Guest Editorial

Energy in Society: Energy Systems and Infrastructures in Society

Energy issues are a longstanding area of interest in the social sciences and Science and Technology Studies (STS) that has received increasing attention during the recent years. The invention and expansion of large-scale electricity systems was among the first widely debated topics of histories of technology and STS in the early 1980s. More recently, scholarship in STS as well as sociology, anthropology, urban planning, and other disciplines has turned attention to challenging issues such as sustainability, low-carbon transitions (Southerton et al., 2004; Coutard et al., 2005; Rohracher, 2008), energy saving, energy efficiency (Wilhite, 2008; Shove, 2003, 2010), security of energy infrastructures (Collier & Lakoff, 2008; Graham, 2009), and the liberalization of infrastructure industries (Graham & Marvin, 2001). Analytical themes raised in recent discussions include path-dependency and path-making in energy systems (e.g. Verbong & Geels, 2008; Heiskanen et al., 2009), critical relations between climate change and shifting urban energy infrastructures (e.g. Hodson & Marvin, 2009, 2010; Blok, 2013), and the everyday use of energy services (e.g. Ornetzeder & Rohracher, 2006; Shove, 2010; Hyysalo et al., 2013a, b), among many other things.

Topics such as these were raised and debated in a two-day international conference, *The Second Aalto Event on Science and Technology Studies: Energy in Society*, organized in November 2012 in Helsinki by the Aalto University School of Business, the Helsinki Institute of Science and Technology Studies (HIST), and the Finnish Society for Science and Technology Studies. In this special issue of Science & Technology Studies we tie these discussions together by highlighting some of the understanding that social science and especially STS scholarship has generated about energy infrastructures in contemporary societies. To this end, the issue collects internationally state-of-the-art research on current energy issues. It also proposes an analytical approach to explore some of the conceptual and practical implications of this research. Here, we argue that the known STS metaphor of large technological systems, as helpful as it is in many different ways, could still in some cases be *scaled down* (Edwards et al., 2009) to better acknowledge multiple possible local uses, configurations, and changes of energy infrastructures, also visible in the articles of the issue. The present editorial concentrates in this conceptual aim and ends with a general introduction of the papers presented in the special issue.

As mentioned, we start the conceptualization with what must be the most classical source, one that underlies many of the works that have followed. The text is *Networks of Power: Electrification in Western Society, 1880-1930* written by historian Thomas P. Hughes (1983). Hughes in *Networks of Power* analyses electrical engineering inventors from the late 19th century onwards and views the expansion of electricity supply in different countries, regions, and cities including US, Germany, England, New York, Berlin, Chicago, and London. The key outcome of the book is well known. This is that more than a mere invention, the society-wide supply of electricity has become systemic, a *large technological system* (LTS).

A general definition of a *system* is that it "is constituted of related parts or components … connected by a network or structure" (Hughes, 1983: 5). Albeit loose, the definition is simple and effective. It frames systems as entities that enclose components that can be controlled – usually but not always centrally – but exclude components that cannot be controlled and are therefore merely in the *environment* of the system. To Hughes (1989: 51), electric power in particular exemplifies a large system that consists of "physical artifacts, such as turbogenerators, transformers, transmission lines in electric light and power systems", but also "organizations, such as manufacturing firms, utility companies, and investment banks", "components usually labeled as scientific, such as books, articles, and university teaching and research programs", "legislative artifacts, such as regulatory laws", and "natural resources, such as coal mines". These are the social and technical parts of a socio-technical arrangement to draw on energy scholar Harald Rohracher's (2008) expression.

Hughes (1983, 1989) made two key contributions according to Erik van der Vleuten (2004). He "revised the sense of enormous societal importance of infrastructures" and "advocated a 'socio-technical' systems research methodology" where technologies are "analyzed from the perspective of privileged actors ('system builders')" (van der Vleuten, 2004: 399). One important societal matter, to draw on the notion of a system, is that energy technology both structures and is structured by institutions, organizations, raw resources, laws, scientific studies, and many other related parts and components that cannot be easily treated separately. The way to study such interrelations, to utilize the systems research methodology, is then to follow experts such as inventors, engineers, and entrepreneurs that strive to build large technological systems. Such insights into multiple levels and their expertise remain highly relevant for understanding contemporary energy systems and their issues, as we discuss below.

Over the last 20 years, a number of scholars have applied the LTS terminology in Scandinavia (Myllyntaus, 1991; Summerton, 1992; Kaijser, 1994), Netherlands (see van der Vleuten, 2004), and many other parts of the world including Asia and South America (see Coutard et al., 2005). Researchers also soon began to expand the initial work by Hughes and his colleagues, as summarized in a review of LTS literature by van der Vleuten (2004: 401-406). Accordingly, the main developments since the 1980s and the 1990s are as follows: many have drawn more attention to the cultural symbolic meanings of large technological systems; to the growing dependence of modern societies on technological systems; to the steady increase of systemic vulnerabilities and risks due to the growing complexity of these system; to the impacts of wider processes like nation state building on large technological systems; to the effects that technological systems have on other spheres like spatiality which then affects yet other aspects of collective life; and to the emergence of "second order" large systems that are systems comprising several "first order" large systems. The details of these heterogeneous discussions are outside of our scope (see further details in Summerton, 1992: 62-74; Allen & Hecht, 2001; van der Vleuten, 2004, 2006; Coutard et al., 2005), but we select a few interests relevant to the themes of this special issue.

First of all, an influential new perspective has drawn attention to how energy systems change, and are changed, in resonance with their perceived problems, for example environmental issues (Verbong & Geels, 2007: 1025). This theme of change is not altogether new: a fundamental principle of LTS is that systems evolve over time, from their invention and development to growth and eventual decline (Edwards, 2010: 10). Furthermore, large system expansion has often been promoted deliberately rather than following a predetermined pathway (Hughes, 1983: 79). But with a few exceptions, such efforts have tended to be seen only as expert actions, mostly confined to the initial stages of technological development. The notable exceptions are major disasters, social crises, and conflicts – such as warfare, oil crises, nuclear accidents, environmental critiques, or big government interventions – that can shape the trajectories of large systems once their pathway has been set (van der Vleuten, 2006: 302; Geels & Schot, 2007). In many cases, this might indeed be accurate because large systems like energy networks have acquired momentum and many of the institutions and the actors that manage these systems would rather support incumbent technologies than challenge them (Hughes, 1983: 140). However, several recent matters that face energy systems – from sustainability to concerns about climate security and risk or market liberalization (Graham & Marvin, 2001; Rohracher, 2008; Teräväinen et al., 2011) – also suggest that energy provisions in society are not always quite as closed from their outside contexts.

To help explore such matters of shifts, authors in recent studies have introduced a number of theoretical notions that can be drawn upon (Borup et al., 2006; Verbong & Geels, 2007; Rohracher, 2008; Heiskanen et al., 2009; Hodson & Marvin, 2009). These include *transition,* which means a change in the technical functionalities, regulations, organizational networks, practices of use, or symbolic meanings of energy systems (Rohracher, 2008: 155). *Transition management*, a more governmental concept, is the long-term thinking and practical policy processes to trigger such change (Heiskanen et al., 2009: 411-412). Transitions take place on many levels, hence the notion *Multi-Level Perspective* (MLP) (Verbong & Geels, 2007: 1026). The levels often reinforce each other, especially in the case of a successful transition (Verbong & Geels, 2007: 1026) and range from political cultures, economic trends, actors, technologies, institutions, rules, and regulations to more protected networks of actors, or *niches* (Hodson & Marvin, 2010: 479-481). *Strategic Niche Management* (SNM) then means deliberate "experiments" that support niches and study their practices, such as pilot field experiments with electric vehicle users (Rohracher, 2008: 156-157). The notion of a system change is not unknown to LTS and the ways in which transitions emerge in different contexts clearly is an empirical question (Heiskanen et al., 2009; Hodson & Marvin, 2010). Nonetheless, the ideas such as above about changing a mature system through local experimenting would probably not be that easy to tackle by being preoccupied with conservative large systems.

Another useful concept to highlight how energy systems change and how this is envisioned is that of *technological expectations*: "real-time representations of future technological situations and capabilities" or slightly more normatively, "wishful enactments of a desired future" (Borup et al., 2006: 286). Certainly technology studies has been long aware that technology projects and their builders orient to the future in various ways, for example by extrapolating past trends, anticipating systems growth, aspiring for more economic production modes, and expecting a steady demand to match continuous production (Hughes, 1983; Bazerman, 1999). Yet, to us all of these seem to be “wishful enactments” about expanding systems: in other words, expectations about how “to increase the size of the system under … control and reduce the size of the environment that is not” (Hughes, 1989: 66). They do not concern, at least directly, future orientations stemming from a large system’s environment: such as sustainability, profitability, or the management of security and risk, which have become topical matters in recent public and political discussions about energy (Graham & Marvin, 2001; Rohracher, 2008; Collier & Lakoff, 2008; Silvast, 2013). Furthermore, the service that energy users expect – not only the “needs” that system growth applies to them – seems also to be missing from traditional expectations among system builders.

This last thing we would argue is a limitation that pertains to many studies about large technological systems. While some argue that LTS research takes technology users into account – namely, that users are merely a different part of the same systems (see van der Vleuten, 2006: 295) – to us the perspective seems fine-tuned to address issues about technological production. At the same time, more detailed work on energy consumption practices has been emerging for several decades now. These studies develop an interest in the ways in which consumption and large technological systems mutually shape each other. Part of this shaping is due to the embeddedness of energy in a culture (Nye, 1998): but it is also true to say that the focus has been on the infrastructure users’ everyday practices. According to Leigh Star (1999), for example, the traits of scientific knowledge infrastructures are closely interlinked with professional conventions of practice. Sociologist Elizabeth Shove (2003) sums up the ends of energy use as the three Cs: comfort, cleanliness, and convenience. Several other studies are sensitive to the ordinary use of “energy services” (e.g. Southerton et al., 2004; Wilhite, 2008) or “infrasystem services” (Jonsson, 2005). In this context, the use of energy relates to day-today practices and routines more often than conspicuous consumption or reflective actions (Shove, 2010). Energy scholars Michael Ornetzeder and Harald Rohracher (2006) though note that users can also be quite reflectively involved with their energy supplies. The users they studied had formed their own self-building groups to disseminate new energy generation technologies and Hyysalo et al. (2013a,b) show similarly how user-run Internet forums function as a highly effective “learning environment” for modifying your own household heating systems. But whether using energy reflectively or not, the key conclusion of all these studies is that users and everyday practices of use determine to a large extent what an energy system is like: users and their expectations shape energy in society as well.

Our introduction to this special issue has now traversed from large systems to transitions, transition management, niches, expectations, and practices of energy use. A justified critical question remains: how should one take into account such diverse matters in a single analytical framework? Here we want to ask a further albeit somewhat explorative question: in spite of its many apparent strengths and possibilities, how apt is the metaphor of a system with some of the current energy issues, as a system traditionally denotes something that is subject to control? Recently many scholars, particularly Paul N. Edwards, have indeed begun to prefer to talk about infrastructures rather than systems. Originally a 1950s

NATO term (Kaijser, 1994; Edwards, 2003), but widely spread in public and political discussions recently (see Edwards et al., 2009), infrastructures are not merely closed, coherent, and centrally controlled systems. They are rather like "webs" (Edwards, 2010: 12) or "open reconfigurable" networks whose coordination is at least partly distributed among different actors (Edwards et al., 2007: 12) from international producers even to local users. According to another characterization, networked systems typically involve questions about "scaling up" – such as expanding their size and reach – but it is also possible to "scale down" the questioning and focus on how "global infrastructures" become "locally useful": this can be helpful because "the actual infrastructures of people's real work lives always involve particular configurations of numerous tools used in locally particular ways" (Edwards et al., 2009: 370). These insights and ideas, while the said two concepts are still similar and notion of LTS has much to offer as we believe, has led us to consider whether energy provision could also be usefully be conceptualized as an infrastructure, in order to highlight its open reconfigurable character, local uses, and multiple possible changes.

The Articles

The articles in this special issue advance the themes outlined above, running through three issues of Science & Technology studies. We have sought to keep dialogue between the above themes alive through these issues rather than compartmentalizing each theme into a specific issue, thus keeping the different sides of shaping the energy infrastructure in each issue. Hence, we have selected papers that address expectations, socio-technical transitions, users, risk, and path-dependency to this first issue, and seek to arrange the ensuing issues similarly. This opens for dialogue also in regards to different research styles at hand, comprising quasi-evolutionary models, constructivist analyses, critical policy analyses as well as ethnographic accounts.

The special issue opens with an article by Les Levidow, Theo Papaioannou, and Alexander Borda-Rodriguez on bioenergy in UK titled "Innovation Priorities for UK Bioenergy: Technological Expectations within Path Dependence". As in other industrialized countries, an increasingly important role has been given to bioenergy in curbing the CO_2 emissions from the UK energy system. The expectations voiced in UK policy documents underscore the need for innovation in the conversion of biomass to sustainable energy, especially in the range of the biomass that is presumed to be converted. The prioritized expectation is to use this range mainly as input-substitute within the current centralized large-scale energy system. The paper seeks to explain how UK bioenergy innovation pathways and expectations forefronted therein have been locked into current energy system through the reciprocal requirements of state bodies and industry, whose investments the government depends upon. The paper builds on critical policy analysis as well as literatures on technology expectations and path-dependency.

The second article of the first issue is by Armi Temmes, Rami-Samuli Räsänen, Jenny Rinkinen, and Raimo Lovio titled "The Emergence of Niche Protection through Policies: The Case of Electric Vehicles Field in Finland". The paper departs from Strategic Niche Management (SNM) perspective to discuss how SNM policies come to amend existing policies, a hitherto rarely examined issue. In doing so the authors pay specific attention to systematic expectations work by protagonists and to how the politicians strategically select technologies to be protected. Examining in-depth two major policy initiatives on electric vehicles in Finland, the authors identify four facets of expectations work: credibility of enactors; credibility of expectations; systematic advocacy; and publicity work. The paper thus examines at the micro level the continued interaction between enactors and selectors in public-private arenas, a central theme also in the UK bioenergy analysis in the first paper of the issue.

The next contribution by Mads Dahl Gjefsen, "Carbon Cultures: Technology Planning for Energy and Climate in the US and EU", concerns carbon dioxide capture and storage (CCS): a set of technologies for capturing carbon dioxide emissions from power plants and other sources and storing them typically underground. Timely topic in sustainability transitions, Gjefsen turns our attention to expectations about these technological projects, in a similar vein to the papers above: to wishful enactments that expert actors make about the future when long-term CCS will be in use. The case of the article concerns United States and the European Union during the last ten years. Studying articulations of CCS in the two policy regimes, Gjefsen finds more than anticipations about expanding systems, better technical qualities, or serving economic interests in the energy discussions. Rather, he demonstrates how assumptions about societal and public impacts of new technology – for example, differing representations of CCS as a "public good" – shape to a large extent what CCS technologies are expected to be like in the two regimes. These and other divergent policy narratives and legal ontologies play an important yet not always acknowledged part in international climate change mitigation, as the paper concludes.

In the final article of this first issue, "Innovating Relations – or Why Smart Grid is not too Complex for the Public", Lea Schick and Brit Ross Winthereik inquire into emerging "upgraded" or more "intelligent" electricity provisions, commonly coined as Smart Grids. Closer in spirit to infrastructures than mere systems or supplies, Smart Grids are electricity networks added with digital communications that mesh together the behaviors of energy producers and users. Such integration among producers and consumers is met with broad expectations by experts all over the world, especially to help balance "fluctuating" renewable energy generation (such as wind and sun). The paper proposes a specific STS starting point to study these kinds of aspirations and transitions: to explore how future infrastructures and their problems are enacted as "things" in those situations and spaces where experts have the opportunity to articulate their expectations in practice. Working from this perspective, Schick and Winthereik study a three-day delegation trip of Danish researchers and enterprises to Germany that discussed Smart Grids and "Smart Green Homes" in particular. Their ethnographic analysis focuses on key prominent visualizations and metaphors enacted about Smart Grids during the delegation meeting. Through thick description of these practices they are able to show how experts envision Smart Grids infrastructures, Smart Grids users, and practices of use, and how the technological expectations end up both in resonance and at a distance from those publics that the Smart Grids are supposed to serve.

The accepted papers to the special issue continue the themes opened by the first part in the second issue that will be out on 15th of April 2014. There Gerhard Fuchs's contribution "The Governance of Innovations in the Energy Sector: Between Adaptation and Exploration" starts similarly to our editorial, by conceptualizing electricity supply as a large technological system and asking how such systems change in resonance with their perceived problems. He also introduces the popular view that energy systems shift mostly in tandem with external challenges, even disasters or catastrophes – for example, market liberalization, oil price shocks, the Chernobyl accident, the impacts of climate change, and the Fukushima catastrophe. The paper then extends this picture considerably by developing an interest in how actors in the energy field actively interpret and mediate system transitions and how that builds new kinds of coalitions and technological expectations. Large empirical studies about Carbon Capture and Storage (CCS) in Germany and Norway and photovoltaics in Japan and Germany are analyzed with the perspective opened up in the paper.

Mark Winskel and Jonathan Radcliffe continue with the important theme of role of incumbent actors in energy transition, with a paper titled as "The Rise of Accelerated Energy Innovation and its Implications for Sustainable Innovation Studies: a UK Perspective". It raises to the fore a specific need for sustainable transition theories: to account for the multiform dynamics of energy systems across a spectrum of continuity-based and niche-led changes. The term 'accelerated energy innovation' has become a prominent aspect of energy policymaking, and in the UK it has a number of distinctive features that render it predominantly regime-led and continuity-based: an emphasis on relatively short term dynamics (years rather than decades), a focus on cost reduction and deployment support for large scale technologies, and a central role for the private sector and public-private partnerships. Winskel and Radcliffe show how the UK energy policy change, accompanied with accelerated energy innovation, shifted from more disruptive to continuity based agenda in the course of 2000s. Their analysis questions the portrayal of transition as predominantly niche-led in both transition management and technological innovation systems literature and calls for further theoretical appraisal on how power, resources, and strategies played by incumbents relate to landscape pressure and niche initiated changes in transitions.

The paper by Mikko Jalas, Helka Kuusi, and Eva Heiskanen "Self-Building Courses of Solar Heat Collectors as Sources of Consumer Empowerment and Local Embedding of Sustainable Energy Technology" moves to examine energy infrastructure change from the end-user perspective. They explore the Finnish solar heat collector self-building courses by asking what impacts the courses have on the participants and in promotion of new renewable energy technology. The authors show that self-building courses offer possibilities for material engagement that has outcomes beyond the immediate objectives of the course. The course participants started to follow energy discussions, collect information, and actively advise others, viewing themselves as increasing capable actors in renewable energy. They also began to engage in energy saving and renewable energy at home on a wide front, even as only 41% had installed the collectors they built on the course soon after. Self-building courses served foremost as a first step into renewable energy even as they have been previously identified also as stimulus for user innovations, local embedding, and diffusion of renewable energy technology. Drawing from practice theory and science and technology studies Jalas et al. empirical material consists of field observations, interviews with teachers, and a survey of participants beginning from the early activities in late 1990s.

Yael Parag's discussion paper turns to the theme of energy security, commonly understood as energy provision that is adequate and reliable as well as affordable, or in some recent depictions, "competitive". The title of the paper is "From Energy Security to the Security of Energy Services: Shortcomings of Traditional Supply-Oriented Approaches and the Contribution of a Socio-Technical and User-Oriented Perspectives" and it focuses on policy work about energy security from all over the world. Parag raises a specific bias in the policies as the starting point: in many cases, what has been at stake in national and other policies is merely the security of energy supply, rather than the security of the energy services that citizens critically depend upon. This observation corresponds closely with the difference that this editorial and many other sources have made between systems (a supply) and infrastructures. Drawing insight from STS literatures, Parag presents us a new way of conceptualizing energy security where the role of energy-using practices and everyday energy services is better acknowledged with a direct link to the end-user perspective presented by Jalas et al., above. Accordingly, paying attention to the resilience of energy services posits another key means for this conceptualization.

In addition to these already accepted pieces there are several articles that are nearly finished or in their final rounds of peer review. However, as the texts are still manuscripts or exist as conference papers at this point, only their working titles and a few details can be given to let you anticipate the contents of the coming theme numbers. The potential contributions include "Expectations Work at Field-Forming Events: Constructing Narratives for Furthering Solar Technology" which continues and deepens the theme of expectations work by protagonists in sustainable transitions. Another paper in review is "Not in Anyone's Backyard? Civil Society Attitudes towards Wind Power at the National and Local Level in Portugal" that juxtaposes policy and institutional frameworks with civil society attitudes to uncover how wind energy is currently developed and deployed in Portugal. In "The Meanings of Practices for Energy Consumption – Comparison of Homes and Workplaces" the authors write about a transition to more sustainable everyday practices by presenting two case studies on buildings' energy use in Sweden and the UK.

The contribution "Adjudicating Deep Time: Revisiting the United States' High-Level Nuclear Waste Repository Project at Yucca Mountain, Nevada" ties together anthropological themes about expertise and law to spotlight techniques of risk governance in nuclear waste management of a famous nuclear waste repository in the US. "System Management and System Failure: An Analysis of Experts' and Lay Persons' Insights into Electricity Infrastructure and its Problems" presents a systems theoretical comparative analysis of electricity management and use in two infrastructure control rooms and households, highlighting differing structuring temporalities, external constraints, and personal skillsets in the three field sites.

Another empirical case is a study on a shift in in nuclear power production from a research phase to an industrial phase. The paper examines the development of Fast Breeder Reactor technology (FBR) in France, from the 1950s to the early closure of the FBR Superphénix plant in Creys-Malville in 1997. The authors discuss how framing a reactor prototype as "industrial" is not only a matter of rhetoric; it may have an important impact on the trajectory of an innovation. Another manuscript in review deals with how nuclear experts and expert organisations exchange risk-related information during the construction of nuclear waste repository in Eurajoki, Finland. Particularly, the authors focus on the handling of a copper corrosion issue in the nuclear waste disposal and the related dialogue between a nuclear waste managing company, Posiva Oy, and a regulatory institution, The Finnish Radiation and Nuclear Safety Authority (STUK).

We will present and connect these manuscripts in the sequel editorials to this triple special issue when their acceptance or rejection in peer review has run its course. Meanwhile, we look forward to publishing in the coming issues many further timely considerations on how energy infrastructures and their risks are managed, how these infrastructures are used, how they change or do not change, how they are changed, and how they are expected to change in society.

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