Coordinating Heat Network Development under Uncertainty: Nascent Heat Networks in Two British Cities.

David Hawkey and Janette Webb[1], University of Edinburgh

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Introduction

One of the solutions envisaged for radical decarbonisation of UK building stock[3] in densely populated urban areas where heat loads are concentrated and diverse, is the development of district heating infrastructure (UK DECC, 2013; Scottish Government, 2014). Technical-economic assessments of such localised energy systems, using a range of sustainable heat sources, repeatedly advocate their value as a critical component of long-term fuel, cost and carbon saving, and as a contributor to systemic resilience (Connolly et al, 2014; IEA, 2014b; UK CCC, 2010; UK DECC, 2013). The UK however has never invested significantly in heat (as opposed to gas) networks, and the likelihood of material development remains uncertain. Current liberalised energy market regulation and structures, together with historical lack of knowledge, experience and expertise, result in regulatory uncertainty, perceived economic risk and associated high costs of capital, which militate against straightforward project development (Kelly and Pollitt, 2010).

Drawing on social studies of energy systems, this paper examines two case studies of attempted coordination of heat network developments in neighbouring British cities. In both cases, engineers, lawyers and finance experts deployed specialised knowledge encoded in technical-economic modelling tools, public procurement regulations and contract law to assess costs and benefits, and carbon saving potential, of heat networks serving

[1] Jan.webb@ed.ac.uk dave.hawkey@ed.ac.uk

[2] http://www.heatandthecity.org.uk/resources/workshop_on_research_findings_on_sustainable_heating_provisions_and_cities_theory,_practice_and_future_implications

[3] UK Carbon Plan 2011: 'by 2050, all buildings will need to have an emissions footprint close to zero' (p.5). Forty-five per cent of current emissions from buildings are associated with use of fossil fuels for heating, indicating that energy saving and low carbon energy for heat are critical to meeting the target.

multiple organisations, notably hospitals, universities, housing providers and local government. In the UK's liberalised energy market, their material development however currently relies on the parties finding a means to jointly assemble a new economic actor, centring on heat users, able to structure a new heat market as a long-term, locally inter-dependent solution to energy supply.

Heat Networks: The Technical-Economic Rationale

Heat networks transport hot water to multiple buildings and usually run through the public realm. In common with most urban infrastructure they are installed underground, but, in comparison with other energy infrastructure, highly insulated pipework and the consequent scale of trenches required contribute to relatively high capital costs. The basic financial model for such high cost infrastructure of many heat networks in Europe has been to enable movement of heat energy from a place where it is of relatively low value (such as residual industrial energy) to one where its value is high (space and water heating). The broad financial structure, then, in comparison with other energy networks, is relatively low input costs (low value heat) but relatively high capital costs. Infrastructure challenges such as time inconsistency are therefore particularly acute for heat networks, especially as heat network infrastructure is long lived (over 40 years).

Areas of high heat demand density and diversity in temporal patterns of heat demand enable higher utilisation of heat network infrastructure, increasing the ratio of the value of heat supply to the capital cost of infrastructure. In addition, and in common with other energy network infrastructure, large users play an important role in the establishment of systems: with relatively high and stable patterns of demand, these users can "anchor" the initial network, to which additional, smaller users can be added later (King and Shaw, 2010).

While consideration of capital and input costs have influenced development of heat networks, their development is multidimensional and reflect issues located in particular places at particular times (for example, urban regeneration and local pollution issues). The value of contemporary heat networks as formulated the UK policy is situated in relation to the 'energy trilemma': affordable, secure, low carbon. Being source agnostic, heat networks accommodate a wide range of heat sources, particularly some which are more efficiently exploited on a large scale (such as deep geothermal). However, this tends to make larger networks more valuable (in trilemma terms) than smaller systems as larger networks open options that small networks do not. Their capacity to store heat means they can contribute to system balancing, enabling efficient CHP generation for times of scarcity

and absorbing power via electric boilers and heat pumps at times of surplus (IEA 2014a). Large networks with multiple heat sources backup only needs to cover likely input losses. It is much easier to connect new heat sources in to a large existing network than to build a network around a new heat source. Furthermore, integration of different heat sources in future, as costs and benefits of different (large scale) heat technologies and resource flows become apparent, is thus facilitated: flexibility over the short run can reduce costs, and longer run flexibility builds resilience to energy security challenges. More subtly, large networks tend to have (or be designed to have) more diverse heat loads, increasing the load factor and giving the network higher ratio of benefit to sunk cost. Higher load factors also support more efficient exploitation of heat sources.

The Energy Market Context for New District Heating in the UK

Despite periodic UK policy initiatives to support the coordinated long-term planning associated with realising the systemic efficiencies of district energy for heating, it has generally 'had to fit as best it could into a system that has not been designed to suit it' (Russell, 2010: 6). The state-owned energy system of the 1980s was already geared to commercial economies of scale, with heating and power held separate in distinct vertically integrated supply chains, with managers seeking to avoid additional social obligations. There were established interests in expansion of centralised electricity generating capacity, marginalising the potential for the types of systemic efficiency gains associated with localised combined heat and power supply and district heating. Systematic 1960s development of networks to supply gas from the North Sea, combined with low VAT rates for domestic or small users, also meant that domestic, public and commercial heating from gas central heating was made widely available. Privatisation, Russell suggested, did not give any greater emphasis to integrated systemic efficiencies or social obligations, and the more complex regulatory structure of the industry made the prospects for CHP and DH more unpredictable. Russell concluded that district energy developments in the UK have always required some form of state intervention to counteract the short-term economics of the energy system, whether under state or private ownership. The implication is that district energy has been constituted as economically marginal by virtue of its embedding in the political-economic institutions, and material infrastructures, of an energy sector converging around the scale economies of centralised electricity generation, and gas grids.

The emergence of heat networks as a component of government energy policy represents a form of state intervention oriented to the long term. UK government Heat Strategy (UK DECC, 2013) for example uses low carbon

scenario modelling to suggest that 'up to 20% of UK domestic heat demand might be served by heat networks by 2030' (p.45); this is based on cost advantages relative to stand-alone heating in individual buildings. Other models are cited with higher proportions of heat load regarded as economically viable for heat network development up to 2050.

However, to date intervention by government has been limited, and contrasts with governance of other network infrastructure. New heat networks are not subject to regulated investment models akin to those available to the regulated gas and electricity sector which exchange an operator's right to monopoly with low but reliable rates of return. Decisions about heat network investment are accordingly governed by the hypothesis of market efficiency which asserts that viable investments will have resources allocated to them by virtue of laws of capital productivity. The role of government is considered to be that of removing market barriers where necessary to stimulate commercial investment. In the energy sector, energy company obligation finance for carbon saving, standards for improved energy performance in buildings, a renewable heat incentive, a carbon price floor and a carbon market (the EU ETS) inform the capital productivity calculus, but these are deliberately technology agnostic:

> *"Rather than pick a winning technology, the Government will create markets that enable competing low carbon technologies to win the largest market share as the pace of change accelerates in the 2020s" UK Carbon Plan, 2011, p12*

This "positive" case for a regulatory, as opposed to planning, role for Government, is matched by a "negative" neoliberal case based on constraints on public finances in a context of downward pressure on tax rates and upward pressure on welfare spending commitments (Le Galès, 2002; Harvey 1989). Government must use its limited resources to organise markets in which investors are willing to deploy their capital: scarce public finance is construed as having greater impact if it can mobilise the far larger pools of private capital, than if invested directly into energy systems.

The contrast with UK development of the 1960s gas network is evident. Uneven, and increasingly expensive, provision of coal gas was replaced, under state ownership of the energy system, in a planned transition to North Sea natural gas, with a gas grid built out from the existing backbone, a 10 year conversion of existing heating and cooking appliances in buildings to natural gas (Pearson, 2014) and a longer period of transition lasting until the middle of the last decade to central heating of homes (Palmer and Cooper, 2013). The underlying rationale was one of infrastructure provision for a growing market for affordable heating supply from indigenous resources.

Contemporary policy emphasis on urban provision from district heating is not primarily regarded as a measure to support economic expansion, but as a means to mitigation of climate change, as well as future provision of affordable and secure energy. It is not being taken forward as a planned and coordinated development, but as a form of 'experiment' in the use of market devices to solve societal problems (Callon, 2009). The 'experimental' nature of local development from the perspective of central government is explicit: lacking data meeting its standards of robustness, the UK Department of Energy and Climate Change in part justifies support for heat network development as a process of revealing their economic characteristics, the better to model alternative energy futures and trajectories.

The high level of initial capital investment needed to secure the eventual economies of heat network infrastructure, combined with lack of an established market for heat, and the internal rate of return set by investors usually over a short timescale, means that few schemes are evaluated as commercially viable in current markets. Mobilisation of finance is consequently limited. This is recognised in UK heat policy (DECC, 2013) which concludes nevertheless that 'in the long run heat networks may give a return higher than other heat solutions' (p.49), given the long period (up to 40 years) over which revenues from the network may be generated. There is however no immediate proposed regulatory solution to address the need for affordable 'patient capital'. The main short-term focus instead has been on the potential for local authorities to act as brokers and coordinators of developments up to investable stage (UK DECC, 2013). Local planning powers are regarded as suited to enabling heat mapping, infrastructure development and required connection of new developments to district heating, and the social, political and economic responsibilities of local authorities create the basis for intermediary or project sponsor roles. In England and Wales, the City Deals programme and the Heat Networks Delivery Unit are intended to secure projects which can 'achieve a commercially viable threshold' (UK DECC, 2013, p.58): "Through our City Deals programme, we are already helping cities to develop their plans for district heating. Central government is not going to build their networks for them, clearly. But we know… that a small amount of help in the initial phase of a project can go long way. It can help to move projects to the point of commercialisation – where the Green Investment Bank and commercial lenders can take up the reins, investing in heat network projects with profit-making potential." (CHPA Heat Conference 2012: Keynote speech by Edward Davey, UK Secretary of State for Energy and Climate Change[4]). In

[4] http://www.gov.uk/government/speeches/heat-conference-2012-keynote-speech-by-edward-davey

Scotland, the government has adopted a related approach, through work with local authorities to develop heat mapping, to coordinate resources and technical, financial and legal advice for development of projects to investable stage, and to set modest targets for development (Scottish Government, 2014).

In the absence of an existing urban market for sale of heat, or regulatory changes to the established economics of sunk investment in gas grids, stand-alone gas central heating and electricity generation, commercial actors currently see limited straightforward potential for investing in district heating infrastructure. Any projected development hence relies on social innovation where large users of energy for heating and hot water, particularly local authorities (as above) but also other public sector bodies, are encouraged by central government to identify a common interest in such energy systems and to develop the requisite economic capacity to act.

The Sociology of an Economic Actor

In this paper, we use economic sociology and social studies of energy as a conceptual framework for investigating the processes of configuring such an economic actor. We explore in particular the processes surrounding attempted coordination of two urban heat network developments in British cities, and reasons why the formation of the actor in these cases has proved precarious. The domain of social studies of energy aims to apply social sciences beyond economic science to the analysis of energy systems. The approach is influenced particularly by social studies of science and technology, and its distinctive concern with *materiality*, where this is understood as encompassing three dimensions: *physical* artefacts, notably technology hardware and representations in monetary price; *corporeality* of human beings, with particular capacities as well as limitations, and *technicalities* of economic models, formal risk valuation methodologies and legal and regulatory instruments which shape decisions and their consequences (MacKenzie, 2009).

Using the work of Michel Callon, an economic actor is conceived not at the scale of the individual, but as an interlinked assembly of multiple human and non-human material components. In modern societies, marked by continuing extension of the market sphere to new domains of social life, agency is distributed across multiple domains of knowledge, embodied in, and performed through, hybrid assemblies, or what Callon depicts as *agencements*, of people, hardware, calculative devices, information technologies and texts (Callon, 1986; 2005). Callon's arguments derive from actor-network theory (Callon and Latour, 1981), which remains contentious, because it attributes agency not just to human beings, but also to the non-human entities, such as financial algorithms, legal contracts, or software engineering models, which

operate in combination with people to create the conditions of possibility for particular forms of action and its meanings. It is however valuable in analysing contemporary socio-technical systems and the technical instruments and expert knowledge which shape social facts and their material consequences. The UK's contemporary energy system for example is simultaneously physical, technical and social: societal expectations are set around continuous supply of energy on demand, from systems whose behaviour conforms with the laws of natural science, as well as being governed by regulatory instruments and market algorithms, and particular policy-makers, and managers, specialist and generalist employees of supply chains and users; patterned, relatively predictable, action continues through its differentiated architecture and institutions, without comprehensive understanding of all details by any particular person or specialist group. Instead specialist domains of knowledge and theoretical propositions, such as those relating to 'the efficient market', or engineering for technical performance and resilience, or contracts governing terms of exchange between complex legal entities, interact with fuel and technology markets to normalise particular energy provisions.

Rather than having fixed characteristics, the actors in such systems are understood as contingent on their constituent elements, but their composition is consequential: in this case for example, the particular modelling tools, financial valuation techniques and legal instruments in use inform societal distributions of costs and benefits of energy provision. Economic sociology of this kind avoids attributing agency *a priori*; rather it explores how attributions of agency are 'shaped and channelled by factors including the composition and configuration of *agencements*' (MacKenzie, 2009: 61). It examines the kinds of actors brought into being through particular configurations of people, organisations, technologies and rule-governed abstract systems. It seeks to avoid normative assumptions about an actor having universal characteristics, such as those attributed to a utility-maximising individual. Instead it examines the formation of the socio-technical conditions for emergence of the utility-maximising actor, including the incorporation of formal knowledge and technical instruments from economic and engineering sciences and so on. It draws attention to the socio-technical achievement of instrumental concepts such as 'internal rate of return', which are made material by virtue of shared belief for example in the facticity of accounting standards, laws of contract and market prices.

Conversely it draws attention to the need to enquire into the configuration of economic actors with capacities other than those of maximising profitability. Research on financial markets, which might be assumed to be the epitome of profit maximising actors, for example shows that elements of gift economies

and trust relations are embodied in trading practices (MacKenzie, 2009). In relation to climate change and future energy provision, we need to investigate what forms of complex economic actor are most likely to support and sustain the common interests of societies in avoiding dangerous climate disruption.

Questions about the formation of agency, or economic actors, are more than academic: there is pervasive concern among government officers, public bodies, private enterprises and community groups, manifest in the discussions and workshops attended during this research, asking who will take the lead in what kinds of action to pursue a low energy, low carbon, affordable and secure system.

Assembling an Economic Actor: the Case of Heat Networks in UK Energy Market Context

In this section we discuss two case studies exemplifying processes involved in the formation of such an economic actor involved in heat supply to multiple organisations in two neighbouring cities which we anonymise. The economic actor in these cases exists only in the potential envisaged by government bodies for district heating infrastructure and services to be developed in a particular locality as a joint enterprise among multiple complex organisations, each with some responsibility and assets in the area. Each party is expected by government and its agencies to have capacity for discovering shared interest in such investment, because their activities entail significant energy consumption, and their objectives, whether business or public sector, include dimensions of energy and carbon saving, and perhaps economic development relating to infrastructure. However, this remains a predominantly voluntaristic activity. Large organisations, particularly in the public sector, who make considerable use of heating and hot water are expected to collaborate to discover common benefit in structuring viable commercial investment propositions. The public sector is a particular focus for government, because public bodies are required to engage in policy to reduce carbon emissions, save energy and reduce spending. Hence each is under some degree of pressure to explore alternatives to normative energy supply arrangements. Local authority powers and responsibilities for the locality are also associated with strategies for urban regeneration, economic development and amelioration of fuel poverty. Investment in district heating may, in these circumstances, be constituted as serving multiple non-energy related objectives, including local social and economic benefits from new infrastructure, and/or indirect benefits from 'place marketing' associated with 'green credentials'. Such long-term orientation to well-being is set against the formal appraisal of heat network infrastructure investment as economically

marginal, and indicates multidimensionality in the formation of a new economic actor.

The virtual character of the economic actors raises questions about where, what and how to study the ensuing work. In these cases, our research commenced with comparison of plans for sustainable energy developments in a number of cities, and with ethnographic fieldwork which tracked discussions about the translation of plans into projects. We gained agreement from each city council, as well as government and related agencies, university and NHS estate managers, engineering consultancies, independent practitioners, district energy utilities, community groups, environmental finance and legal experts. Fieldwork has entailed observing meetings and taking hand-written notes, and sometimes contributing when invited; studying local authority and government energy-related plans and strategies, district heating project planning documents, maps and feasibility reports where available, and conducting semi-structured interviews generally lasting from one to two hours. The latter were mainly audio-recorded and transcribed in anonymised form, and followed partly a biographical format, and partly a problem-oriented format seeking insight into processes of economic actor formation in relation to specific heat network projects. In the case of East City, we draw particularly on a subset of ten interviews with a total of twelve contributors; in the case of West City, we draw particularly on a subset of eight interviews with a total of eight contributors; the larger data set is grounded in a total of 114 interviews with 159 contributors.

East City

May 2013, a meeting, hosted by the city council, is held among a small group of people to establish 'if there is a willingness amongst stakeholders to consider the feasibility of a project to develop a heat network' (Briefing Note for Meeting) at a significant green field development site in East City. All partners were represented: the NHS board (with one existing hospital and one in planning), the university, government and two of its agencies – responsible for enterprise and resource efficiency – as well as city council and an independent practitioner recently contracted to government who facilitated discussion[5].

The site in question had begun development a decade previously, when a major teaching hospital opened, with its own energy centre and combined heat and power system, and the university also established new clinical research facilities. Government and development agencies sought to capitalise on co-location of these 'knowledge economy' enterprises, emulating

[5] JW was present as observer, and was also asked to comment briefly on the sustainability credentials of district heating.

European and USA models of science parks, and in 2006 an adjacent area of land was acquired for development as a global centre for public and commercial research in health and life sciences, as well as care facilities. The city council is the planning authority, and owns neighbouring land and housing areas. As a green field site, development was contentious, and the aim was always to ensure that all buildings were sensitive to the protection of the environment and met high standards for energy and resource efficiency, including use of efficient, low carbon or renewable energy supply. This was expected to be more attainable than in city centre retrofit. Planning guidance accordingly set principles emphasizing sustainable development, and the initial environmental report on a site sustainability framework examined options to ensure CO_2 emissions would be 50% below minimal compliance with building standards. A high-level options appraisal in 2012 identified district heating as a key factor in meeting the target and the site environmental consultant was commissioned to conduct more detailed technical, economic and legal feasibility analysis of potential for an area-wide district heating network.

In 2014 discussions about carbon saving via shared energy supply from a heat network remain unresolved. During this period further buildings have been built or commissioned with arrangements for heating independent of the network proposal.

Using Markets to Solve Problems of Sustainable Development

Economic action at the development site during the last decade has been shaped both by late twentieth century deregulation of financial markets, and resulting mobility of capital, and by the 2007 financial crisis in global markets. The associated belief in market devices as least cost means to solve societal problems, and requisite development of regulatory mechanisms and valuation models to govern decision-making, has shaped a range of economic actors geared to competition between states, and major cities, to secure resources, with facilities such as science parks positioned as strategic assets to secure critical investment:

> *'Whether it's about infrastructure or whether it's about… it will be market driven, it has to be these days, because we don't have the funds to deliver the whole thing. We can maybe add money in for elements of infrastructure and the likes, but… you know, it's a changed world and so we are reliant upon the competitiveness and the attractiveness of East City as an investable place, I suppose.' (Chris, East City economic development officer).*

In accordance with this model, and a UK economy then in a period of growth, science park development was envisaged as a joint venture with a private investment partner:

'We have an American partner who creates life science parks throughout the world, or did until the market downturn… from 2006, we went into a partnership with them. We would have been looking for a pre-let from a large, something like GSK, or one of the large pharma companies, and speculatively building a building for them.' (Jake, enterprise officer).

After the 2007 financial crash, the private partner however 'very much took a back seat' (Jake), and subsequent investment has derived from the public sector: the enterprise agency successfully bid for government infrastructure funds, which were part of short-term economic stimulus, to build serviced research office and lab facilities for the commercial sector, and a second NHS hospital and research facilities have been commissioned.

Original planning guidance had emphasised sustainable development throughout, but the same market devices govern decision processes; carbon and energy saving rationales are translated into price impacts, and regulatory instruments are geared to commercial investment:

'we were looking at it very much from cost reduction perspective. You know, looking at how to sell that, and also just in terms of even, you know, institutional investors…' (Alex, Enterprise Officer).

The calculus of short-term cost reduction proved to have greater traction than metrics of long-term carbon saving, and the new building for business start ups proceeded with conventional stand-alone heating:

'When it's one building in a large plot… commercially it's just not viable to do anything other than really what we did, which was more or less fairly traditional in terms of the heating systems.' (Jake, Enterprise Officer).

By 2013, the ambition for sustainable energy on a collaborative basis had been displaced onto future phases:

Interviewer: 'You said that your role is to look at sustainability issues. Is that sort of focussing on these forthcoming stages or on … work that's already happened or…

Alex, Enterprise Officer: No, it's more on the forthcoming stages. It seems to be that [new small business start up building] has been developed with a pretty standard type of heating system, you know, oil and gas fired... But…we're looking at how we can incorporate that... And I would think this … can be seen as a bit of a pilot for [Agency]… If we get it right here, I think there's a big momentum building up to look at district heating in many schemes.'

Using Technical Devices to Frame the Process: Carbon targets and building standards as a component of the economic actor

It had been assumed that collaboration, and hence formation of a new economic actor, for district heating at the site, could be developed through the use of formal technical-economic modelling of energy, carbon and cost saving, with expectations that this site would act as significant demonstration:

> *'potentially the opportunities are greater than if you're looking at the inner city, city centre locations…' Margaret, Enterprise Officer.*

In practice however the agency of the technical-economic feasibility study has proved tenuous, despite its conclusion that the most cost-effective methodology to achieve targeted on-site emission reductions would be via gas-fired combined heat and power (CHP) system and district heating. The financial model argued that, with what it presented as conservative assumptions, the system could sell heat to the various organisations on the site at competitive prices while making average financial returns of up to 15% per year over 25 years. However, the technical-economic model had limited power to format collaboration in part because the parties are simultaneously components of a public procurement actor, governed by technical definitions of open competition and contract law, and risk reduction priorities. In practice therefore, the power of technical-economic measures of carbon saving to govern collaboration in energy investment is limited:

> *'once you're starting meeting with partners, yes, the rewards in terms of energy savings, and potentially return, can be much greater. But so again can the risk, and you know, the risk of delay, risk of…' (Margaret, Enterprise Officer).*

A carbon and energy saving target is itself a technical standard reliant on expert knowledge embedded in formulae for translating industry benchmarked energy use data to compare 'business as usual' energy consumption and carbon emissions against district heating, to forecast total future energy consumption, capital and operating expenditure, revenues and future prices. Such measures are contestable, particularly when conventional risk appraisal mechanisms and competitive procurement rules are prominent actors. Critical to the assumptions made in the technical-economic model for this site was for example the inclusion of the planned new hospital, and clinical research facilities. The hospital was expected to comprise around half of predicted thermal demand, and was hence a critical "anchor load" to secure the carbon and cost economies of collaboration in provision of district heating. The model however had weak authority in relation to the potency of increasingly elaborated public procurement instruments and timetables.

Technical Instruments of Competitive Procurement Weaken Formation of A New Economic Actor For Localised Energy

The work to configure a new economic actor for district heating is hence enmeshed in the existing instruments of energy markets, competitive contracting and public sector commissioning, where formularised competition is expected to be the best means to appraise options and allocate scarce capital.

This is illustrated by the position in relation to the existing hospital at the site, which was developed in 1998 under a PFI[6] contract with a 30 year term. Inter-party discussions about potential for site-wide heat network with shared heat supply suggested that there were potential efficiencies from connection of the hospital's own CHP system, which generates surplus heat, to an area heat network. The Special Purpose Vehicle (SPV), created to design, build and operate the hospital, was refinanced in 2007 and is currently owned by a consortium of businesses and financial institutions. The current contractual arrangements, and risk modeling, were established without consideration of heat as a utility. The complex legal structure of the multi-party contract results in any proposed management variation, such as that involved in creating a new interface where heat from the hospital CHP is supplied to, or taken from, another network, is perceived as introducing new cost-bearing risks. The PFI contractor and its funders are hence averse to any variation in contractual terms, in a structure which the NHS body perceives as frustrating, counter to its duties of sustainable consumption, and failing to secure systemic efficiencies in use of surplus heat, with potential benefits for hospital finances:

> *'It just seems to be an absolute nightmare because effectively the whole [SPV partners for the existing hospital] are the operators. It's 12 banks that are financing it, and for any decision to be taken, all 12 banks need to agree… So [SPV partners] have told us before and told the NHS that they do not wish to see any change in their risk profile and any change in their profit, because that will cause the banks major headaches, because they obviously… they're buying into an income stream that they will project and if there's any change… so for good or bad.' (Margaret, Enterprise Officer).*

The procurement of the new hospital at the site is structured by similar market devices, albeit modified to constrain excessive profits associated with earlier PFI projects. A Special Purpose Vehicle, structured around debt financing from banks or capital markets, will be used to design, build and manage the facilities, including a dedicated energy centre, over a 28 year period. Unlike carbon saving metrics, these devices are potent in material

[6] Private Finance Initiative

action. Although the NHS partner to the site had indicated potential to use the new hospital as base load for a district heating network: 'they were really needing to … nail down their procurement documentation by the end of October, so they had said that that's our deadline; we need to come back with something then, which we did' (Margaret, Enterprise Officer).

Discussions between the enterprise agency and NHS, using the modelled benefits of collaborative district heating provision, with reduced carbon, affordable heat supply and additional space (resulting from a shared energy centre located elsewhere), however proved unproductive. The project board responsible for commissioning the new hospital considered the technical-economic model results, but decided not to include a requirement for district heating connection in the competitive tender document, arguing that uncertain timing of any joint network infrastructure, combined with legal issues around the relationship between the hospital contractor (who would be expected to take the 'availability risk' of heating supply) and a heat supplier would add unnecessary risks, jeopardising the hospital development timetable. The level of detail, and hence work and stress, entailed in specifying a commercial contract of considerable duration, and the perceived human and economic costs of any subsequent variation in terms made collaboration unlikely:

> *'I think the NHS … took the decision that in their view it was just… the certainties weren't there, and they felt because of that it couldn't be embedded within the procurement documentation. It was very, very disappointing for us' (Margaret, Enterprise Officer).*

The frustration of trying and failing to secure economic agency for low carbon heat networks through the instruments of carbon and cost accounting reflects the voluntaristic framework for collaborative action, in the face of market commissioning of public facilities. The same logics had of course already acted on development by the Enterprise Agency of a new building without low carbon energy systems, again weakening the potential for collaboration needed for viable district heating.

Initial invitations to bidders for the new hospital were advertised with a closing date of early 2013; negotiations have not yet concluded. Further discussion between the enterprise agency and NHS project team, with mediation from related government agencies, have sought to salvage something from the process, notably through requests to NHS officers to consider introducing a requirement for the successful contractor to provide for future connection of the facility to a DH network. Even this weaker requirement has in turn proved problematic, this time because the agency with responsibility for co-ordination of government investment expressed

concern that any variation in the terms of the procurement document risked increased financial costs and set undesirable future precedents:

> *'If they ask all the bidders to review the bid to allow for a future connection, only one bidder will be successful. The others may then seek financial compensation for additional work. And they [government agent] don't want to set any precedent by saying, "Right, OK, that's fine."' (Margaret, Enterprise Officer).*

The same government body is however simultaneously responsible for the sustainability of new infrastructure, which it seeks to integrate into project development, including investable propositions for DH, but this been insufficiently powerful to resolve the tension between competitive procurement and development of a site-based low carbon heat network.

The same countervailing agency was evident in a further potential source of heat from a nearby planned waste treatment facility for an area-wide network:

> *'…procurement: friend or foe? In this case [procurement of energy from waste facility] was foe to the district heating… At the time when the contract (the specification and the like) was being looked at, there wasn't the issues in there of the potential of buy back [of electricity by the councils] or of district heating… Consequently the procurement process moves forward on that basis, you've gone through invitation to tender, you've gone to PQQs[7], that is a whole machine that cranks up and goes and you can't stop it.' (Karen, City Council sustainability officer).*

The waste treatment project, a joint exercise between two councils, is again governed by competitive procurement instruments:

> *'Basically the way it operates, it's not dissimilar to a standard PPP[8] type project … rather than doing it ourselves we've transferred a lot of risk to the private sector... Once it's handed over to them it's all their risk to see that the facility is all up and running or they don't get paid.' (Howard, environmental officer for the Councils' waste partnership).*

The contractor operates on a commercial model, charging gate fees for fixed volumes of waste, and producing and selling electricity from its incineration. Such plants produce very large volumes of heat, and regulators can specify a level of energy efficiency (as in Norway for example) which effectively enforces their operation in combined heat and power mode:

[7] Pre-Qualification Questionnaires
[8] Public-Private Partnership

'these plants (EfW) … they could produce more electricity and less heat, they could produce more heat and less electricity but as things stand at the moment the money is in the electricity. So they'll tend to produce as much electricity as they can, as little heat as they can, but still meet their efficiency standards. Because there's just not that impetus for heat use…' (Harold, environmental officer for the Councils' waste partnership).

The commitment to the hypothesis of market efficiency, embedded in technical and regulatory instruments of public procurement, have so far proved to exercise significantly more agency in governing action than carbon metrics and modelled technical-economic feasibility of district heating for new development sites.

On Striving For and Not Assembling the Economic Actor

'I think there's a feeling that all the ducks are in the duck pond, but nothing's quite lined up' (Karen, City Council officer).

Two meetings between partners in 2013 aimed to salvage from the original ambitions a contingency plan for collaboration, and involved a facilitator with long experience in the public sector, notably in a project to take heat supply from a waste incineration plant for community heating in a different UK city. The intention was that any further proposed district energy project at the East City site would take account of potential for heat supply from the waste treatment plant being considered by council, as well as other possible sources of low carbon heat. The main outcome was the reaffirmation of in principle commitment by the partners to site-wide district heating as a low carbon measure, whilst acknowledging the loss in the immediate future of the significant anchor load provided by the new hospital. This outcome was made material through the commissioning of a second, more detailed, technical-economic feasibility study, by a different consulting engineer, to reconsider a site energy centre and heat network, also linking adjacent social housing and other community facilities, as well as potential for heat supply from the proposed waste plant. The completed study remains under consideration by parties. Its findings, generated from discussions with parties and technical modelling, using proprietary business software, again presented the case for district heating development as affordable, low carbon and a contributor to wider energy system resilience, where the nascent heat network would serve as a foundation for a city-wide network, as well as offsetting costs of electricity distribution network reinforcement. The Report also shows however that emissions reductions and cost savings are significantly reduced by the absence of the new hospital as an anchor load, resulting in a longer timeline for meeting carbon reduction targets.

The next partner with immediate building construction timetables is the University, whose officers, already experienced in campus CHP and district heating systems, indicated in principle willingness to collaborate, but not to lead such a venture, and who will again proceed autonomously in the absence of a lead body directing shared development:

> *'Even down at [science park site], you know, you just despair. If anything is set up to benefit from things like district heating in a properly coordinated support structure, your major new hospital sites with all this expansion for the next 20, 40, 50 years; you can't even have a sensible discussion about integration because it is all your different stakeholders, different contracts. Unless you're legislated it ain't going anywhere.' (Andrew, University estates officer).*

Although recognising the factoring of the CRC 'carbon tax' into its budget calculus, and again suggesting in principle willingness to manage networking between parties, the city council continues to have limited strategic orientation to energy provisions and efficiencies:

> *'energy as even a theme isn't given a huge emphasis within local plans or even within a lot of the strategy development that local councils do…. you don't get energy seen in any strategic context; it's spread, it's disparate, it's a little bit there, it's a bit of an issue over here, and consequently there's no joining up of it' (Keith, Council Economic Development officer seconded to government).*

In relation to energy provisions, as a new area in an already tightly resourced public sector, the capacity to establish complex contracts 'in a way that it can be confident that it's going to be fair' (Keith) and perhaps more potently, compliant with formal rules constituting "best value" use of public resources, is tenuous. The East City council is not using its planning powers directively, recently deciding against the option to require new developments to connect to available DH networks:

> *'Councillors view it [DH] as too much hassle, too complicated and it takes too long… some councillors still remember the failed plans from the 1980s' (Karen, City council sustainability officer)*
>
> *At present, each party continues to step away from shared commitment: 'you need to be able to have people around the table that are influencers and decision makers not just observers… and that's hard.' (Margaret, Enterprise officer).*
>
> *'There's lots of people sort of tip-toeing around the edge of projects, but to actually sign the deal, to do the procurement, to spend the money to make it happen. It's about risk and sort of being concerned that you're not starting from scratch again with some sort of pathfinder project, but – no, no, no this is*

something other people do, it makes sense, you're not taking a leap into the unknown' (Susan, government officer).

In effect, none of the large organisations wishes to take responsibility for leading such development, when the veracity of the technical-economic evaluations of DH is itself contested and is secondary to potent competition and finance instruments embedded in complex legal frameworks acting to reinforce conventional autonomous energy provision. The NHS, university and government agencies have not in other words managed to identify the 'hinge' that would reward their different objectives (Abbott, 2003) through creating a shared district heating system.

West City

May 2012, a meeting, hosted by one of West City's universities, is held among a group of "stakeholders" to hear presentation of a feasibility study from an international engineering consultancy, and to discuss transition to the next stage of project development. In addition to the team of consultants, participants paralleled those involved in the East City case described above: the local NHS board, two universities, a further education college, the city council (with various departments represented), government and one of its agencies responsible for carbon management. In addition partner organisations of a city-wide sustainability initiative ("West City Future", or WCF), including one of the UK's major utilities, were represented.

In contrast with the East City proposal, the project discussed was largely a retrofit of district heating (though including the redevelopment of the further education college), and would involve breaking streets rather than installation with green-field development. All partners had contributed money to fund the study (with the government agency matching funding). Partners' involvement was voluntary, though the specific project was framed by the broader WCF initiative, which aims to meet ambitious sustainability targets through a multi-sectoral partnership model. The WCF partnership had identified district heating as central to city-wide energy and climate goals, and the project discussed here was one of a handful of opportunities being considered. Being the most centrally located possibility it was dubbed the West City Centre Cluster (WCCC). The specific analysis presented by the consultants was a more detailed analysis of an opportunity that a previous consultancy had found to be marginal. At 16.6 kt CO_2 per year, the new study estimated a communal heat network would achieve almost five times the carbon abatement of the earlier analysis, would require twice the upfront capital (£14m) but payback a year and a half faster (8 years vs 9.5) and achieve an internal rate of return described as "commercially attractive" and twice as high as the previous study.

By 2014 discussions about a WCCC heat network were ongoing. With the exception of the city council, all of the public sector organisations in the WCCC had explored onsite CHP schemes and were at various stages of development. These undermined the configuration presented in 2012, though (through studies conducted by another consultancy) ideas of a multi-organisation system, now drawing in other heat users including social housing, were still being discussed.

The right kinds of heat users

The city-wide WCF initiative was led by the city council and one of the city's universities (principally as a centre of knowledge and expertise rather than major energy user), and initially counted as partners two of the UK's major utility companies, a government development agency, a New York based Investment Bank, and the energy services subsidiary of an international municipal-services contractor. The initiative conducted an audit of the city's energy use and greenhouse gas emissions, set ambitious targets to combine emissions reductions with urban regeneration and economic growth, and proposed a series of projects in the city that would meet these targets. While projects were described at a high level in the initiative's launch document, they were positioned as being technically and financially integrated. Heat networks would form the backbone to a series of local energy initiatives, taking heat from industries and CHP stations, themselves fuelled by a combination of fossil fuels and renewables, some of which would be locally sourced. Financial integration would depend on aggregation of projects with different financial characteristics, such that an overarching trust could use near term returns of some projects to support investment in longer term propositions, while offering attractive returns to the public and private investors providing capital. The initiative envisaged mobilising £1.5bn investment and drawing a significant share of the UK Government's financial support mechanisms into West City.

The WCF initiative's identification of near-term heat network retrofit opportunities was based on the concentration of heat-related emissions and the presence of the "right" kinds of customers (particularly large commercial and public sector organisations envisaged able to anchor networks over a long period). The WCCC cluster also initially included high rise social housing, a shopping centre and local heat-intensive industry. A series of meetings was organised by West City Future, bringing together heat users in the cluster area to discuss possible integration into a heat network. However, marshalling these organisations into the collective actor imagined by the initiative proved difficult. The exploratory nature of these meetings made it difficult for West City Future to make a clear offer to potential partners,

which led to some of them, particularly commercial organisations losing interest:

> *'someone pulled out a map of West City and saw [commercial building] fills up four blocks and they thought, woar, we'll have them! […] You don't get a couple of city centre business together and just say, we're going to start putting a pipe network underneath West City and start selling gas, but that's what it was like.' (Bill, commercial building facilities manager)*

In 2011, the government agency commissioned a scoping study based on energy demand in the area. The study was relatively high-level, and sought to arrive at an order-of-magnitude cost for the heat network and identify any obvious technical, financial or environmental barriers to its implementation. However, in the wake of UK government policies of fiscal retrenchment, the future of the government agency was cast into doubt, as were the finances of the local authority, and development of the WCCC heat network began to drift. Public sector participants looked to the council to lead the process but perceived them to be more interested in other projects.

The alignment of local organisations around the initiative was further strained by closure of one industrial plant, and organisations pursuing their own heating renovations. The high-rise social housing, part of the portfolio of a large housing association in the city, was scheduled for reinvestment, and replacement electric heating installed precluding a heat network in the near term. Public sector organisations in the area had been developing their own sustainability strategies independently of (and pre-dating) the city-wide strategy. Following adoption of legally binding national carbon targets, these strategies were growing in importance. One of the universities had developed proposals for its own campus-based CHP and secured an offer of government grant funding. The facilities managers at the university understood their institution to be committed to "the common weal" and pressed the West City Future initiative to make progress on the heat network proposal, going so far as to organise and host further meetings of the cluster of organisations. However, by common consensus the joint approach would be too slow for the grant funding deadline, and the university went ahead with its onsite solution, making its connection to a communal system less attractive (in the consultants' report, the communal system would achieve a higher rate of return if the university did not connect).

The sociotechnical configuration of the heat network under discussion therefore shifted around through the process. Technical and economic analyses, rooted in the local distribution of energy demand were important in faltering formation of a multi-organisation *agencement*, but so too were a range of economic and social contingencies which brought buildings and

organisations in and out of the process at a pace faster than the project could be developed.

> *'If we had got our act together, which would have been pretty difficult, all the players were all at the same stage. At one stage we were all at the same stage. We've all went off on our own […]. If you were building a new city it would be easier, wouldn't it? But because we've all got different aspects it's going to be difficult.' (Peter, facilities manager, university A)*

Whereas the international partners in the WCF process had established an image of financially and technically integrated systems which could be packaged as an investment opportunity, the coherence of this bundling found no basis in the actions of local organisations. Instead, these were left to self-organise through a process in which support and encouragement, but limited direction was given by WCF, local or national government.

Collective optimisation? Best value and different images of an economic actor

The detailed feasibility study presented to the partners in May 2012 included an outline business case for the combined proposition, as well as indications of the benefits to each partner individually. The business case structured the initiative as a financial package, calculating costs and revenues incurred by a putative economic actor over 25 years, and using standard technical devices based on discounted cash-flow analyses to establish whether the proposition would be sufficiently attractive to finance providers. The study suggested three types of Energy Services Company (ESCo) that could be configured around this financial package: privately owned, municipally owned or a municipal/private joint venture. Heat users would engage with this entity as retail customers. However, the perspectives of participants at the feasibility presentation varied considerably. Whereas the consultants' report envisaged all users being charged the same rate for heat supply, participants in the meeting immediately began questioning whether their involvement was subsidising the benefit derived by others. In part the difficulty stemmed from the fact that at the time different organisations faced different heating costs due to the different technologies and energy tariffs they were currently using. The hospital, whose current heating costs were calculated as lowest, was presented with *zero* saving in heating costs. Furthermore, the consultants suggested locating the energy centre on the hospital site, and while noting this would imply demolition of a building and use of land with potentially high value, these were not factored in to the costs and benefits presented. The benefits allocated to the hospital were discounted electricity and GHG emissions savings (which, via carbon charges, translated into financial savings). Estimated financial savings for the hospital were higher than for other partners, but the second highest financial saving accrued to one of the universities. Here financial savings were about 10% lower than at the hospital,

in spite of the university only using less than a third of the heat the hospital required.

The details of these relative benefits and the reaction of the participants in part reflect the absence of a regularised standard of fairness in allocating costs and benefits in this kind of communal scheme. For example, the consultants made the decision to allocate GHG *savings* from the overall scheme to different organisations in proportion to the amount of energy each took from the scheme, whereas an equally defensible position would be to so allocate *emissions*, or to weight heat and electricity differently, each option having considerable impact on how emissions would be accounted. What would a fair outcome look like? Two approaches to establishing a model which all would consider fair were mentioned in interviews. First, an outside ESCo could step in to operate the system and take responsibility for constructing an offer to each subscriber which would then be judged on its own merits. While this was closest to the economic actor envisaged in the consultants report, WCCC stakeholders regarded as unlikely the prospect of, as one put it, "Joe Blogs energy company" saying "we'll invest in the whole scheme and supply whoever puts their hand up." Rather they considered it more likely that each would have to provide at least a proportion of the scheme's finance themselves in order to demonstrate commitment attractive to outside investment, and to give heat users a greater degree of control over the system. That is, the economic actor would have to be collaboratively constructed by the partners. This both heightened the issue of fairness and raised the prospect of a protracted process of negotiation among the system's users.

Concerns about fairness among the facilities managers involved were conditioned by the mechanisms within which they routinely operate, structured around the notion of "best value" from public expenditure:

> *'Because of the tendering process, etc. etc. everything we buy now has to be justified. It's got to be 'is the taxpayer getting value for money?' Hence why we've got [a public sector procurement club] getting involved with [energy] contracts etc. etc.' (Peter, facilities manager, university A)*

For gas and electricity procurement all stakeholders were party to the same joint procurement process, designed to use the purchasing power of the public sector to drive tariffs down. While the procurement club was common, the tariffs it offered to different organisations varied as suppliers bidding for the overall contract differentiated between different users. This, therefore, established one set of standards against which the communal system was to be judged, and while the consultants' report had sought to demonstrate *some* value to each organisation of participating, it wasn't able to pre-empt what configuration would constitute *best* value for each organisation. The outcome

of a negotiation of how costs and benefits would be allocated could not be foreseen, but perhaps more pressing for facilities managers was concern whether assumptions made in the feasibility analysis, particularly on long term energy prices, would be borne out. The possibility of committing to a system whose costs proved higher than continuing with standard energy procurement created both financial and reputational risks:

> *'[A freedom of information request could reveal] you were paying x before, now you're paying x+10, who thought that was a good idea? Then your name's all over the papers about squandering…' (Robert, estates manager, university B)*

> *'At the end of the day, if the press gets hold of it, the press just tears these things to shreds and blows them out of proportion' (Graham, estates manager, NHS board)*

In contrast, the reverse counterfactual, that costs within the procurement club would exceed those of the communal system, such that *not* developing such a system would result in higher costs, was not presented as a cause for concern. Deviation from the procurement club model would mean perceived inefficiency would be blamed on the organisations (or even the facilities managers) themselves. Within the procurement club, the club itself would be the site of responsibility for achieving "best value". Whether the procurement club *actually* achieved better value to its participants than alternative arrangements was, however, subject to some dispute. Some facilities managers cited ancillary benefits such as bureaucratic advantages (including less pressure on facilities managers). However, whether a relationship between models of energy procurement and cost could be demonstrated was subject to debate:

> *Neither you nor anybody else in this world would be able to demonstrate that's produced better prices. However, there are plenty of diagrams and calculations to show how much money's been saved. But, let's say we save forty million, where's the forty million? Is that going back into the economy? It's all notional savings. Whereas if you buy ten business cards it will cost you a pound, if you buy a hundred thousand business cards they may cost you a penny each, and you can do that. I don't think you can do that with energy, because energy prices will go up, come down, so therefore, so we're paying less now than we did last year, or the year before, so why is that? Is that because it's a procurement exercise, or the market going down. And you're paying more, so is that because of procurement or because the market's gone up. And of course, I'm oversimplifying it, because there are far more factors that actually make the difference to what you actually pay. (Robert, estates manager, university B)*

In this context of uncertainty in future costs, continuation within the procurement club therefore could more easily be regarded as "best value".

This was not because a comparative techno-economic analysis demonstrated this, but because the "best value" question could be passed from the individual organisation on to the club, where it would be answered by theories grounded in dominant ideas about competitive markets.

This structural conservatism, while an important issue and contributing to hesitancy among participants, did not override other concerns. WCCC public sector participants recognised that failure to exploit opportunities to contribute to GHG abatement and City West Futures' vision would carry cost, both in terms of the non financial values perceived to comprise their motivations, and in terms of political costs of failing to support local and national government aspirations. However, as the process of developing a communal system carried on, the partners began to examine *other* ways in which similar objectives could be met.

Development of onsite solutions – asynchronous development

Following presentation of the consultants' report, the hospital, perceiving the capital costs of the communal system to be disproportionate to its benefits, commissioned a further report, comparing onsite CHP with the communal system. The consultants responded with a proposal one third the capital cost of the communal system, considerably higher financial return and carbon savings around 40% of the original scheme, though lower than the carbon savings *allocated* to the hospital in the communal feasibility analysis. Furthermore, an on-site solution was not encumbered with ambiguities as to how costs and benefits would be shared across users or a new economic actor. Instead, the upfront costs and combined savings could all be allocated to a single actor (the hospital), and risks associated both with running pipes through the public realm and the participation of other organisations, were eliminated.

As noted above, one university secured grant funding to reduce carbon emissions early in the exploration of a communal system. The other university, building on the understanding of CHP it had developed through engagement with WCF, also bid to the same grant funder. These on-site approaches to carbon and energy saving were not pursued as means to undermine the communal system, but as ways of increasing the value captured by each organisation (particularly through access to electricity generated from CHP) while reducing the risks they perceived in working together. Indeed, each on-site scheme was designed to be compatible with a future communal network.

On-site approaches were found to be more straightforwardly compatible with financing possibilities, particularly financing mechanisms designed to

support public sector decarbonisation, with different mechanisms for different parts of the public sector.

> *'Because [the grant funder] is giving the cash to ourselves it needs to be ring fenced around, [the grant finder] can't be giving us money to enable somebody else. (Michael, carbon and energy manager, university B)*

Furthermore, public sector finance designed to stimulate action on sustainability tends to exacerbate the difficulty of coordinating action across neighbouring organisations.

> *'Clock is ticking, usual government criteria is 'here's a lot of money and the key criteria is you need to spend it by a deadline' – it's the reality of public sector funding.' (Michael, carbon and energy manager, university B)*

Thus the temporality of investment for these organisations was not conditioned by their relationships with each other, but by the narrow windows of opportunity that opened and closed according to processes outside the locality. For example, funding for carbon reduction in the higher education sector became available because of perceived limited progress on sustainable energy in that sector: thus the opportunity for the local universities to mobilise finance were conditioned by expectations of, and progress within, the national higher education sector, not their relationships with their geographical neighbours and not the economic rationales embedded in either the consultants' report or the West City Future vision of financially and technically integrated systems development. In a parallel with the temporal constraints created by procurement rules in the East City case (i.e. procurement would allow only a narrow window, the initial tender specification, to insert a communal system), the scope for alignment of windows of opportunity at a local level are thus highly constrained. Conceived as sociotechnical *agencements*, the units that would be combined under the imagined communal system are only partially local: their temporal dynamics are equally embedded in national and international processes.

Development of onsite solutions – the right users in the wrong roles

The interaction between onsite CHP development and the prospects for a communal system are subtle. In some respects, onsite CHP is positioned as a precursor to a communal system, particularly where a group of buildings within an organisation are reconfigured from individual boilers to a campus network, reducing the complexity of integrating the group into a communal system in future. Indeed the WCCC partners developing on-site CHP incorporated future connection into their designs. However, linking these campus networks together would create a considerably different configuration to the communal system envisaged in the consultants' report. Rather than being heat customers, facilities managers saw a communal

system as creating opportunities to dispose of surplus heat. Onsite generation of electricity was considered to be of higher value than heat, creating pressure to run CHP systems even when onsite heat demand can't absorb production:

> *'our question is how big do you put in? The bigger the CHP unit you put in, the more electricity you generate which is where all of your financial savings come from but then you have a hell of a lot of heat you need to get shot off. […] It's worthwhile for us to over-aim the size of the CHP slightly. There's a financial benefit to us, even if we just dumped all of the heat into the atmosphere, you know, you reach a break point once you get past a certain size that allows you to generate electricity a lot more efficiently and you get a lot of benefits.' (Michael, carbon and energy manager, university B)*

The shift from sites of heat demand to sites of heat production changes the role of these organisations in the network envisaged by the West City Futures initiative. Large heat users anchor network development to the extent that they represent large and reliable opportunities to provide heat. The scale of their heat demand means the differential between low input costs and the sale price of heat creates revenue which is both large and predictable enough to cover the high capital costs of the infrastructure. In contrast, preferring to use their onsite CHP, the WCCC organisations would take heat from the network only to make up their shortfall, meaning both a lower level of demand and greater concentration in (and sensitivity to) the coldest months of the year. A communal system could take surplus heat from these organisations to other users, but this would imply that, rather than the system being anchored by the large users and extended to smaller ones, the financial model would be dependent on a large number of smaller users simultaneously forming a market for the large users' surpluses. Whereas the consultants' analysis of a communal WCCC system presented the cost of an interconnecting network as justified by heat sales, it became far less clear what financial logic could support interconnection of on-site systems.

> *'we pitched [the grant application] right up to interconnecting the entire city centre network and [the grant funder] came back and said 'well […] it's going to cost you an extra four million or six million pounds to put this network out to the wider partners. That's not the point of this project and we're going to need the boundary a little bit closer to our campus.' Which I think is the correct thing to do but it still leaves this question of if the NHS have their system, […] and we have our system here and there's four million pounds worth of interconnection work that needs to happen in between them, who is going to pay for that? That's an interesting question.' (Michael, carbon and energy manager, university B)*

Thus, rather than self-assembling a system that is technically and financially integrated as the WCF initiative had envisaged, the WCCC organisations, each pursuing its own metric of "best value", began developing separate systems, ensuring technical potential for integration but undermining the financial model of their integration. Ironically, by stimulating interest in localised energy production, the WCF set in train developments which raise the bar against which a communal system would be judged.

On the failure of an economic actor to assemble itself

From the perspective of the WCF intiative, the significance of the retreat from communal to single-site heating systems lies not so much in the comparative carbon savings associated with these two configurations, but in the lack of technical and financial integration which it positioned as central to its ambitious vision for energy transformation in the city. In a parallel with East City, a new waste incinerator is under development. Integrating the heat demands of the organisations in the WCCC on a communal system was envisaged as creating a site of sufficient heat demand to justify investment in connection to the incinerator. However, in practice, the development model for the WCCC system effectively relied on the self-organisation of an economic actor to plan and invest in the system. The absence of such an actor was clear to participants, none of which elected to lead a communal approach. One facilities manager explained this in terms of the weak relationships among the organisations:

> *'[The city council are] the ones everybody knows. The hospital don't know who we are. [… T]he reality is we've no real need to operate at this level together. […] For example, Carbon Trust, you know, training sessions, how to do an awareness… stuff like that. Yes, you'll meet people from NHS, you'll meet business, the reality is, other than that there's no need for us really to interact with the hospital. There's no real need for us to interact with the city council. There's no need for us to really interact with [university A] and even less with [West City Housing Association]. So, you know, we don't naturally sit together and all meet every week, if you know what I mean. So somebody has to bind all those people together, and you have to* ***bind*** *them together, […] first of all you have to force them to work together, and once you give them a common purpose, I think it will work, but it won't work naturally. We won't all come together.' (Robert, estates manager, university B)*

Discussion and Conclusion

Gaining the envisaged sustainability benefits of heat networks in the UK is dependent, just as the creation of any multi-user energy network infrastructure, on substantive change in the socio-technical infrastructures of both social transaction arrangements and physical hardware. This notably

includes the formation of new user-supplier relations, regulatory instruments and heating practices as well as embedding of new material infrastructure. Initial project development relies on cross-sector coordination of complex actors around a common spatial and financial plan, governance structure and timetable. Parties have to agree the allocation of shares of responsibilities or risks, and associated costs and benefits, which has historically proved highly demanding, even when policy instruments are directly supportive (Summerton, 1992). Heat network infrastructure creates long-term interdependencies between heat providers, distributors, retailers and users, all of whom can shape the degree to which cost, carbon and energy saving are delivered in practice. In these cases, such interdependencies are framed as risk rather than benefit, and during the time a collaborative solution was being sought individual organisations began investing in their own heating systems in ways that served to weaken the viability of the shared initiative.

Our case studies show striking parallels. At a basic level, similar casts of organisations were involved in each city, plans were produced, supported in principle, but undermined by development of on-site energy efficient technologies. More specifically, in both cases a potential heat network was presented through techno-economic assessments which cast it as advantageous to both users and investors, but which left underspecified what form the economic actor arranging the heterogeneous elements of the system would be. Such an economic actor could, conceivably, have spontaneously emerged through voluntary negotiation once the opportunity and the user organisations had been identified, but such coordination proved excessively difficult.

Each party to the project at East City and West City, and to the notional development of an economic actor capable of collaboration in energy supply for sustainable heating, is simultaneously party to the economic agency of regulatory and legal requirements of competitive contracting and market commissioning of public services, and is one of the components of other complex actors in the higher education sector, the health service, the governments of the UK and so on. Each party brings considerable skills and resources to the pursuit of the technical-instrumental rationalities of, investment, and public finance accountability. Such instrumental rationality as currently configured serves however to weaken, if not undermine, the systemic rationality of collaborative action to address the societal problems of climate change and future energy provision. This happens in several ways:

- Technical mechanisms instituted to ensure "best value" in the use of public finance focus on the elimination of potential inefficiencies in the public sector, and course through structural hierarchies organised on the basis of the public sector as a whole, functional sectors (health,

tertiary education, etc.) and individual organisations. To the extent that spatial relations structure these mechanisms, they operate over regional scales rather than cities or districts. In Le Galès' (2002) term, the extent to which cities are *incomplete societies*, composed of social actors for whom the city is just one level at which interaction takes place, is partially constituted by the form and technicalities of "best value" mechanisms. These are embedded, not in the immediate neighbourhood, but in the international markets for hospital construction, in the European Union rules on procurement, and in sectoral funding programmes. While national and city-wide techno-economic appraisals see financial and environmental value in communal heat provision, the technical mechanisms (feasibility analyses and business models) which seek to translate these into established structures of "best value" are too weak to overcome the countervailing effects of short-term, individualised contracting rules and timetables, and other constraints on the use of public finance. These limits confound a collective solution both by narrowing windows of opportunity which must be aligned among organisations and by narrowly determining what benefits (i.e. only those accruing to individual organisations) can legitimately be used to justify expenditure. Thus the rational economic market actor exemplified by the individual utility-maximising decisions of each party produces the irrationalities of incapacity to act in coordination.

- The corporeality of humans involved in these technical devices also creates a conservative force towards continuation of current energy arrangements. The inscrutability of the cost advantages created energy procurement mechanisms means that, rather than being adopted on the basis of a hypothesis about their effectiveness (which human limitation would preclude testing of), their effectiveness is treated as axiomatic. Thus a communal system in comparison has a different mode of legitimacy than participation in a procurement club: an organisation committing to a communal system is exposed to reputational risks that are absent under the procurement club, creating pressure to stay within the club irrespective of the prospects for cost savings. In quite different form, human limitation is expressed in the difficulties re-opening PFI contracts: significant effort would be required to coordinate multiple investors consideration of reconfigured energy supply.

Thus the *materiality* of established public sector financial and energy management in the UK, predicated on the power of market and market-mimicking mechanisms to flexibly and efficiently allocate scarce resources, exert a series of pressures against local integration into new communal

systems of energy provision. This happens in spite of evidence that such systems would contribute to organisational, as well as societal, interests in energy and carbon saving, even when this evidence is formatted by the same analytical devices (such as time discounting) that are used to justify established decision making routines.

Central government's declaration that "[we are] not going to build [cities'] heat networks for them, clearly" is echoed by all parties in our case studies. This constraint, requiring effectively the spontaneous formation of an economic actor out of the alignment of narrow windows of opportunity across multiple complex organisations, helps explain limited district energy development in the UK. Experienced district energy practitioners note "we are awash with feasibility studies" unmatched by actual network investments (Hawkey, 2013), and where heat networks do develop they are characteristically smaller and more fragmented than elsewhere in Europe (Wiltshire et al. 2013).

In these circumstances governments need to do more than marginally modify financial calculi (for example by taxing carbon) and revealing potential projects through heat mapping and feasibility studies, important though these interventions are. If governments' aspirations for heat networks are to be realised, they will need to both assist in offsetting the counter-rationalities of technical "best value" mechanisms and contribute to conditions under which at least *some* economic actors find creation of multi-user heat networks as crucial to their objectives, rather than hoping for spontaneous coordination. We have observed examples of the latter process in European case studies, where heat networks have been developed as solutions to industries' "excess heat problems," themselves created through regulatory pressures (Hawkey and Webb, forthcoming).

In the UK, there is as yet no answer to questions about the configuration of an economic actor for sustainable heating with capacities most likely to support and sustain development of a low energy, low carbon, affordable and secure system, and the common interests of societies in avoiding dangerous climate disruption.

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