Testing a lab-based model in the envisaged contexts of use, however, introduces previously excluded variables, and potentially wider understandings of costs and benefits, encompassing social, political and cultural spheres. These perspectives are generally legitimated by different 'orders of worth', which may be derived from civil society, state, domestic or other settings, as well as markets (Boltanksi and Thevenot, 2006). In this case the local energy system modelling proposition embodied in the EPN concept was brought into engagement with highly complex, intersecting variables: the political-economic institutions and associated decision-making practices of English and Welsh governments and LAs; the local cultures, social composition and historical legacies of different places, and UK energy market regulations geared to large scale, centralised generation and transmission systems. Questions of fit and fitness thus arose.

In some instances, expert systems engineering models introduced into such complex social ecologies do have performative effects: they make the 'real world' more like the model; they reformat markets, investments and/or governance structures (MacKenzie, 2006). We also know that, if this occurs, it is not simply a matter of superior technical-economic knowledge acting in a linear rational-economic process. Instead it may variously entail sponsorship by elites, such as business or political leaders, and improvisation or exploratory learning over an unpredictable period, with an indeterminate mix of actors and resources (issues we return to in theme 4). In this case, the model has encountered a variety of challenges, and next steps seem uncertain. The framings, and the material and institutional structuring, of the 'sustainable heat problem' remain far apart. The LAEP pilots were conceived by the ETI as a means to define a local planning method and prove its deliverability and value, in the absence of a market, or funding, for such planning or whole system tools. Development and testing of the EPN tool, and sample production of local strategies, have not however solved the problem of reformatting markets around the LAEP model. Some local and central government research participants suggested this is at least in part due to the lack of a business model or models to clarify local applications of EPN. Models suggested were: an open source tool, with consultancy to support local authority use; a licensing for use in combination with a quota of consultancy support; and/or a simpler product in the form of planning guidelines and decision rules to support action in LAs with limited prior engagement. We return to this issue below.

Further questions concern where the LAEP problem definition fits into the complex legal standards and regulatory demands of local government planning. Some of this exploratory learning and sponsorship has been occurring through the long period of engagement around SSH and the LAEP pilots, with ETI/ESC, UK and Welsh Governments and LAs. Notably when the agreement to end ETI was made, the UK Government sponsored the problem framing by investing in SSH Phase 2, partly to ensure that the models produced in Phase 1 could be taken further in contexts of use. There was a particular concern to test the 'heat/energy as a service' proposition, and hence to inform future government strategy; there was also commitment to financing fixed-term LA liaison managers to support local smart energy plans, testing the scope for project development, and near-term value from LAEP.

Problem framing, whether with respect to the LAEP and EPN model, or the energy as a service business concept, or more widely in relation to local heat and energy planning, remains contested. The parameters of the heat decarbonisation problem are clearer, in part due to the long-term cross-sector work of the SSH programme. There is a shared understanding that the answer is not purely a technical economic one, and that what is technically optimal may be impractical for many (changing) political and social reasons. There are critical questions about costs and their distribution, and how local and central governments can develop confidence that long term, and very large, investments will deliver decarbonisation whilst minimising impact on consumer bills. The need for significant public debate and consensus building around the future of heat, and the role, if any, for what variants of local energy planning, is evident, but so too is the elusiveness of any such consensus.

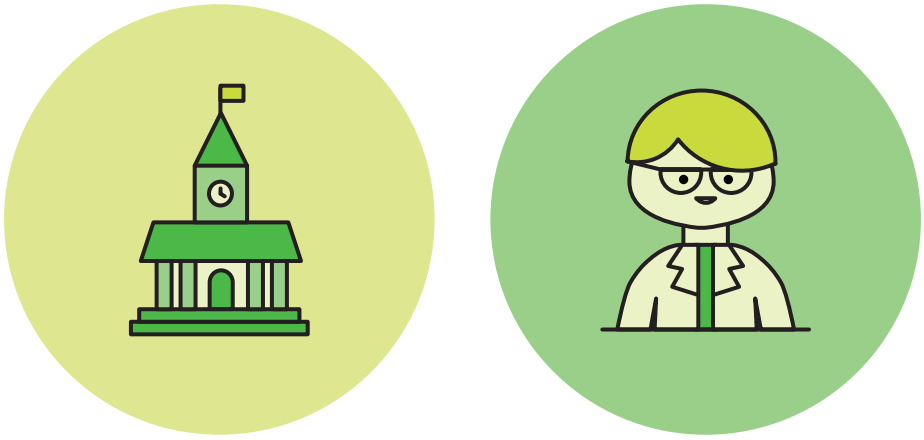
Theme 2: The engagement process: local councils as 'civic scientists'

Experiences from the LAEP pilots, within the SSH programme, have much to tell us about engaging LAs in energy planning and mainstreaming such activities, but there is a need to consider whether the issues discovered might be particular to demonstration work rather than local energy planning as a formalised activity.

If we focus on the process of engaging LAs in the LAEP pilots, then that presupposes a whole set of relationships and potential issues. To help us understand them, one might draw analogies with the concept of 'citizen scientists' – i.e. the utilisation of 'lay' publics as collectors of data or performers of analytical work to input into a wider scientific project. The challenges, for the professional scientists, involve (i) recruiting participants likely to be suitable, (ii) sustaining their commitment while recognising their freedom to leave the project, (iii) recognising that citizen scientists are people with their own agency and values but also (iv) finding ways to govern their input such that any data provided or analyses performed meet the perceived requirements of the science. There are balances to be struck between drawing on and fostering goodwill while also, unavoidably, utilising citizen scientists as instruments. These balances may be held in place by expectations of the likely benefits (and costs) to be felt by all parties through their cooperation, as well as relational qualities like trust. They may also require on-going negotiation.

On a prima facie basis, LAs agreeing to act as test beds for research projects has some similarities to citizen scientists, though as they are public bodies the label 'civic scientists' might fit better. However, there are also key differences between citizens and public bodies. Whereas citizen scientists are individuals (or households), LAs are multi-sectoral, democratically elected, composite entities, embracing professional, public and political spheres. While the participation in science by individuals and civic bodies is voluntary, and prospective participants will weigh up costs and benefits, the fact that LA involvement has financial and opportunity costs gives this weighing up extra importance. Officers leading LA participation do so as part of their paid job, and are publicly accountable; they have to justify their participation to others. There is also the task of managing participant inputs, given that some LA participants are already, or may gradually become, sufficiently knowledgeable to challenge the whole model of useful knowledge, and/or raise questions about the context, content and direction of the demonstration work. These questions may be highly pertinent, but the challenge for scientific leaders is whether their project is capable of absorbing or answering them.

These problems may be magnified where the LA participants are not just assisting in research, but are also among the prospective users of the demonstration work, meaning that issues of ownership and control of the knowledge enter the relationship. It is here that simple analogies with 'citizen scientists' break down.



How then did these issues map out across the SSH programme? LA involvement began with a competitive selection process in which the application form indicated that significant investment in a limited number of 'demonstrator sites' would be forthcoming (in SSH2). Prospective LA participants were asked *inter alia* to 'identify up to three local areas (area name, council ward and also streets, if possible) that your Authority has considered for the demonstrator' and to indicate their preferred role in any such development (ETI SSH Programme LA Questionnaire, 2013). Initial expectations among the three successfully recruited LAs were that participation would constitute an exchange relationship, structured through a competition, with the 'prize' of material investment in a low carbon domestic heating demonstrator. They were hence not expecting to use their knowledge about the local area only to pilot and refine development of whole systems engineering models and the LAEP framework. The fact that funding for large scale demonstration projects did not emerge as envisaged thus represented a significant change in relationship; one in which the perceived benefits to the LAs potentially diminished. It contributed to the LAs' uncertainties about the constituents of the 'compact or contract' that they had entered into.

Managing the potentially disruptive fall-out required ETI/ESC time and skill, and the 'client management' activities achieved some success in translating the value of LA participation for a rather different proposition. The three LAs maintained participation. The process of testing and demonstrating LAEP using the EPN tool was not undermined; there has been no suggestion that the LAs did not continue to do what was asked of them i.e. the LAEP research was not damaged. It may – for some participants, in some LAs – have contributed to a sense of mistrust, but this is not the overall response. Only in one LA did the non-appearance of the significant demonstration projects emerge spontaneously in discussions as a source of problems, contributing to frustrations over lengthy time-frames and – at times – uncertainty over local benefits. The issue was present more widely across the interviews, however, as one aspect of a feeling of being recruited for a journey where the destination was unclear.

The loss of the originally envisaged large-scale demonstrator projects was clearly damaging to trust. It is however difficult to know what weight to place on this in relation to the more enduring lessons from the pilots. If treated as a mistake, as the outcome of a series of unexpected events, then it is obvious that such mistakes need to be avoided. Does it have wider systemic relevance for local energy planning? One might say that the non-appearance of the anticipated major demonstrators constitutes another symptom of wider instability of government energy strategy (curtailing of FITs, reductions to ECO budgets and the rise and fall of Green Deal are others), and of modes of governance that subdivide broader agendas into short-term projects (Sjöblom and Godenhjelm2009). Negotiating constantly changing conditions could thus be an endemic reality of engaging local authorities as 'civic scientists', with the risks and managerial challenges that creates for researchers or plan-makers. It also indicates how any modelling tools have to be resilient and responsive to such shifting circumstances, if they are to be influential in decision processes over the near and longer term.

The LAEP pilot experiences show that many of the challenges, and the balancing activities required to engage the LAs as 'civic scientists', could be expected to become more demanding as the duration of the project extended. The LAs faced shifting pressures around their commitment, especially as austerity continued to bite. Problems might also be expected to be greater where the wider policy context for the demonstration project is uncertain and shifts, and there is contention over problem definition, policy goals, parameters and domains. Iteration may be valuable or unavoidable in long-term scientific work, but it means that the terms and conditions of the relationships with participants come under pressure and have to be re-made. Flexing the terms of the LAEP pilots to embrace both the innovation sought by the ETI/ESC, but also more immediately deliverable 'deployment' projects sought by the LAs is an example of this iteration, and of the kind of work required to keep such partnerships together.

As an additional facet of these challenges, we have provisional observations about how different LAs and officers perceived and navigated the substantive and temporal uncertainties of engagement in the SSH programme. This may offer insights into the dynamics of civic engagement in demonstration work more widely. A number of factors served as variables:

- *Start point* – the extent to which LAs already considered themselves active and effective in local energy projects shapes the extent to which they are likely to perceive that engagement in demonstration work 'adds value' in itself. Smaller councils with less of a track record might be more likely to be pleased just to be involved, and roll with changes in focus, compared to those already making advances in energy planning.

- *Expectations* – the extent to which LAs participate on the basis of expecting concrete (investment) outcomes to materialise, and individual officers feel dependent on such being delivered, affects their perception of involvement. This was more clearly the case in one LA, which expected that engagement would generate a tangible step change in local energy planning and investment, which then had negative consequences as tangible outcomes failed to materialise. In others officers were more comfortable with the idea of R&D demonstrator projects, which might not necessarily yield immediate results.

- *Eggs and baskets* – LA officers' capacity to negotiate the ups and downs of engagement while rationalising their ongoing participation seemed to depend on how far they had other eggs in their basket. Some councils were engaged in a wider range of energy-related projects and officers attributed the emergence of these to involvement in the LAEP pilot. At an individual level, the lead officer for LAEP tended to work across a range of environmental topics and was not therefore tasked just with delivering on energy. In some cases, officers were able to utilise involvement in SSH to advance their own energy and decarbonisation agendas.

Two other points of systemic relevance also emerge. Firstly, while we have been exercised analytically by the task of extrapolating lessons from a demonstration project that might apply to a fully-formed process of local energy planning, arguably these two activities should not be seen as wholly distinctive. Indeed, as we elaborate below, there are merits in seeing local energy planning not as an activity linking 'fully made science' to option selection and formation of policies. If we envisage local energy planning as more deliberative, collaborative and adaptive in the face of uncertainty, then it follows that all interventions acquire some of the qualities of an experiment, from which wider learning needs to be extracted. The idea that 'demonstration' is a discrete, bounded task, which precedes planning, starts to break down. Knowledge, plans and low carbon-futures are all continually in the making. The Smart Energy Plans produced under SSH2 exhibit something of this hybrid quality.

If this is the case, however, then the kind of relationship issues associated with civic scientists are of wider relevance. As the next section shows, what happened through the LAEP pilots can be read as much more than the testing of a structured process of engagement or software model. One might read it as a complex (socio-technical) power struggle over what constitutes relevant and valuable knowledge in this domain, deeply interconnected with different future strategies for local energy systems, and with debates around who could control those spheres of knowledge. There were also high stakes all round: IP, safeguarding the investment of its members and enabling effective exploitation, in ETI's case; political capital and the socio-economic future of localities in the other; all unfolding at a time of financial and political upheavals in UK.

Theme 3: Making knowledge: what is useful knowledge for local energy planning?

When asked about useful outcomes in the LAEP project, LA respondents pointed to a number of spheres where their participation had been beneficial:

- In terms of *knowledge and agenda-setting*, there is recognition that working with ETI/ESC has advanced councils' state of knowledge. The programme expanded awareness of whole system future energy options and innovations in the pipeline, and local consequences for low carbon heat and energy performance of building stock, including in the private domestic sector.
- In terms of *network building*, the ability of LAs to bring together and work collaboratively with cross sector interests supported LAEP knowledge-production processes and was instrumental in building relationships for local socio-technical innovation. Involvement in the project variously deepened engagements between LA and gas and electricity DNOs, universities and other levels of government. Interactions with DNOs also helped to make local electricity networks and consumption data more transparent, and exposed council officers to trends in energy markets, network investment planning and demand management.
- In terms of *material products*, the relations created by engagement in the LAEP pilots have, in some cases, helped the LAs to secure other energy-related investment. Sometimes, the authoritative nature of the LAEP outputs and scenario analyses had been used to underpin new and existing planned projects, to add to the credibility of funding bids and help sustain forward momentum. It has assisted in legitimising and/or testing the viability of local ambition and strategy. On other occasions, participation in the ETI/ESC SSH programme was seen as creating reputational gains for the area, with the potential to attract new energy business investment.

However, these uses of the LAEP outputs are not direct or linear; nor are they always based on the detailed content of the EPN whole systems modelling and analyses. In some instances it is the political-symbolic value of participation in knowledge-generation projects, and working with credible, well-funded partners, that generated outcomes. There is something of a paradox to explain, in that LA officers were often appreciative of the 'cutting edge' nature of the EPN modelling and the knowledge generated by the LAEP work; they did not necessarily question its scientific veracity, but nevertheless they still found that knowledge difficult to 'use' in any direct or instrumental sense (Rich 1997).

An explanation for this can be located in differences between useful knowledge as represented by the LAEP pilots, and as perceived by local politicians and officials in their work to rationalise and lever actions on energy and heat. Indeed, what constitutes useful or practical knowledge for future urban decarbonisation strategies has emerged from the study as a matter of debate, uncertainty and exploration.

So what is the basis of these different conceptions of useful knowledge? The SSH LAEP concept was geared to technological innovation through whole systems, multi-vector, local energy planning. This can be characterised as a technically and economically rational theoretical ideal; the objective is to develop policy-neutral cost optimisation modelling to inform decisions. Modelling results are intended to suggest energy system designs which meet carbon reduction and energy security targets at least overall cost, whilst taking account of technology operation, demand peaks and resource geography. The rationale for the approach is that such complex system interdependencies are rarely considered, with the focus instead on stand-alone solutions.

The SSH team envisaged a number of modelling tools emerging over time to support a local, area-based planning process that could identify optimal decarbonisation pathways, structured around periodic review and productive cross sector dialogue. LA priorities and responsibilities, on the other hand, are not directly concerned with energy planning, and useful knowledge from this perspective, whether incorporating results from whole system and other modelling or not, needed to support local political objectives associated with economic regeneration and welfare, as well as climate protection. With limited powers and resources, LAs were necessarily opportunistic about what a local energy planning process might consist of and what could realistically be achieved in current political-economic and social contexts of local government. Useful knowledge was hence practice-based, and needed to encompass diverse interests and difficult responsibilities; it was inextricably social and political, as well as technical. Useful knowledge from the LAEP pilot needed to have tangible outcomes and material benefits to residents, economy and environment, whether or not these were embedded in a longer-term, technically rational area-based strategy. Such benefits were critically important in their own right, but also essential to the professional reputation of the officers and the credibility of local politicians. Hence there were concerns about how the knowledge embedded in the whole system modelling could be made serviceable locally.

To some extent, the different conceptions of useful knowledge were methodological. Two of the three LAs had expected to gain practical access to tools directly to extend their prior energy planning capability, but found EPN more complex, time intensive and more dependent on specialists' skills than they had anticipated. Consequently, respondents raised immediate concerns about the time and other resource costs of any LAEP process reliant on using EPN, or similar detailed data-driven, modelling. Different actors perceived these methodological problems as requiring different solutions; the SSH team regarded them as soluble with a more streamlined and structured framework for LAEP, while other parties regarded them as requiring simpler or more accessible models for local energy planning. There is interest in the prospects for cheaper, more user-friendly 'EPN Lite', or similar toolkits, perhaps enabling the kind of non-expert user engagement that some respondents had originally envisaged. The SSH team in turn have indicated concern about the risks of over simplification, with loss of the granularity of more complex modelling and planning. The expectation here is one of future step changes in computational power, combined with increasing accessibility and prominence of data to aid planning. It is not clear at the time of writing what future formats for local energy planning will materialise, and interview respondents were hesitant about the likelihood of replicating and scaling up local energy planning across the UK, including take-up of scenario development models. There is no consensus about needs, or methods, for local energy planning, and therefore no clear support from central government or other sources.

Differences also had a structural basis, which reflect the complexities of local areas as sites of knowledge use. Not only may the demands of local actors – LAs, DNOs, universities – differ from each other, but local authorities themselves are not homogeneous consumers of energy-related knowledge. The knowledge needs of the planning department differ from those of an economic regeneration team, or a corporate energy and climate change team. Although all of these are significant for energy use, they are commonly treated as distinct spheres of responsibility, pushing energy system implications into the background. Consequently, in many decision-making arenas the claims for action that might be based on knowledge derived from the LAEP pilots must vie with – but can often fail to dislodge – claims for action based on other priorities, drawing on other knowledges. Decarbonisation (or decarbonisation faster) may be a major issue in principle, but has to be somehow fitted into statutory responsibilities for social care, and priorities for reducing fuel poverty, increasing jobs, skills and revenues. Knowing what an optimal solution would be does not help a regeneration officer to win arguments with developers in an economic situation in which the LA is reluctant to push anything that would make life more difficult or costly for developers in the very short term i.e. where any disincentive for developers is seen as suboptimal.

Navigating these sectoral structures and priorities matters, because LA officers seeking to mobilise energy and decarbonisation objectives have to enrol the assistance of colleagues in departments with greater regulatory and investment powers (such as planning, regeneration, housing, finance). Indeed, some LA officers have been diligent in finding ways to translate the 'higher level' EPN work into simpler points, more attuned to the priorities of such colleagues. The technical complexities of the EPN work were sometimes unhelpful here. LA officials reported that the complexity of the model created a sense of 'black-boxing' the way that knowledge was produced, limiting its local face validity. Scenario models combining large scale technical and economic data to support complex decisions in uncertain circumstances may hence struggle to recruit champions to convey and translate the local relevance of this knowledge and the value to be derived from its use.

In a number of ways then, our research observed contestation over the relative potency and authority of different forms of knowledge about the city, and their significance for local heat strategies. There is another aspect to this debate about relative potency – time. We noted above that LA respondents saw improvements in their knowledge as a key win from engagement in the LAEP pilot, but this greater knowledge also raised more questions for the LAs about the full costs of decarbonising their local energy systems, and risks of their inequitable distribution. It also triggered concerns about the responsiveness of the modelling approach to uncertainties in energy policy and technology, including the emergence of hydrogen scenarios, hybrid heat pumps, electrification of transport and digital platforms for local electricity trading, local system balancing and demand side management. Respondents occasionally mentioned that energy service provision was a field in which some business could move faster than government, but also than large-scale analytical modelling work. Questions thus arose as to how the insights generated by the LAEP pilots would maintain their value over time in this highly fluid problem context, and who would fund any updates.

Decarbonisation (or decarbonisation faster) may be a major issue in principle, but has to be somehow fitted into statutory responsibilities for social care, and priorities for reducing fuel poverty, increasing jobs, skills and revenues.

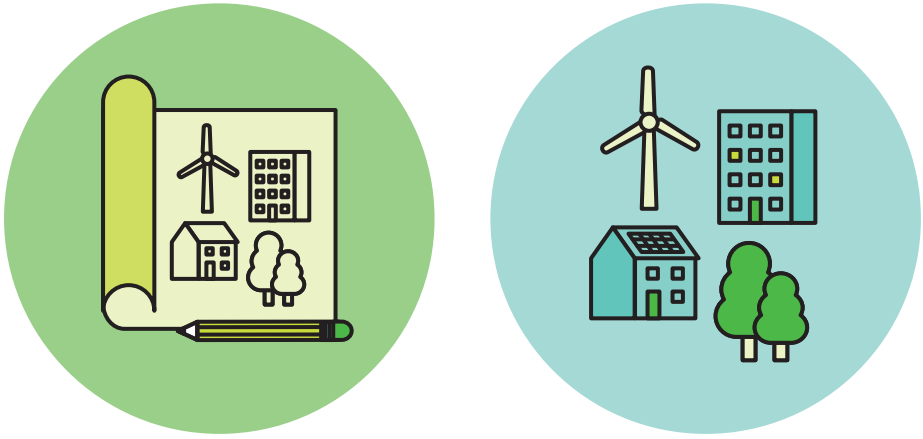
Theme 4: Making plans: different conceptions of local planning for energy

A pivotal concern for this scoping study is to extract potential lessons from the LAEP pilots for the prospects of mainstreaming 'local energy planning', particularly as a mechanism for promoting systematic strategies for energy system transition. Some of the insights focus on the likelihood that any local energy planning will encompass the EPN tool as a significant part of its analytical base, and approximate to Local Area Energy Planning (LAEP) as conceived by the SSH programme. Our research also suggests a number of more fundamental considerations that are likely to affect the future prospects of Local Area Energy Planning, and which question how far local energy planning could draw its power and impetus from complex modelling tools. We have discussed above the problems that the LA actors encountered in seeking to use complex knowledge to enrol the assistance of colleagues in departments with greater regulatory and investment powers (such as planning, regeneration, housing, finance). Lessons can also be derived from other forms of planning where modelling plays a role.

Certainly, most areas of planning could be reasonably described as a 'technical-political' hybrid activity, because modelling and other forms of technical expertise form inputs to option generation and policy formulation. Examples include transport, drainage design and flooding, planning for housing and construction minerals. To extrapolate to energy, however, it is important to note that these models have not acquired an enduring role simply because their technical qualities are beyond question, but also because of a wider set of social processes. The planning processes to which models contribute have been set goals and targets with consistent political support, and which in turn help legitimise the use of models as interpretive devices. So Bredem and derived models have attained important roles in relation to energy ratings and building regulations (Kavgic et al 2010). In addition, the use of models in planning has not been without criticisms, many stemming from the interface between knowledge generation and use. In the sphere of flood risk, assessment of potentially elevated risks has often not dissuaded planning authorities from allocating at-risk land for housing. In the spheres of transport, housing and minerals, the role of models and cognate analyses has attracted regular challenges, focusing on their role in underpinning 'predict and provide' policies with adverse environmental consequences, but also on concerns that models can serve to 'black box' the values and assumptions they embody and the political nature of policy choices. Such concerns can be amplified where models are perceived as lacking transparency (Kavgic et al 2010).

To understand the prospective role and resilience of models, one also needs to understand how models and the knowledges they produce have co-evolved with bodies of expertise and organisational structures. In transport for example, modelling is an important component of transport planning, and the system of governmental departments (at local and national level), consultancies and university departments engaged in transport planning activities, often strongly geared to particular kinds of development outcomes (i.e. building new road capacity). This sectoral organisation grants strong roles for models and often affords them a dominant role in informing options and policies, but it also has its pathologies: an imperviousness to change and to adopting new, cross-sectoral goals (Degeling 1995). It is a concomitant of the nascent and as yet non-consensual nature of heat in buildings as a policy problem that there is no clear, single or stable organisational home for models and the knowledge they generate. One might add that these problems of organisational embedding become more pronounced where models and prospective planning approaches push a whole system (i.e. cross-vector) view of energy. In planning more widely, while models have acquired established roles in more confined analytical tasks, larger, integrated land use models have gained little traction (Coucelis 2005).

These concerns about the role of models in the sectoral structure of government help explain a wider institutional problem in the context of knowledge use – that it is far from clear that in local government there is a simple, widely shared conception of 'local energy planning' to which the EPN whole system modelling could attach. This reflects well-known historical path dependencies. Although in the early twentieth century many LAs had significant roles in organising and delivering energy, successive waves of (centralising) nationalisation, privatisation and liberalisation have seen energy largely organised out of LA organisational structures and responsibilities. Previous research has mapped the patchy evolution of recent local energy activity (Webb et al 2017); even where LAs engage in some energy strategy-making it does not take the form of visions driven by singular forms of analysis, or which claim to encompass the totality of requisite energy transition actions. It tends to be more fragmented, incremental and opportunistic. Within land use planning, energy-related activity has been focused primarily on regulating applications for renewable energy projects and only more tentatively seeking to steer heat choices in buildings (Committee on Climate Change 2019). Indeed, the energy/carbon performance of existing buildings is an area where innovative action through planning by LAs has been restricted by government, under pressure from the volume house builders (Cowell 2015; Committee on Climate Change 2019, p.12), in favour of using standardised cross-national Building Regulations. Turning to LA action beyond planning, and low carbon energy action is a facet of diverse projects: often single vector, and not always coordinated. Here 'strategy' co-evolves with projects, rather than driving them.



One of the institutional factors limiting local energy planning is that LA action on energy remains a voluntary activity – with or without any plan - and must vie with responsibilities that are statutory and non-negotiable, such as social care. The SSH team recognised that the dynamics of knowledge use might change if LAs were placed under an obligation to engage in local energy planning, and that this might generate a demand for assessment tools. The introduction of obligations or targets can sometimes shift the dynamics of energy use, as the question shifts from 'do we need to take action in this area' to 'how do we best meet our obligations in this area'? As noted above, agreed targets are part of the assemblage of elements that underscore the role of models in other areas of planning.

Exploring the prospect of some form of legislative compulsion with respondents from local and other levels of government generated a mixed response. For actors in smaller LAs, perhaps where action on energy is more fragile, there was some hope that 'higher-level' carbon or energy obligations could strengthen their arm in discussions with recalcitrant colleagues. Carbon budget periods instituted under the Climate Change Act 2008 may have some reinforcing justificatory effect, amplified perhaps by sub-national strategising (ESC and BEIS 2019), albeit that these remain at a resolution 'above' individual LAs (Committee on Climate Change 2019, p.25). Respondents in higher levels of government were more equivocal, with doubts reflecting the sectoral organisation of government and the position of energy within that. Thinking of instituting planning processes in some obligatory fashion without levers that could be pulled to deliver outcomes was not seen as useful. Others questioned the value of introducing formal obligations to create local energy plans, partly because they were seen as no substitute for political and officer commitment, and partly because of doubts about the value of strategic planning in a fluid and rapidly changing socio-technical situation. More widely, post-privatisation energy policy thinking in Westminster has been doubtful of the merits of technology-specific targets in the energy sphere, as part of a wider aversion (often expressed but not always followed) to 'picking winners', preferring de-carbonisation targets alone.

Our discussions with LAs, the SSH team, UK and Welsh governments, have confirmed that, if there is a need for local energy planning, there is no clear consensus about form, purpose, knowledge requirements or location of responsibility. Through our interviews across all levels of government, some recognised the need for strategic, territorially-attuned planning on energy, which drew on a suitable evidence base, but the views expressed often slipped freely and seamlessly between 'local energy planning', action within land use planning and action on energy by other parts of government with planning responsibilities. Indeed, the ETI's reflections on LAEP shift between 'local area energy planning' and 'spatial planning of the energy transition' (ETI 2019). Such conceptual slippage around planning is a reflection of the uncertainties surrounding the heat decarbonisation problem more widely.

Exploring the prospect of some form of legislative compulsion with respondents from local and other levels of government generated a mixed response.

The prospect of adjusting planning policy to legitimise more robust regulatory action on the heat performance of *new* properties is an area of more focused and active debate. Across our cases, we found officers trying to persuade planning departments to introduce stricter, less negotiable policies on sustainable heat (more 'developers must'; less 'developers should have regard to') and also to promote technologies like heat pumps as well as heat networks. In some councils it seems likely that planning departments will be persuaded to go further, and interviewees report that the 'sound science' of the LAEP project is being used to add credibility to the underpinning arguments. The Committee on Climate Change (2019) and the Chancellor's Spring statement have lined up behind a requirement that all new homes built from 2025 must be heated by systems free from fossil fuels. The mechanics of executing new and tighter planning standards is an area warranting further investigation in its own right, and a subject that again combines technical and societal elements. Of course, focusing on new buildings risks limiting action within a broadly familiar policy domain, neglecting old buildings and the interactions between new and old within whole energy systems. One future use for EPN work, suggested our respondents, is as part of the analytical basis of simple planning decision rules guiding low-carbon energy priorities for particular areas, with potential to underpin regulations; but potentially in a way that achieves wider systemic benefits.

Two further debates arise from this assessment of local energy planning, which raise questions for 'the local' and for the meaning of 'planning'.

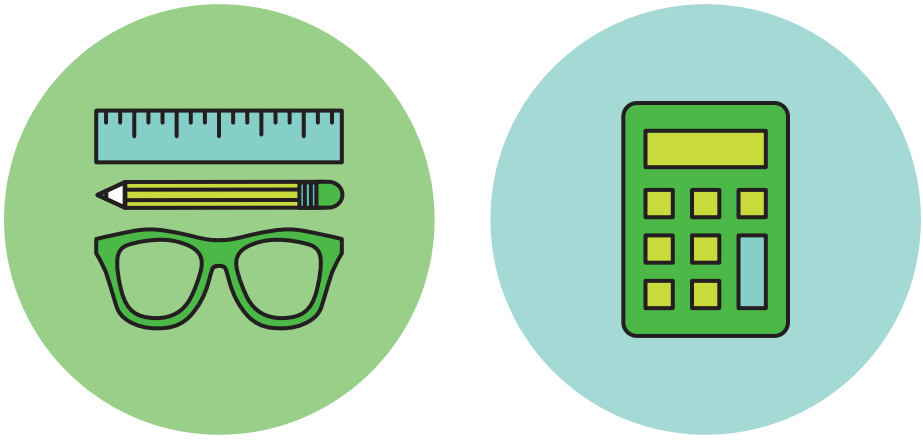
On 'the local', there is broad support for the idea that, of all the energy-related conundrums of decarbonisation, heat requires more localised and spatially-sensitive governance. Given this, LAs have characteristics that make them important actors. They have responsibilities for key elements of the built environment, and thereby for energy use – though austerity has tended to reduce the assets they control. They are an enduring institutional presence – though personnel certainly change, as do internal structures and occasionally boundaries. Their political basis creates accountability to local publics and their concerns. All of the above can make them trustworthy, at least for many organised stakeholders, and underpin LAs' 'convening powers' i.e. the power to bring actors together. These organisational qualities are often asserted, and our research with the LAs tended to confirm their significance.

However, it is one thing to recognise the territorially embedded and spatially differentiated qualities of heat, and to acknowledge the prospective roles of LAs, but it is quite another to deduce that LAs should be either the key actor or main driver of local energy planning. In the uncertainty surrounding heat decarbonisation, it is almost a default position to assume LAs need to be there in some capacity, but when scrutinised directly, precisely what capacity is uncertain. There is some risk of 'local issue dumping' i.e. where central government responds to a policy vacuum by externalising hard problems to lower levels of government, regardless of the limited resources and relevant powers they possess. There are also other ways of conceiving of local civic involvement in energy transition other than planning e.g. through investment/ownership, or as more active participants in systems of regulation (think of the way utilities are regulated in North America). A positive outcome of the SSH programme is the way that it brought together LAs with gas and electricity DNOs in discussion of decarbonisation transition options, but this should not disguise the gap that persists between the area-based system planning by the DNOs and anything that LAs might lead on. In addition, if future action on heat in private sector housing focuses primarily on individualised householder consumers through 'heat/energy as a service' business models, then this would appear to engage LAs in a different (one might say thinner, more detached) role, than actions entailing heat networks and area-based building retrofit.

There are also different ways of considering 'planning', some of which may have more to offer the problem of heat decarbonisation. We noted above how the LAEP pilots tended to follow dominant conventions of planning in the built environment in assuming a model of knowledge use that was linear, direct and instrumental. This may also be reflected in a similar tacit model of planning, which assumes the process begins with data collection and technical analysis to inform the optimal selection of options, the preferred of which form the basis of a plan which is designed to deliver them. One can characterise this as an engineering or technocratic model of planning (Healey 1997), and the difficulties with this in the heat decarbonisation field have been discussed above.

However, various assessments of local land use planning have shown it often to be opportunistic, tactical and short-termist; seeking to respond to and deliver near-term choices rather than pursuing long-term future visions (Coucelis 2005). Such plans seek to reconcile LA preferences or obligations (for example on housing targets), with the prospective sites and projects promoted for inclusion in the plan by private sector interests. If they have advantages in contextual attunement to immediate local priorities, capacities and deliverability they also have pathologies. The kinds of projects that are thinkable and actionable may represent just a small subset of the areas in which progress needs to be made, and serve the short-term demands of incumbent interests, but fall way short of the rate of change required by decarbonisation targets.

However, there are other ways of thinking about planning, including for local energy, not as a linear knowledge-driven option selection and delivery task, but as one of a number of venues – one might say a very important set of venues – for fostering civic deliberation and learning. This may be more appropriate – and embody a more appropriate model of knowledge use – given that the overarching problem remains one in which there is little consensus. Such models echo qualities of 'adaptive planning', in which there is less emphasis on 'the old plan-and-implement model aimed at achieving particular outcomes' (Kemp et al 2005, p.25) in favour of 'a more open-ended, process-oriented philosophy'. Adaptive planning thus takes an iterative approach with a greater emphasis on 'monitoring, researching and adjusting', allowing the redirection of previous management goals and activities 'in light of new information and surprise' (Lessard 1998). In the energy field, this might mean that rather than pursuing a single vision of decarbonisation, or a single technology approach, there is a commitment to explore a diversity of different routes in a more iterative way. A portfolio of ideas would be used, including 'transition experiments', to develop circles of learning and adaptation. These routes might connect diverse technologies to trajectories of change for whole energy systems.

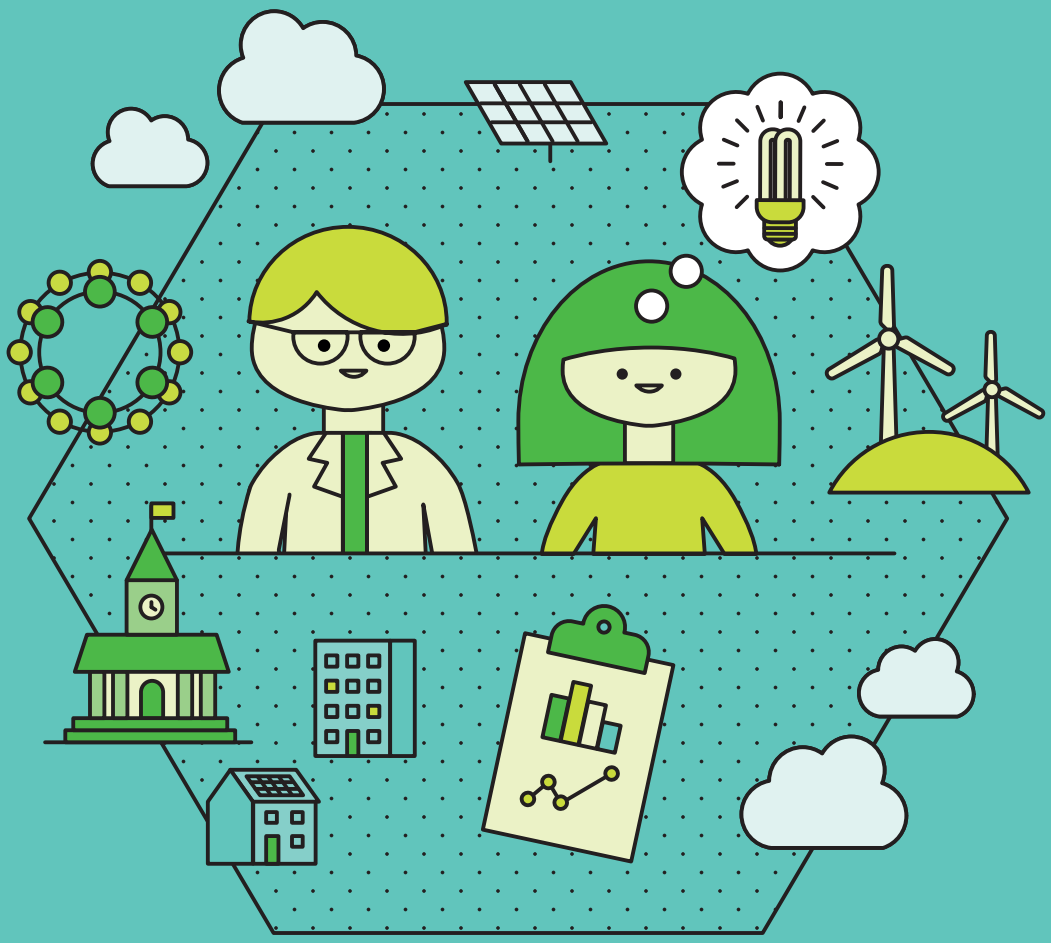


More adaptive forms of planning have a number of implications:

- Treating local energy plans as an opportunity for learning requires greater reflexivity between levels, sectors and actors in the policy system. Even if plans are rolled forward in a given locality, led by a particular agent, it may be that higher levels of government, or different departments of government, or commercial actors are best placed to pick up the salient lessons, and take actions that accelerate the rate of change (such as the adjustment of financial incentives; Hvelplund and Djørup2017). This reflects the fact that 'the power to shape structural change in society and technology is distributed across a multitude of actors and societal subsystems' (Newig et al 2007, p.187). Connections between local energy planning and national deliberations and strategy-making become more important. There appears to be recognition of this in the Smarter Energy Plan for GMCA (ESC, BEIS and GMCA 2019). Not only does it exemplify some qualities of adaptive planning, but there is explicit attention to how the knowledge generated from large scale testing can (p.30) 'provide a compelling case to Government and the relevant regulator … to enable policy and regulatory reform to be trialled and tested', too.
- The types of knowledge that are best suited to such planning situations are those where there is a degree of collaborative input to the agenda and problem framing, and where the knowledge outcomes can be more readily shared. One can see how knowledge wrapped in IP rights and NDAs could be problematic.
- Such adaptive planning approaches have their own tensions and challenges. Inviting local government to undertake actions that are experimental, even disruptive, is not a commonplace of UK national-to-local governmental relations. There is an urgency to decarbonisation, and a point (or points) will be reached where it must be agreed that the level of learning about energy system options is sufficient to move to widespread adoption of particular holistic solutions. By way of example, one cannot adaptively plan a heat network at major scale in urban areas or repurpose the gas grid – these require years of planning, engagement, design and delivery. Creating stable, de-risked conditions for such investment means some level of insulation from deliberation and challenge (Smith and Stirling 2007). Better quality evidence may help to reduce or structure potential uncertainties, but the persistent uncertainties permeating the heat decarbonisation problem show that 'better knowledge' per se will not stabilise the context for action on its own.

The kinds of projects that are thinkable and actionable may represent just a small subset of the areas in which progress needs to be made…

Conclusions



Socio-technical analysis of the LAEP pilots, and of prospects for mainstreaming local energy planning more widely, has generated insights, embracing more diverse understandings of the problem, new thinking about how knowledges and actions might productively co-evolve, and directions for further investigation.

The LAEP work itself has delivered significant outputs, including complex whole systems options appraisal using the EnergyPath Networks tool, energy strategy documents based on detailed evidence about the three areas, and Smart Energy Plans for the three local authorities. There are also important 'soft' outcomes in terms of organising and sustaining collaborative work on the LAEP agenda, bringing together key actors from the energy sector, government and academia. This collaboration has progressed in SSH Phase 2 to plan potential energy innovation zones and a route map for a pipeline of innovation projects with commercial potential, and to work on deployment projects. The LAEP pilots have demonstrated the time commitment, skills and work entailed in forging some common knowledge between parties about the value and applications of complex models such as EPN, in relation to equally complex local economic, social and political processes. There is potential for the LAEP pilots to provide a platform for wider progress in energy planning and business innovation.

Nevertheless, given evolving policy and the complexity of decarbonising heat, the longer-term trajectory for the LAEP/EPN work and associated local strategy development was perceived as indeterminate. Challenges included the need for clarity over terms of access to, and costs of, the resource-intensive scenario modelling using EPN, and the capacity for regular updating and flexibility in the underlying model, with respect to changing technologies and cost profiles, including hydrogen systems, or gas hybrid heat pumps.

From a socio-technical studies perspective, two aspects of our findings contribute to understanding some of the reasons for this indeterminacy. The first concerns aspects of the LAEP pilots and social-political problems of engagement between the technical expertise, represented by the SSH programme, and local authority actors in knowledge creation and use. The process of engagement was itself framed by initial uncertainty about purposes, and therefore the roles of the LAs and ETI/ESC. This ambiguity introduced uncertainties about the relevance of results for local decision making, and about the potential for 'local ownership' and implementation of any resulting strategy, given the lack of devolved powers over energy markets and regulation.

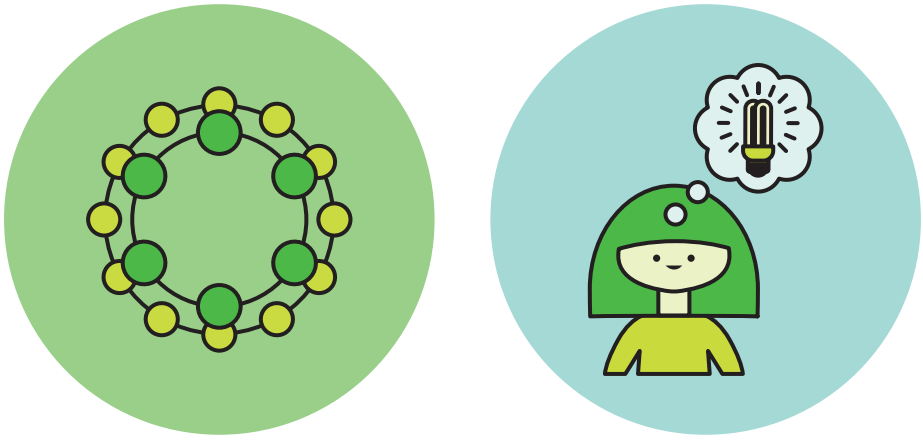
The second aspect of our findings concerns the underlying compatibility, or otherwise, of wider objectives, responsibilities and priorities of the different parties, which direct the type of strategies valued. Here the dynamics of the LAEP pilots can be seen to reflect in microcosm wider intractable qualities of the heat decarbonisation problem. Disjuncture between purposes and perspectives cannot easily be ameliorated by improvements to processes of engagement and technology design alone. The framings, and the material and institutional structuring, of the 'heat problem' remain far apart. The SSH LAEP/EPN pilots have been geared towards technologically innovative cost-optimal solutions tailored to different places. The local authorities, lacking mandatory powers for local energy systems planning, prioritise relatively short-term opportunities related to building stock and (re)development schemes, and rooted in readily available, higher-traction arguments including energy poverty, economic regeneration and jobs. Local circumstances hence shape the value of knowledge from a whole systems engineering model such as EPN; these circumstances encompass a wide range of variables including the changing political composition of the council; local economic structures and social divisions, and differential status and powers of the locality in the UK's uneven multi-level governance institutions. Scenario models combining large scale technical and economic data to support complex decisions in uncertain circumstances may hence struggle to recruit champions to convey and translate knowledge and its use values from setting to setting.

Formations and uses of knowledge are shown here to be inextricably social and political, as well as technical, especially in multi-actor, multi-sector processes requiring diverse interests to be encompassed. LAs, other local actors including DNOs and universities, and technical experts such as ETI/ESC have different conceptions of the city and optimal routes to low carbon heat, giving varying emphasis to technological innovation, as opposed to innovation in policy, business and governance. Moreover, LAs themselves are not homogeneous consumers of energy-related knowledge: the knowledge needs of the planning department for example are different from those of an economic regeneration team, or a corporate energy and climate change team. This results in multi-dimensional contest over the relative potency and authority of different forms of knowledge about the city, and their significance for local energy strategies and investments. By being ambitiously whole-system in orientation, the LAEP pilots arguably magnified the problems of attaining cross-sector buy-in.

What has changed through the duration of the SSH Programme and LAEP pilots?

Much has changed through the duration of the LAEP pilots, sometimes productively but not in all instances. On the positive side, there has been multi-dimensional negotiation over serviceable knowledge for local planning in relation to the LAEP pilots, which has contributed to framing the wider problem of decarbonising heat. Findings from this scoping study indicate that some key questions are at least partially specified and there is growing local and central government political awareness. There are however few answers about how to proceed, even in relation to any requirements and standards for area-scale planning and implementation at an affordable cost.

A range of initiatives are however informing discussions; these include GMCA's Smart Communities project with Japan's New Energy Development Organisation (NEDO); the EU funded Flexible and Integrated Energy Systems (FLEXIS) project in South Wales; the UK RHI scheme; UK Government Heat Networks Delivery Unit (HNDU) and Heat Networks Investment Project (HNIP), and recent hydrogen innovation funds. New additions are the Industrial Strategy Challenge Fund (ISCF) *Prospering from the Energy Revolution (PFER)*. ESC is itself responsible for the Energy Revolution Integration Service (ERIS) and is using knowledge from LAEP pilots, including data foundations for system planning, to support demonstration projects and new business design concepts. Ofgem is using its Future Insights work to consider regulatory changes which could support local energy systems. UK BEIS has funded English local energy hubs combining a number of LAs and Local Enterprise Partnerships to develop local plans. Infrastructure investment through City Deals and regional devolution deals are also potential components of local clean energy planning. Rather than working in parallel, these initiatives could be integrated into a systematic framework for shared learning, and combined strategic investment in low carbon heat transition, either locally, regionally or at national scales. A relevant, although tentative, finding from our research is that local capacity for energy strategies can be more advanced where there is some form of regional governance structure, with clear commitments to addressing climate change, but this is not a universal feature of UK multi-level government. City/region devolution deals are patchy, and constructed on varying terms; low carbon infrastructures have not thus far been well integrated into these, and democratic accountability of decisions has been questioned (O'Brien and Pike, 2018). Overall, patterns of knowledge production risk reproducing diverse and fragmented problem framings, rather than working towards closure.



Neither are current LAs materially equipped to take on responsibilities for local planning and project management for major retrofit of building stock and associated financial innovation, whatever the ultimate policy direction. In that context, local planning remains necessarily tentative and patchy. Waves of optimism for the prospect of civic energy (IPPR 2014) have also ebbed and flowed in the face of austerity and shifting market rules. Improvements to thermal efficiency of buildings have declined, following short-term changes in policy frameworks which have weakened supply chains and standards of work, and willingness of households to proceed (Rosenow et al, 2017; Committee on Climate Change 2019). There is even less impetus for change in heating systems: public awareness is very limited, and there is little comprehension of the scale of change, because this has not been properly introduced into public debate.

Debate about smart local energy systems has also centred on the *demand* side, and on potential for digital platforms to inform energy use and energy saving. Such innovations are expected to be replicable in different places. Less attention has been paid to supply infrastructures, where solutions may be locally or regionally differentiated, and central government policy, standards and regulation, are likely to be critical to any local planning. The implications of these wider complex questions over new heating systems, pricing, cross-subsidy and cost sharing over what period are only beginning to be aired. One example referenced in discussions was the conversion of gas networks to transport hydrogen for heating. If this is associated with locally differentiated solutions, then more industrialised areas might be early demonstrators, with hydrogen as the major industrial energy source, a local hydrogen distribution network for local building stock and carbon dioxide storage for methane reformation. But this model may not be transferable to less industrial areas, and even if it was, there are questions of cost versus timing: would some sectors of the population need to contribute to the high costs of new hydrogen systems in other areas, even if they do not benefit directly in the immediate term? Preferred solutions may also differ, with greater potential for use of waste heat and heat networks, or electrification, in some places, depending on building stock and geography. How should costs then be apportioned?

The complex of questions over the future of heat, at the scale of every person/every building, is paralysing for any government. Current UK government is also struggling over future political and economic relationships with Europe and beyond; the financing of public services and infrastructures; and the security of democratic institutions. No clear programme, with potential for local energy systems planning, incorporating large scale demonstration, longer term business models and commercial investment has yet emerged. This is unlikely to take shape while UK government heat policy remains undecided, given the multiple inter-dependent uncertainties over fuel sources, network infrastructures, and combinations, as well as financial, regulatory, customer protection and social justice questions.

Gaining momentum for decarbonising heat, and avoiding the risk of 'paralysis by analysis', requires governance and societal frameworks for thinking broadly, and flexibly, about the strategic problems. Any expectation that knowledge, embodied in technical-economic models, for future heat systems can be developed and applied in linear, uncontroversial and instrumental fashion is shown consequently to be unrealistic. To quote one UK government source: 'heat supply and heat demand, there are so many local considerations; it's about countries, locations, behaviours, it's a bigger beast. And you can't just build up a modelling tool and sell it, or build a new bit of kit and solve the problem.' Technical solutions are only part of the puzzle; to command legitimacy across civil, state and market sectors, public engagement and politics are fundamental. Governance frameworks will hence need to encompass more than commercial and industrial orders of worth (Boltanski and Thévenot 2006), by recognising and incorporating civic, public sector and domestic values. The scoping study findings suggest the value of explicit commitment to more organic, less mechanistic, models of knowledge, to ensure more positive contributions and synergies for longer-term learning and innovation. The state of knowledge points to the value of breaking away from overly-commercial problem framings at exploratory stages of definition and knowledge development, and substituting inclusive and boundary spanning work across sectors to retain flexibility over future options. This more organic model of knowledge formation needs to retain flexibility to respond to emergent insights and innovations.

Gaining momentum for decarbonising heat, and avoiding the risk of 'paralysis by analysis', requires governance and societal frameworks for thinking broadly, and flexibly, about the strategic problems.

Further Research Questions

The scoping study has led to further social science research questions about energy innovation and climate protection, at the interface between UK central and devolved national and regional governments, local authorities and expert market and technology innovation bodies such as ETI and ESC. Our findings indicate the range of models for energy transition planning for low carbon heat, from planning as a locally-led enterprise, with varied results geared to local priorities, to planning as a top-down uniform process, led by UK Government and energy businesses, and geared significantly to individual property owners deciding to purchase heat/energy services in a competitive market. A centrally coordinated, but regionally devolved, model of energy planning and implementation lies somewhere in between.

The core challenge is conceiving of how knowledge generation and action might productively co-evolve. To that end, this scoping study offers the following recommendations for further investigation:

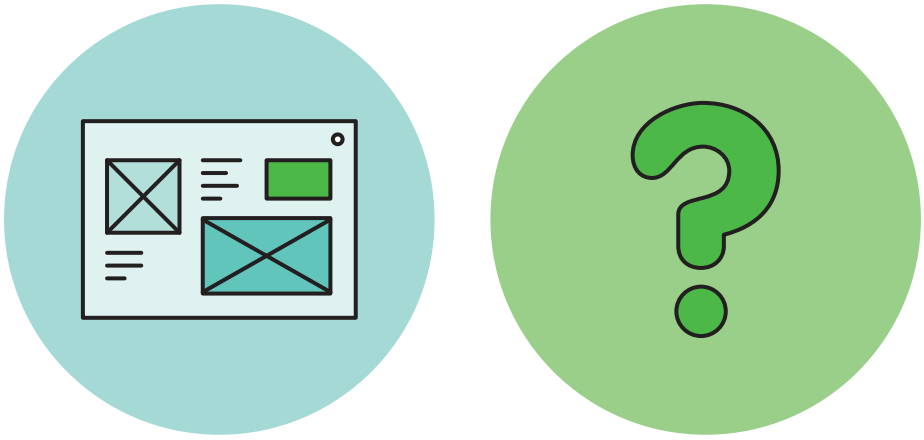
- A key question is what would an enduring, legitimate governance framework for heat decarbonisation comprise and who needs to be party to such decisions? The structural divisions in UK central government between BEIS, MHCLG and HM Treasury have not been conducive to empowering LAs as heat/energy planning intermediaries. To what extent do these divisions need to be ameliorated to support more collaborative knowledge development for policy innovation beyond the technocratic sphere? How could a more collaborative policy planning and decision process be used to identify and implement significant scale demonstrators around an integrated social, economic and climate protection agenda?

- Whether we think of such collaborative and consensus building processes in terms of identifying the missing pieces in an actor network/systems ecology, or in terms of new fields of knowledge to destabilise the status quo, research could pursue comparative analysis of energy model integration into local planning and low carbon heat innovation in other countries.

- The prospect for more intensive action, through planning or cognate regulation, on new buildings appears a more tractable part of the challenge. Is this a sphere where the translation of the LAEP work could help refine guidelines?

- A primary area for further research is the political tension between devolution and centralisation of responsibility, and resources, for whole energy systems planning. In principle some devolution of responsibility for low carbon heat and energy planning breaks the problem down into more manageable pieces. Political risks are however high if different localities and regions pursue different strategies and others do nothing, with potential uneven impacts on energy services, costs and reliability, and differential public responses. Would a UK Secretary of State be held responsible for failure of services in a particular part of England? Equally would any local or combined regional authority take responsibility for setting and implementing a carbon budget without guaranteed major new resources? What scale of government is most suited to implementing supportive measures for solutions discovered to be effective in particular localities? This adds a further question about the most effective scales for planning and investing and the means to streamline and reduce transaction costs. Forms of joint responsibility seem essential, but specific terms and conditions need to be negotiated across the UK central, devolved and local governments. What institutional changes in government are needed to enable such negotiations and how might these be stimulated?

- LAs do not necessarily need to lead any energy planning within local areas, and at present they lack powers and resources to do so. There are however good reasons for arguing that potentially they have very important roles to play. These reasons need to be scrutinised and tested through research in relation to the following points.
    - In UK government hierarchies, are LAs (or other scales of government) the appropriate basis for governing systematic building stock retrofit, tailored to the idiosyncrasies and opportunities of locality?
    - In what ways could LAs be parties to planning more localised energy systems, using digital platforms to integrate energy vectors and storage, to reduce system costs and to contribute to local regeneration? The capacities and capabilities to take on such roles, and the relative pros and cons of LA leadership, compared with leadership by other bodies, need to be investigated. Changes in infrastructures, whether through major investment in electrification, gas grid repurposing or heat networks, all involve LA responsibilities for roads, pavements, public services, land use planning, waste and environmental management, and safety. There are however significant unanswered questions about innovation in established planning processes to integrate systematic and responsive energy planning.
    - In coordination with central and devolved national governments, LAs may be critical to public legitimacy of coordination and governance for low carbon heat systems; again the effective skills, and resources, for LAs to conduct public engagement need to be investigated, alongside questions about the role of other bodies including industry, civil society and community organisations.
- Political awareness and public engagement will be integral to innovation, with councils now beginning to debate climate emergencies and low carbon energy. There are hence research questions about the role and activities of LAs as potential guardians of public interest outcomes. This may be their main role in governance of heat decarbonisation, where action focuses on individualised home owner market-based service and retrofit solutions.



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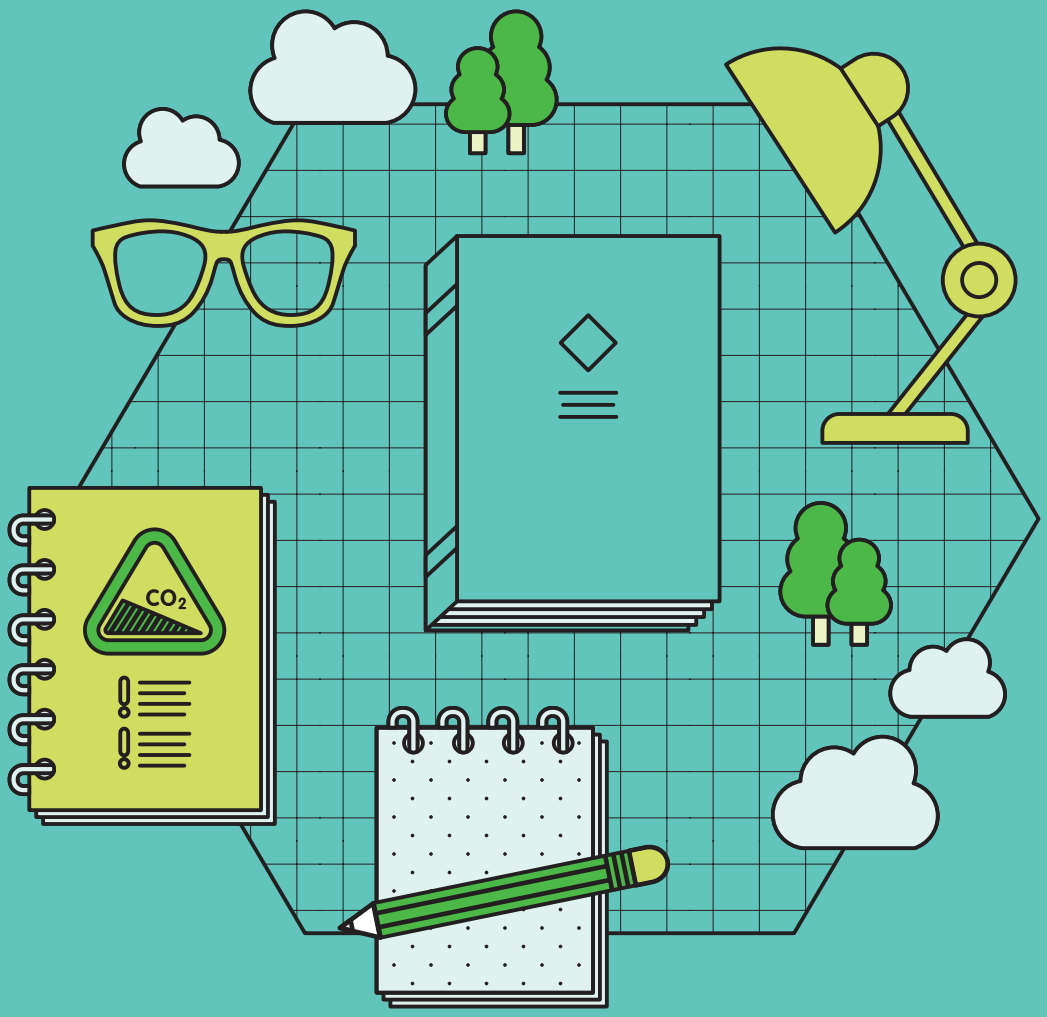

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