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Designing urban knowledge: competing perspectives on energy and buildings

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Abstract. The author engages with debates about buildings, energy efficiency, and the innovation process—issues that are of great significance for urban sustainability because buildings are such an important constituent of urban energy consumption. Within this context, the author explores what it might mean to develop an interdisciplinary understanding of technical change. Questioning conventional accounts, he develops a sociotechnical perspective on competing energy knowledges and contexts of design, development, and consumption. It is argued that energy research and policy-making for the built environment is underpinned by a common understanding of technical change, which fails to take account of the contextual nature of energy-related choice. Describing cultural, organisational, and commercial factors shaping technological innovation, the author explores how more-or-less energy-efficient choices influencing urban development are made in response to changing opportunities and practices which sometimes favor energy efficiency, sometimes not. The author draws upon sociological accounts of technical change and illustrates both a sociotechnical perspective on energy and buildings and a key role for sociologists in the field of architecture, energy, and environmental studies.

1 Introduction

> "... those who call ourselves energy analysts have made a mistake ... we have analysed energy. We should have analysed human behavior."
>
> Schipper (1987; quoted in Lutzenhiser, 1993, page 247)

> "A renewal of social theory which informs energy consumption and conservation is called for in the face of environmental challenges."
>
> Wilhite (2001, page 331)

The challenge of mitigating and reducing the energy consumed in cities is commonly cited as a key policy objective at local, national, and international scales. In a typical recent statement, the United Nations Environment Programme (UNEP) points to the "uncontrollable pace of urbanisation, and a consequent rise in energy demand ... leading to greater emissions of green house gases".(1) According to UNEP, there is an "urgent need for the incorporation of energy efficiency issues to be included in urban planning and construction." Of course, this is hardly a new policy issue. Debate about energy, buildings, and cities has been around for many years, periodically leaping to the front pages stimulated variously by worries about shortages, security, safety, and pollution. As a result, we already possess immense knowledge about energy efficiency and conservation in buildings and cities. In particular, the contribution of building scientists to our knowledge about energy-efficient buildings is substantial. Energy-saving technologies and materials have been successfully developed and manufactured, energy-efficient building designs have been constructed, tested, and widely publicised. In fact, for some time we have possessed the technical knowledge and identified the best-practice design techniques necessary to construct zero-energy buildings. Moreover, extensive monitoring of local, national, and international building stocks means

(1) See: http://www.unep.or.jp/ietc/Activities/Urban/energy_city.asp.

we know more than ever before about the precise potential for improved energy performance. But, having perfected energy-efficiency technologies, it seems we still possess relatively little knowledge about why apparently proven technical knowledge is often ignored in design and development practices, and why architects and occupiers alike consistently fail to adopt energy-saving techniques. In the face of the "inadequate diffusion of apparently cost-effective energy-conserving technologies" (Jaffe and Stavins, 1994, page 2), the knowledge provided by building scientists must be supplemented by exploration of the nontechnical processes of technology transfer, which raises the complex question of consumption.

Many researchers, like Schipper and Wilhite quoted above, have questioned the notion that the challenge of improving the energy efficiency of buildings is simply a task for building science, a "term now widely used ... to describe the growing body of knowledge about the relevant physical science and its application" to buildings (Hutcheon and Handegord, 1983, page 4). Across international boundaries and research cultures, the common aim of building science is to produce "more and better knowledge about buildings and how they perform" in order to "identify promising solutions" to the problem of energy inefficiency (Hutcheon and Handegard, 1983, page 432). The critical issue here is the definition of 'better knowledge' about building performance and the subsequent identification of problems and solutions within a scientific, or what we might term a techno – economic paradigm (Guy and Shove, 2000). As with other branches of physical science, it is "the reactions of materials and other inanimate objects (that) are the legitimate interests of the building scientist" (Hutcheon and Handegard, 1983, page 4). Like problems of rain penetration, fire safety, or structural soundness, the issue of energy efficiency in buildings becomes defined as a technical problem amenable to scientific methods and solutions. The belief is that proven technical solutions are transferable and readily applicable to other technically similar situations. Consequently, the research agenda of building science is geared toward the scientific resolution of what are taken to be physical problems. Energy efficiency is no different. As Lutzenhiser has pointed out, energy-management strategies have "focused almost entirely on the physical characteristics of buildings and appliances" (1993, page 248). Vast sums of money have been, and continue to be, invested in scientific research to identify and fulfil (at least experimentally) the technical potential for energy savings in buildings.

2 Theories of technical change

Acknowledgement that an "actual improvement in buildings has not always matched growth in knowledge" (Hutcheon and Handegord, 1983, page 7) has led to the realisation that "building scientists must appreciate the contribution of the life sciences" (page 4). What is meant by the 'life sciences' in this context is often a little vague. However, the most natural fit has proved to be between building science and economic theory, rather than disciplines like sociology, anthropology, geography, or political science. This may be because economists tend to reinterpret social processes in terms of a market arena which neatly divides the world into separate, but interlinked, domains of knowledge and action. On the one hand, a world of perfect information and on the other hand a definable logic of (utility-maximising) rationality is posited. The elegance of the economic approach, as Hope and Owens (1986, page 852) observe, is that under perfect competition and if households and firms are left to their own devices, "the optimal combination of things corresponding to the distribution of wealth in society will actually be produced." This economic confidence in the capacity of individual decisionmakers to quantify the benefits of energy efficiency is central to the techno – economic view of technology transfer. The ability of building users to, literally, count the costs of energy consumption will ultimately lead to more rational energy use. This approach has found eloquent expression in the field of energy economics, and the use of energy audits which "enable the new user to cope with the complex conversion equations and calculation of energy costs per standard unit" (Chadderton, 1991, page 20). The link to economics is explicit:

> "An energy audit of an existing building or a new development is carried out in a similar manner to a financial audit but it is not money that is accounted. All energy use is monitored and regular statements are prepared showing final uses, costs and energy quantities consumed per unit of production or per square metre of floor area as appropriate. Weather data are used to assess the performance of heating systems. Monthly intervals between audits are most practical for building use, and in addition an annual statement can be incorporated into a company's accounts" (Chadderton, 1991, pages 20–21).

This model of rational action suggests that financial and energy consumption-related decisions are comparable, and that business and domestic users alike are self-interested, knowledgeable, and economically calculative when considering energy measures. Business users in particular, "skilled at marginal cost and future calculations", would "only seem to need to see the potential competitive economic advantage of innovation to move towards energy efficiency" (Lutzenhiser, 1994, page 868). Following a similar logic, the development of a visible market for energy efficiency would, in turn, encourage domestic consumers to minimise their costs by substituting more efficient ways of satisfying needs for energy services such as heating, cooling, or water heating. Here, the methodological presumption of building science—that, with careful monitoring and scientific control, it is possible to reproduce the technical achievements of the laboratory universally—is mirrored by an economic logic which promises that technological potential will be fulfilled in any market situation that demonstrates a "static, intertemporal and intergenerational Pareto optimality" (Harris, 1983, page 46). Put simply, the view is that economically rational actors, replete with the necessary technical and economic information, will consistently put science into practice. As Hinchliffe puts it, "a rational, profit maximising man is visualised at work, at home and at play", while "the engineering model tends to picture humans as optimally utilising technologies after the fashion of their creators" (1995, page 94). This epistemological coalition of building science and economics has led, internationally, to a prescriptive view of technological diffusion based on the twin technical and economic logics of proven, replicable, science and idealised consumer behaviour. As a result:

> "a physical-technical-economic model (PTEM) of consumption dominates energy analysis, particularly in energy demand forecasting and policy planning. The behaviour of the human 'occupants' of buildings is seen as secondary to building thermodynamics and technology efficiencies in the PTEM, which assumes 'typical' consumer patterns of hardware ownership and use" (Lutzenhiser, 1993, page 248).

The techno–economic view of energy efficiency suggests that, if technical knowledge is rigorously tested and demonstrably proven, and if market forces are not "disturbed" (Jonas, 1981, page 101), then consumption choices should be made rationally, with the "right decisions being taken by millions of individual consumers, both at home and in their place of work" (page 105). The role of government is clear:

> "to set the background conditions and prices such that consumers will take decisions which are both in their own and the national interest" (page 101).

Thus "an ideal, rational and individual calculator is taken to be axiomatic in policy documents" (Hinchliffe, 1996, page 54).

3 Barriers to energy efficiency

This way of seeing technical change is not merely a matter of the attitudes or perceptions of individual policymakers. Rather, it provides an organisational logic or operating principle upon which energy research and policy proceed. As Burgess has argued, both "ontologically and epistemologically, economics resonates strongly with the mind set of environmental policymakers" (2005, page 277). The result is an epistemic view of the research – policy interface as "an unproblematic, linear relationship in which the output from one process, the production of knowledge by disinterested experts, becomes the raw material for another, the making of policies and decisions by elected representatives and their officials" (Owens, 2005, page 288). The outcome of this view in policy terms is that human and financial resources are, almost exclusively, committed to a continual demonstration of the technical efficacy of energy-efficient innovation through the provision of information on technical means to reduce energy consumption and the development of best-practice demonstration schemes. So "the drive to provide individuals with information, either to 'create' responsibility or to affect consumption, underpins the choice of national policy mechanisms used to forward sustainable consumption issues" (Hobson, 2002, page 115). Hinchliffe (1996) illustrated this logic of "rational consumption, individualism and market wisdom" in his analysis of the UK government's Helping the Earth Begins at Home campaign of the early 1990s, illustrating how David Heathcoat Amory (the then Conservative Energy Minister) saw the government's responsibility as little more than assisting in the dissemination of information.

> "There is no doubt that every family can save on energy bills—both for themselves and for the country—and at the same time improve their home comfort. We shall be telling them how to go about it and where to go to get further advice."[2]

In this way, Hinchliffe argues, the government tied promotion of energy efficiency to a "logic of rational consumption, individualism and market wisdom" (1996, page 58). Trudgill (1990) has, approvingly, formalised this techno – economic way of seeing innovation in his formulation of the 'acknowledgement, knowledge, technology, economic, social, political (AKTESP)' barriers to the resolution of environmental problems. Trudgill presents an image of technological innovation as a path from ignorance to enlightenment, with the evils of social, political, and economic reality cast as unpredictable obstacles to an otherwise assured technical utopia. Critically, the key to overcoming AKTESP barriers is almost always located within individual motivations. As Trudgill puts it:

> "Motivation for tackling a problem comes from our moral obligation and our self-interest in enhancing the resource base and its life—thus enhancing, rather than destroying, planetary ecosystems and plant and animal species, including ourselves" (1990, page 105).

When such motivation arises we are in a position to solve the remaining barriers to the solution and implementation of environmental problems. The vocabulary of solution and implementation are similarly individualised: 'inadequacy of knowledge', 'technological complacency', 'economic denial or complacency', 'social morality/resistance/leadership', 'political cynicism/ideology'. Within this model of technical change, individuals are consistently the linchpin of effective energy-saving action. Changes in the level of energy demand of the built environment is seen as a process involving "thousands" of individual judgments by "property-owners and other decision-makers" (Olsen, 1988, page 17). The technical, organisational, and commercial complexity of energy-related decisionmaking is here replaced by an image of

[2] Quoted by Hinchliffe (1996, page 56).

'autonomous' actors each free to commit themselves to a more sustainable urban future. As Howard has argued:

> "there are lots of decision-takers. There are lots of people who have to be influenced, right from government to local authorities, developers, designers, material producers, professional and trade bodies. They all have a role to play. And what we have to do is try and influence all of them" (1994, page 14).

We are faced here with a self-sustaining, mutually reinforcing package of beliefs spinning between the realms of technology and policy without really belonging to either. Although policymakers and energy researchers would never acknowledge adopting such a perspective uncritically, it has proven powerfully resistant to critique (Guy and Shove, 2000). For Owens (2005, page 288), the "the most striking feature of this technical rational model ... is its sheer tenacity." Each element of the pervasive bundle—the transferability of technical knowledge, the individualistic theory of technical change, the sequential logic of research and development, the implicit distinction between the social and the technical—feeds into the next and provides a "powerfully intuitive appeal" (page 288).

4 Leaping the barriers

> "By defining what is acceptable as evidence, certain privileged methods also act to exclude other sorts of data. It is in this way that certain questions remain unasked, and certain types of evidence are ignored or dismissed as invalid."
>
> Leach and Mearns (1995, page 13)

Leach and Mearns's observations highlight how wide acceptance of the techno–economic view of technology transfer has hitherto marginalised explanations of technical innovation concerned with the social shaping of technical change. As Hilmo suggests, the notion of barriers suggests that "problems are absolute" and that "some actors" (that is, scientists) "know the truth about a problem", while "other actors" (nonscientists) "do not and obstruct the solutions in different ways" (Hilmo, 1990, page 124). Hence, the role of the social scientist is in turn reduced to that of market researcher, typically undertaking attitudinal surveys designed to identify the human barriers to good energy practice which the promotional campaigns outlined above are designed to overcome. Hinchliffe exemplifies such a link between the 1991 'Hedges report' on attitudes to energy conservation in the home and the design and development of the Helping the Earth campaign (Hedges, 1991; Hinchliffe, 1996, page 55), Such research has typically been described as exploring the behavioural or human dimensions of energy efficiency (Rosa et al, 1988). Drawing upon diverse intellectual sources from economic sociology to environmental psychology, such research shares a view of energy efficiency as the product of a slow cascade of more or less rational individual choices. Although Stern and Aronson usefully identify five archetypes of energy user (the 'investor', 'consumer', 'member of a social group', 'expresser of social values', and 'avoider of problems'), their narrow focus on the attitudes and motivations of individual energy consumers tends to isolate and atomise the decisionmaking process. We hear little in this research about the consumption practices of organisations, or the role of the organisational actors and groups who actually design, finance, and develop buildings. As Janda points out, although this approach "usefully delineates differences in individuals' attitudes, human dimensions research does not reveal where these differences originate, how they develop, or if they can be changed" (1998, page 31). In a recent review of intervention studies aimed at household energy conservation, Abrahamse et al similarly concluded that such psychological perspectives tended to focus "predominantly on changing (individual-level) MOA (motivation, opportunity, ability)-variables (for example, attitudes, abilities)" at the expense of "macro-level factors" such as "demographic or societal developments" (2005, page 283).

A key problem with the techno–economic perspective is that attitudes and decisions are always shaped and framed within wider social processes and, as such, are subject to change. Discussing attitudinal research in relation to impact assessments, Burningham (1995, page 110) notes that such "systematic variations in what is said cast doubt on the enduring and homogenous nature of the speakers supposed internal state." Abstraction of the opinions and outlook of energy consumers, and of design and development actors from the contexts of production and consumption, tends to isolate and freeze what are always contingent practices. This narrow behavioural view of technical change fails to recognise the routine complexities of energy-related decisionmaking. In particular, there is little room in this model to view technical innovations and social processes as interrelated, or to assess how energy-efficient choices may be embedded in the mundane routines of domestic life and commercial practice. As Owens puts it, "The problem is that the research/policy boundary that it portrays is barely discernable in the real world" (2005, page 288).

We can contrast the techno–economic way of seeing energy efficiency with an alternative view which we will term *sociotechnical*, which questions what Mulkay (1979) has termed the "standard view of science" which exists, already formed, outside society. In its place, a broad church of sociologists[(3)] have presented a revised image of science as a "socio-cultural phenomenon" which questions the "authority of science", locates "knowledge-claims in their social context", and identifies the "relationship between such contexts and wider economic and political processes" (Webster, 1991, page 14). This approach to understanding science and technical change can be characterised by a series of questions. Volti asks, for example, "What accounts for the emergence of particular technologies? Why do they appear when they do? What sort of forces generate them? How is the choice of technology exercised?" (1992, page 35). Rather than analyse the process of technical change internally, in terms of developments within the technology itself, or by reference to the ideas of famous scientists, inventors, and entrepreneurs, such research is interested in discovering to what extent, and how, does the kind of society we live in affect the kind of technology we produce? McKenzie and Wajcman have asked:

> "What role does society play in how the refrigerator got its hum, in why the light bulb is the way it is, in why nuclear missiles are designed the way they are?" (1985, page 2).

Questioning the notion that technological change "has its own logic" (page 2), this way of seeing technical change recognises the wider social contexts within which design solutions emerge and patterns of consumption evolve. Rather than viewing science and technology as "asocial, non-political, expert and progressive", innovation is viewed as a "contested terrain, an arena where differences of opinion and division appear" (Webster, 1991, page 1). In relation to the analysis of energy problems, such research avoids individualist explanations of technological innovation (the rational energy consumer), rejects any form of technological determinism (technical innovation as handmaiden to an energy-efficient economy), and, critically, refuses to distinguish prematurely between technical, social, economic, and political aspects of energy use. As Hughes has graphically illustrated, in exploring the development of the American electricity system, "sociological, techno-scientific and economic analyses

(3) For the sake of simplicity we are ignoring the different histories of the sociology of science and the sociology of technology. For a clarification of the links between each discipline, see Pinch and Bijker (1989).

are permanently woven together in a seamless web" (1983, page 16). In this world without seams, social groups and institutions are considered, alongside technological artefacts, as actors who actively fashion their world according to their own particular logic of social action. This sociotechnical analysis of energy use replaces techno–economic descriptions of universal barriers to energy-efficient innovation (apathy, ignorance, lack of financial interest), with analysis of the ways in which the changing social organisation of energy-related choices structures opportunities for more efficient energy use.

There are complementary methodological issues at stake here. Bridging the theoretical gap between the social and technical features of energy use demands a more qualitative research agenda. Rather than relying solely on positivist research tools, such as surveys, opinion polls, and statistical analysis, undertaking sociotechnical research means attempting to peer over the shoulder of the actors making energy-related decisions by following actors through their professional and personal routines. In this way research into energy efficiency finds itself on what Callon has termed "a new terrain: that of society in the making" (1987, page 83). This refocuses analysis away from pure energy questions to a wider set of debates about design conventions, investment analysis, development costs, space utilisation, and market value. Idealised notions, of a rational energy user or best technical practice, make little sense here. If we must view buildings as technical objects then we need to understand how they "participate in building heterogeneous networks that bring together actants of all types and sizes, whether human or non-human" (Akrich, 1992, page 206). Seen this way, the social and the technical form a network of associations that serves to frame the meaning of energy efficiency, thereby encouraging or delimiting opportunities for innovation over time and space, and between organisational settings.

5 Contexts of consumption

A significant amount of academic work has been undertaken which attempts to put energy use into its social context. Social psychologists and sociologists have emphasised the importance of seeing energy problems and solutions in terms of adaptive social systems, and, as Stern and Aronson (1984) argue, to treat energy policies and programmes as forms of 'social experiment'. Reviewing this work, Lutzenhiser found "a consensus in the literature" that to understand the sociotechnical complexity of energy-saving action, policymakers must concern themselves more directly with "the social contexts of individual action" (Lutzenhiser, 1993, page 262). As Lutzenhiser points out:

> "While the physical-technical-economic model assumes consumption to be relatively homogenous and efficiency to be driven by price, the empirical evidence points towards variation, non-economic motives, and the social contexts of consumption. Economics can supply normative guides regarding when investments would be economically desirable, but it tells us little about how persons actually make economic decisions" (page 269).

Wilhite and Lutzenhiser draw attention to the social nature of energy consumption and the social dynamics of change as a form of 'social load' (Wilhite and Lutzenhiser, 1998, page 281). These social loads have peaks which drive the dimensioning of peak energy loads. Wilhite provides examples from his anthropological research into lighting use in Norway. Here, home lighting is designed not simply to provide a sufficient degree of brightness to support basic human activity, but rather to provide a 'cosy aesthetic' (1998, page 283)—a dark house was described by Wilhite's respondents as a "sad house". Extra lighting fittings were always fitted and utilised to make sure guests feel cosy, and for social visits on a winters evening lights will be left on in every room to provide a welcoming glow as guests arrive. This of course means the use of extra energy. In his study sample Wilhite found an average of 11.5 lights per living room. This social peak "drives the dimensioning of the material and energy system behind lighting, which based on a straightforward provision of lumens would be far smaller" (Wilhite and Lutzenhiser, 1998, page 284). Wilhite argues elsewhere that "the things we use energy to achieve—a comfortable home, suitable lighting, clean clothes, tasty food—have also been assumed in models of consumption to be generic and physically determined". Wilhite goes on to argue that there is an "urgent need for the development of a more robust theory of consumption, one which incorporates social relations and cultural context, as well as perspectives on individual agency and social change" (2001, page 331).

6 Sociotechnical theories of change

In table 1 the two broad positions outlined so far are contrasted. The effect of these analytical assumptions is cumulative, with a techno–economic or sociotechnical view of buildings as an artefact leading correspondingly on to particular ways of seeing energy-efficient design, energy-saving action, technical innovation, or market failure. Commitment to either a predictable, linear, or socially shaped diffusion pathway for energy-efficient technologies frames the contribution of social science research to understanding innovation and the direction of energy policymaking in relation to energy efficiency and conservation in buildings.

These competing ways of seeing energy-related technical change in buildings raise a number of research dilemmas. Commitment to a techno–economic or sociotechnical perspective on innovation focuses our attention on different actors (key decisionmakers

Table 1. Ways of seeing energy efficiency in buildings.

	Techno–economic	Sociotechnical
Buildings	materially similar, physical structures	material product of competing social practices
Energy-efficient design	replicable technical solutions	outcome of conflicting sociocommercial priorities
Energy-saving action	individual, rational, decisionmaking in a social vacuum	socially structured, collective choices
Technological innovation	series of isolated technical choices by 'key' decisionmakers	technical change embedded within wider sociotechnical processes
Market failure	existence of social barriers	lack of perceived sociocommercial viability
Image of energy consumers	more or less rational	creative, multirational, and strategic
Role of social science research	evaluation of technical potential and the detection of environmental attitudes and nontechnical barriers	identification of context-specific opportunities for technological innovation
Energy policy	provision of information, granting of subsidies, and setting of regulations	forging of context-specific communities of interest, and promotion of socially viable pathways of innovation

versus relevant social groups), different practices (technical design versus development strategies) and different processes (technological diffusion versus social and commercial change). We are faced with a series of choices over how we conceptualise the problem of energy consumption in buildings.

As Groak suggests, we can view buildings in terms of their physical attributes, as "essentially static objects" formed in a relatively standardised manner from an assembly of interconnecting construction materials (Groak, 1992, page 6). Seen this way, buildings appear remarkably similar. Irrespective of geographical location, ownership patterns, or operational function, the technical character of building form appears comparatively homogenous. Alternatively, we could view buildings as material products of competing social practices. This would suggest a different analytical approach. For sociologists such as Latour, understanding "what machines are" is the same task as understanding "who the people are" who shape their use (Latour, 1987, page 259). Seen this way, technologies and technological practices are "built in a process of social construction and negotiation", a process driven by the shifting social, political, and commercial interests of those actors linked to the design and use of technological artefacts (Bijker and Law, 1992, page 13). Although the complexity of buildings differs from the individual technologies often studied within sociological studies of science and technology, we can, nevertheless, develop a similar analytical approach. Thus, to understand buildings we must trace the characteristics of the "actor world" that "shapes and supports" their production (Bijker et al, 1987, page 12). Adopting this perspective would mean relating the form, design, and specification of buildings to the social processes that underpinned their development. So, although two identical buildings, standing side by side, may well appear physically and materially similar, investigation into their respective modes of production and consumption may reveal profoundly different design rationales, which in turn might help explain variations in energy performance.

This stress on the social organisation of design is at odds with the techno–economic perspective which emphasises how a "repertory of well tried technical solutions" provides "reliable precedents for designers" (Groack, 1992, page 6). Here, new technical challenges are seen as solvable by shifts in design emphasis—mirroring the march of scientific progress. Although the form and specification of buildings may well vary spatially with climate and culture, the objective is always viewed as the same—the provision of universal needs of shelter and comfort. Technical design is viewed as a process of adaptation and modification to suit changing physical circumstances. Emphasising the social logic of design raises a different set of questions. Rather than supporting a linear model of innovation, studies in the sociology of technical change have revealed the multidirectionality of the technical design process. Rather than one preordained process of change, we are faced with competing pathways of innovation. Typically, Pinch and Bijker describe the "development process of a technological artefact ... as an alternation of variation and selection" (1989, page 28). For example, Bijker's study of the development of fluorescent lighting points to a range of innovation pathways that could not be resolved by appeals to technical superiority. Instead, a stand-off between lighting manufacturers (who supported a high-efficiency daylight fluorescent lamp) and electric utility companies (who, worried about the effect on electricity sales, supported an energy-intensive tint-lighting fluorescent lamp), led to the introduction of a third design alternative—the high-intensity daylight fluorescent lamp which combined efficiency with a high light output, thereby maintaining electricity demand. Bijker's study illustrates how a socially optimal design was derived from a range of technically feasible possibilities through a process of compromise between competing social interests. In doing so he highlights the "interpretative flexibility" of design (Bijker and Law, 1992, page 97). We might similarly ask how rival energy efficient designs are valued by different members of the design and development process, and how this process of contestation and compromise frames the resulting design strategies.

In approaching these questions we might begin to draw attention to the idealism surrounding the techno–economic image of enlightened, rational individuals motivated by a growing stock of technical knowledge. Although these more, or sometimes less, knowledgeable individuals are placed in a hierarchy of influence—from the key decisionmakers to designers and top managers, to technicians and lower management, to domestic consumers—their social, spatial, or temporal situation appears of marginal importance. From a sociotechnical perspective the relationship between individual and context is emphasised and made fluid. Particular technical choices are viewed as expressive of the prevailing social, political, and commercial pressures operating within spatially and temporally contingent contexts. Here, technical choices are not considered to be determined solely by knowledge or motivation but, rather, are shaped by the existence of a more or less socially favourable context. For a variety of reasons, consumers may be unable or prefer not to use particular technologies, or may even use technologies in unpredictable ways not envisaged in the original design. To understand this social structuring of technical choice, Cowan, in her history of home heating and cooking systems in America, treats the consumer "as a person embedded in a network of social relations that limits and controls the technological choices that she or he is capable of making" (1987, page 202). For Cowan consumers come in "many different shapes and sizes", and operate in a variety of social contexts (page 203). Her analysis of the introduction of cast-iron stoves to replace open hearth fires for cooking traces the interconnections between stove producers and merchants, fuels suppliers and merchants, and their networks of influence through production, wholesale, retail, and household domains over both urban and rural consumers. This emphasis on the embedding of the decisionmaker within wider social networks focuses analytical attention on the "place and time at which the consumer makes choices between competing technologies" (page 203). This allows Cowan to unpack the "elements" more "determinant of choices" and the technical pathways which "seemed wise to pursue" or which appeared "too dangerous to contemplate" (page 203). As she points out, "Today's 'mistake' may have been yesterdays 'rational' choice" (page 201). Drawing upon this approach, a sociotechnical perspective on energy efficiency might identify the shaping innovation of multiple rationality and how these relate to the contrasting 'universe of choice' in which design and development actors operate.

If we begin to accept that the nature and direction of technical change are subject to interpretative flexibility, underpinned by multiple rationalities of context-specific choice, then we would also have to begin to alter our understanding of the process of technological innovation. As we have seen, the techno–economic perspective views technical change as following an almost pre-ordained pattern of design, development, and diffusion. By contrast, a sociotechnical analysis would explore why particular technical solutions emerged at a certain time and in a particular place. For example, in studying the electrification of cities, Nye (1994) illustrates how the emergence of streetlighting was less connected to the rational technical ordering of urban space, and more intimately linked to the need of utility companies to increase load and the commercial instincts of shopkeepers keen to attract business. Nye suggests that "shopkeepers understood lighting as a weapon in the struggle to define the business centre of the city dramatising one sector at the expense of others" (1994, page 178). Framed this way, "electric lighting could easily be sold as a commercial investment to increase the competitiveness of a business." As a result, the subsequent spread of street lighting was accelerated as "electrification of one street quickly forced other commercial areas to follow suit or else lose most of their evening customers." Following this lead, a socio-technical analysis of energy efficiency would ask what roles were played by architects, developers, governments, investors, manufacturers, retailers, and consumers in fashioning innovation in building design and use. This approach would mean widening the nature of analytical enquiry away from explicit decisions about energy efficiency studied in isolation, to an examination of the embedding of energy-related choices in the manufacture, distribution, and retailing of the technologies themselves, and the commercial processes framing building design and development.

Finally, asking different questions about the process of technical innovation may provide a different understanding of the market success or failure of proven energy-saving technologies. Instead of characterising nontechnical barriers as both universal and timeless in nature, a sociotechnical approach would explore the degree to which the marketability of technical innovation can be identified as a socially, and temporally, contingent process. For example, Cooper highlights how the seemingly pervasive nature of air-conditioning systems in America masks a more contested story about the emergence of heating, cooling, and ventilating technologies. She shows how attempts by engineers to promote the most "technically rational design" (1998, page 190), which demanded sealed buildings and passive use, was resisted by what engineers saw as "irrational users" (page 184) who preferred mobile, plug-in air-conditioning systems which, although less efficient, provided greater flexibility and active control. As Cooper suggests, "the engineering culture that characterised the custom-design industry did not produce the best technology, neither did the market forces that dominated the mass production industry" (page 190). The result is localised compromises that reflect the "seesawing power relations surrounding the development of air-conditioning" (page 5). In particular, Cooper's study underlines the contrasting image of the energy consumer underpinning the techno – economic and sociotechnical views. Put simply, the techno – economic "irrational user" is translated into a "guerrilla fighter of those disenfranchised from the design process" in the sociotechnical literature (page 185). Herein lies a key distinction: rather than assume the intrinsic marketability of technically proven innovations, a sociotechnical approach would assess the sociocommercial viability of the artefact in varying social contexts. Instead of explaining market failure in terms of ubiquitous and timeless barriers, a socio-technical analysis would seek to explain market success or failure in situationally specific situations. Some contexts may favour innovation, others may not. Mapping what Bijker (1995) terms the "technical frames" of "socially relevant actors" is vital here for, as Cowan recognises, any one of those "groups or individuals acting within the context of their group identity... may be responsible for the success or failure of a given artefact" (1987, page 262).

7 Conclusion: reconstructing energy knowledge

> "If we are to seriously address questions about the sustainability of modern levels of consumption and other resources, then we will need analytical approaches and vocabularies which acknowledge the cultural and social significance of consumption and allow us to more closely consider the sensitive issues of identities, values and quality of life."
>
> Wilhite (1997)

The aim of this new agenda is not to produce abstract social theory. Instead, a growing number of social scientists are striving to articulate a new role for social scientists in research and policy debates about energy consumption and environmental change.

These researchers are exploring the heterogeneous and contested nature of consumption practices that shape energy use in buildings. Rather than simply assuming that people use energy, they are analysing how energy intersects with everyday life through diverse and culturally inscribed practices such as heating and cooling, cooking, lighting, washing, bathing, working, and entertaining. To achieve this they are drawing upon methods and theories beyond science and economics, including sociology, anthropology, geography, psychology, and cultural studies, and they are learning lessons from consumption debates beyond energy and the environment, including fashion, food, and shopping. The result is a perspective that argues that present and future energy use depends less upon attitudinal shifts and rather more on understanding how conventions and practices of energy use evolve over time and the differences within and between cultures (Wilhite, 2001).

A key focus of this research perspective is unpacking our notions of the energy user. For the "way an innovation takes hold can not be reduced to any one model, for example, the rational economic consumer, the status-seeking purchaser or the inveterate trend-follower" (Akrich, 1995, page 167); instead, "the success or failure of innovations frequently depends on their ability to cope with dissimilar users possessing widely differing skills and aspirations" (page 167). Escaping any view of users as passive recipients of approved technologies, this approach would seek to explore the appropriation of or resistance to new technologies as they surface in changing consumption practices. A good example here is that of constructive technology assessment (CTA), approach which seeks to explore how the "social effects of any technology depend crucially on the way impacts are actively sought or avoided by actors involved in the development of technology" (Rip et al, 1995, page 3). By emphasising the 'co-production of impacts', CTA analysis explores the interconnectedness of technologies and users in particular contexts of use. Advocating the development of 'social experiments' through which users have the opportunity to shape the design process and thereby promote learning on the part both of designers and of users, CTA offers an alternative means of managing technological innovation.

Critically, such sociotechnical research is careful not to disentangle these active users from the wider technical networks which frame their choices. Instead, it would seek to explore "the processes by which technologies and user identities are co-constituted in evolving sociotechnical networks" (Summerton, 2004, page 486). For example, Otnes followed the daily routines of housing consumption in order to illustrate the fuzzy borderlines between private (individual) and public (mass) energy consumption represented by the intermingling of technical networks and the routine consumption practices of daily life in what he termed "collective socio-material systems" (Otnes, 1988, page 120).

> "Starting with 'the rise' and connection to the telecommunication system through a radio-alarm clock, then through the washing ritual with its mediation through water and sewerage systems and then to breakfast; ... I head for the kitchen—Its terminal, the kitchen stove, attached to the public electric power plant and its cable and wire network. ... On my way back to the kitchen check the heating, going through the rooms turning on electric radiators, or fan ventilators ... I return with the paper, brew my tea and toast two bread loaves. In five minutes breakfast is ready—tea with milk (from the fridge)."

His biography of daily routines shows clearly how the nature of everyday life critically depends upon the availability of essential services such as power, water, and telecommunications. In this way we can see how utility networks structure patterns of resource use while, at the same time, changing lifestyles may crucially reshape systems of infrastructure provision, as any history of the home or the office will illustrate.

As Cowan puts it:

> "The industrialisation of the home was determined partly by the decisions of individual households but also partly by social processes over which the households can be said to have had no control at all, or certainly very little control. Householders did their share in determining that their homes would be transformed ... but so did politicians, landlords, industrialists and managers of utilities" (1983, pages 13–14).

By avoiding individualist explanations of technological innovation (the rational energy consumer), moving away from any form of technological determinism (technical innovation as handmaiden to an energy-efficient economy), and, critically, refusing to distinguish prematurely between technical, social, economic, and political aspects of energy use, we may develop a more critical understanding of how the changing strategies of the suppliers of networked services may reshape contexts of consumption. As Hughes has graphically illustrated, in understanding the development of the electricity networks, sociological, techno–scientific, and economic analyses are permanently woven together in a 'seamless web' (Hughes, 1983). In this world without seams, social groups and institutions can be considered, alongside technological artefacts, as 'actors' who actively fashion their world, constantly reshaping contexts of sociotechnical interaction. Sociotechnical analysis of energy use could then replace conventional descriptions of universal barriers to energy-efficient innovation (apathy, ignorance, lack of financial interest), with analysis of the ways in which the changing social organisation of energy-related choices, in turn shaped by the providers of networked services, structures opportunities for more efficient energy use. One such approach is to identify and explore the emergence of 'niches' in which radical innovations are nurtured, tested, and promoted. Citing examples such as electric cars and solar houses, Geels argues that such niches provide vital "incubation spaces" for "learning processes, for example, about technical specifications, user preferences, public policies, symbolic meanings" (2004, page 912).

The scope of this research agenda, then, takes us in a different direction to the techno–economic analysis of energy consumption which, as we have seen, tends to be dedicated to identifying the potential scope and scale of energy-performance improvements in different building types, in different building sectors, and to the setting of technically feasible CO_2-abatement targets. It also suggests a role for social scientists much deeper than the forms of market research, evaluating the attitudes of what are taken to be key decisionmakers towards energy that typify research on human behaviour and attitudes. In developing a sociotechnical approach to energy efficiency, researchers concern themselves more with identifying context specific opportunities for embedding proven technologies into appropriate social practices. In this way, rather than being led by calculations of technical potential, their task is to seek to identify how specific social, spatial, and temporal configurations of processes of building design, development, and use encourage, or militate against, effective forms of energy-saving action. As a result, the aim for researchers is to identify the circumstances in which energy-efficiency practices do or do not flourish and to search for stories about successful technical change. This focus of these sociotechnical research practices takes us far from the world of building science and the paradigmatic certainties of the techno–economic perspective, and instead reveals the construction of energy knowledges in varying social worlds and reflects the contested nature of building design and development and energy-consumption practices.

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