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Guest Editorial

Energy Systems and Infrastructures in Society: Part 2 of 3

The previous issue of Science & Technology Studies began our collection of internationally state-of-the-art research on energy issues, an established area of interest in the social sciences and Science and Technology Studies (STS). Energy has become a timely topic in STS and elsewhere, and the number of papers that we received and that were accepted in peer review was especially high. Initially meant as a volume to publish papers from a conference event in Helsinki, the special issue was expanded to run through three numbers of Science & Technology Studies. Its first part was published in the December 2013 edition of the journal (Vol. 26, No. 3) and contained four papers. These discussed and developed new understanding about path dependence and technological expectations in UK bioenergy (Levidow et al., 2013), niche protection policies of electric vehicles in Finland (Temmes et al., 2013), political articulations and expectations about carbon dioxide capture and storage in the US and EU (Gjefsen, 2013), and the development of updated or more intelligent electricity infrastructures, so-called Smart Grids, in Denmark and Germany (Schick & Winthereik, 2013). In our introduction to the issue, we also proposed a conceptual approach that tied some of these themes together and drew on known STS ideas about large socio-technical systems and infrastructures (e.g. Hughes, 1983; Edwards, 2003), energy system transitions (e.g. Geels & Schot, 2007; Verbong & Geels, 2008; Hodson & Marvin, 2010), technological expectations (e.g. Borup et al., 2006), and the everyday use of energy services (e.g. Ornetzeder & Rohracher, 2006; Shove, 2003; Hyysalo et al., 2013). Starting from common notions about large energy systems – as relatively coherent and controlled expert provisions – we argued that more attention could be given to the open reconfigurable character, local practices of use, and multiple possible changes of energy infrastructures. The details of this approach and its further discussion are in the previous issue's guest editorial (Silvast et al., 2013).

In this second special issue on Energy Systems and Infrastructures in Society, five papers are published that carry on advancing energy-related STS topics including socio-technical transitions, path dependencies, technological expectations, technology users, and risk management. In the opening article, Mark Winskel and Jonathan Radcliffe continue with the important theme of role of incumbent actors in energy transition, a topic also discussed by Gerhard Fuchs's contribution below and in several contexts in the previous special issue. There, authors asked how sustainable energy generation technologies become locked into centralized energy systems (Levidow et al., 2013). Another paper studied how politicians strategically select which actors and activities are to be protected when sheltering them under so-called niche management of innovations (Temmes et al., 2013). The paper by Winskel and Radcliffe is 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 second contribution by Gerhard Fuchs, "The Governance of Innovations in the Energy Sector: Between Adaptation and Exploration", starts by conceptualizing electricity supply as a large technological system and asks how such systems change in resonance with their perceived problems, for example environmental issues. Fuchs also introduces the common view that energy systems shift mostly after external challenges, even disasters or catastrophes – for example, energy market liberalization, oil price shocks, the Chernobyl accident, the impacts of climate change, and the Fukushima catastrophe (see also Geels & Schot, 2007; Silvast et al., 2013: 5). The paper then extends this picture considerably by advancing an interest in how actors in energy organizational fields actively interpret and mediate system transitions and how that builds new kinds of coalitions and technological expectations. Large empirical studies about carbon dioxide capture and storage in Germany and Norway and photovoltaics in Japan and Germany are presented by the article. Analytically, Fuchs builds on the Theory of Strategic Action Fields by Neil Fligstein and Doug McAdam and demonstrates its use in exploring energy system transitions.

The contribution "Constructing Expectations for Solar Technology over Multiple Field-Configuring Events: A Narrative Perspective" by Heli Nissilä, Tea Lempiälä, and Raimo Lovio continues and deepens the theme of expectations work by protagonists in sustainable transitions. It examines multiple "field-configuring events" in an effort to map out expectations building over time in furthering a nascent technology field, in this case Solar technology in Finland. The analysis identifies six narrative themes and their evolution in the building of complementary visions and expectations for a new technology. The analysis reveals that rather than explicitly aligning expectations, events can lead to an initially narrow storyline gradually spreading into multiple narratives upon which a field's future can be projected and its advocacy guided and strengthened.

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 increasingly 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. Their exploration into solar building courses continues the line of S&TS research that seeks to examine the role of different citizen groups and user collectives in the building of competences related to renewable energy technologies. Hyysalo et al. (2013) similarly stressed how the engagement with renewables was slow to deepen, and considerably facilitated by peer interactions, in their case Internet forums.

Finally, 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 the security of energy supply rather than the security of the energy services that citizens critically depend upon. Drawing insight from STS literatures, the author then assembles a way of conceptualizing energy security where the role of energy-using practices and everyday energy services is better acknowledged, with a link to the end-user perspective presented by Jalas et al., above. Accordingly, paying attention to the resilience of energy services posits a key means of this conceptualization.

A number of additional articles submitted to the special issue are almost finalized or in their last round of peer review. One paper is called "Not in Anyone's Backyard? Civil Society Attitudes towards Wind Power at the National and Local Levels in Portugal" and combines the study of policy and institutional frameworks and civil society attitudes to uncover how wind energy is currently developed and deployed in Portugal in comparison to other countries. 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 exploring and comparing 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 highlight 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.

When the peer review and acceptance or rejection of these papers has been carried through, we will present them in the third special issue on Energy Systems and Infrastructures in Society, due in 2/2014 to appear in 15th of August.

References

Borup, M., N. Brown, K. Konrad & H. van Lente (2006) 'The Sociology of Expectations in Science and Technology', Technology Analysis & Strategic Management 18(3-4): 285-298.

Edwards, P. (2003) 'Infrastructure and Modernity: Force, Time and Social Organization in the History of Sociotechnical systems', in T. Misa, P. Brey & A. Feenberg (eds), Modernity and Technology (Cambridge, MA: MIT Press): 185-225.

Geels, F.W. & J. Schot (2007) 'Typology of Sociotechnical Transition Pathways', Research Policy 36(3): 399-417.

Gjefsen, M.D. (2013) 'Carbon Cultures: Technology Planning for Energy and Climate in the US and EU', Science & Technology Studies 26(3): 63-81.

Hodson, M. & S. Marvin (2010) 'Can Cities Shape Socio-technical Transitions and How Would We Know If They Were?', Research Policy 39(4): 477–485

Hughes, T. (1983) Networks of Power: Electrification in Western Society, 1880-1930 (Baltimore: Johns Hopkins University Press).

Hyysalo, S., J. Juntunen. & S. Freeman (2013) 'Internet Forums and the Rise of the Inventive Energy User', Science & Technology Studies 26(1): 25-51.

Levidow, L., T. Papaioannou & A. Borda-Rodriguez (2013) 'Innovation Priorities for UK Bioenergy: Technological Expectations within Path Dependence', Science & Technology Studies 26(3): 14-36.

Ornetzeder, M. & H. Rohracher (2006) 'User-Led Innovations and Participation Processes: Lessons from Sustainable Energy Technologies', Energy Policy 34(2): 138-150.

Schick, L. & B.R. Winthereik (2013) 'Innovating Relations – or Why Smart Grid is not too Complex for the Public', Science & Technology Studies 26(3): 82-102.

Shove, E. (2003) 'Converging Conventions of Comfort, Cleanliness and Convenience', Journal of Consumer Policy 26(4): 395-418.

Silvast, A., H. Hänninen & S. Hyysalo (2013) 'Energy in Society: Energy Systems and Infrastructures in Society' Science & Technology Studies 26(3): 3-13.

Temmes, A., R.-S. Räsänen, J. Rinkinen & R. Lovio (2013) 'The Emergence of Niche Protection through Policies: The Case of Electric Vehicles Field in Finland', Science & Technology Studies 26(3): 37-62.

Verbong, H. & F. Geels (2007) 'The Ongoing Energy Transition: Lessons from a Socio-technical Multi-level Analysis of the Dutch Electricity System (1960-2004)', Energy Policy 35(2): 1025-1037.

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The Rise of Accelerated Energy Innovation and its Implications for Sustainable Innovation Studies:
A UK Perspective

Mark Winskel and Jonathan Radcliffe

'Accelerated energy innovation' has become a prominent aspect of energy policymaking in response to more urgent drivers for change. This paper charts the rise of accelerated energy innovation in the UK, and considers its possible implications for sustainable innovation studies and research-policy exchange. As manifest in the UK, accelerated energy innovation has a number of distinctive features: 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. We argue that because it is predominantly regime-led and continuity-based, accelerated energy innovation presents a challenge to niche-led, more disruptive theories of sustainable innovation (Transitions Studies and Technological Innovation Systems theory). We conclude that sustainable innovation studies – while maintaining its critical and reflexive stance – should more fully reflect the multiform dynamics of energy systems under urgency, across a broad spectrum of continuity-based and niche-led changes.

Keywords: energy policy, innovation theory, accelerated innovation

Introduction

This paper considers recent changes in the political and economic context for energy system change, associated changes in the dynamics of innovation in the energy sector, and the possible implications of these changes for sustainable innovation studies and innovation theory. Reviewing recent developments in the UK, it charts a rising emphasis in energy innovation policy and practice on relatively short term targets (years rather than decades), to support for large-scale deployment and cost-reduction rather than longer-term research and development, and to continuity-based change rather than more disruptive innovation. We characterise and interpret these changes as manifesting an 'accelerated energy innovation' imperative, and we suggest that they carry significant implications for energy innovation dynamics, governance and research.

'Accelerated innovation' has become an important term in contemporary energy policy debates – and some research studies. The term has a natural appeal for energy policymakers (and policy-engaged researchers) in the face of urgent, concurrent challenges: decarbonisation, supply security (or 'energy independence'), affordability, business development and economic growth. In this context accelerated innovation offers the compelling promise of more affordable change pathways, and it has been invoked in a number of prominent national and international policy and research contributions. The International Energy Agency (IEA) has repeatedly deployed the term (e.g. IEA 2010; 2011; 2012). In 2010 the IEA set up a dedicated project on Accelerated Energy Innovation, which concluded that 'the transition to a low-carbon economy clearly requires accelerating energy innovation and technology adoption' (IEA, 2011: 38). The Global Energy Assessment similarly concluded that 'substantial and accelerated innovation is essential to respond to the sustainability challenges of energy systems' (Grubler et al., 2012: 1711). The term has also featured prominently in US debates on energy futures (e.g. Anadón et al., 2010; PCAST, 2010; Henderson & Newell, 2011).

In this paper we consider the emergence and manifestation of accelerated energy innovation in the UK. While there have been a few UK policy and academic 'prescriptive' studies of the potential of accelerated energy innovation (e.g. Stern, 2007; Grubb et al., 2008; Winskel et al., 2011), our concerns here are more empirical, interpretive and reflexive: to trace the remaking of the UK energy innovation system in response to the perceived accelerated innovation imperative, and then consider its possible implications for sustainable energy innovation theory. We suggest that the accelerated energy innovation imperative emerged in the UK with the setting of highly ambitious, relatively short term policy targets for decarbonisation and renewables deployment in the late-2000s.

Although as yet more of a policy and strategy phenomenon than a material influence on energy system change (in terms, for example, of accelerated deployment of large scale technologies), the working-out of the accelerated innovation imperative has already seen the wholesale remaking of the institutions, governance and spending patterns of the UK energy innovation system. New organisations and networks – typically business-driven or public-private partnerships – have significantly changed energy innovation practice for both private and public researchers, and the role of innovation in wider energy system change. The UK has been a particular setting for the playing out of the accelerated energy innovation imperative, reflecting its weakened and heavily liberalised institutional base, a powerful decarbonisation policy driver and the influential role of private business in UK public policy (Kern, 2011; Anadòn, 2013). At the same time, the wider uses of the term suggests that it is an international phenomenon reflecting pressing global drivers on energy systems.

We propose that the UK case invites critical reflection within sustainable innovation studies, and the paper draws-out some of the possible implications of accelerated energy innovation for sustainable innovation studies. We suggest that because it is mainly a regime-led and continuity-based phenomenon, accelerated innovation presents a challenge for evolutionary theories such as Transitions Studies and Technological Innovation Systems theory which articulate predominantly niche-led theories of change. This resonates with other recent contributions within Transitions Studies on the heterogeneity of transition dynamics and regime agency, and on the need for an opening-up of sustainable innovation studies to different disciplinary perspectives. Like others in the sustainable innovation studies community, we consider research, policy and practice as related, co-evolving domains which aspire to interactive, mutual learning. In that spirit, we conclude that sustainable innovation studies – while maintaining its critical and reflexive stance – should more fully reflect the rise of accelerated energy innovation and the multiform dynamics of energy innovation across a broad spectrum of continuity-based and niche-led changes.

The paper combines an in-depth case study of a national energy innovation system with a detailed critical review of the sustainable innovation studies literature. Methodologically, the paper is based on a detailed desk-based review of official and 'grey' policy papers, an extensive and detailed review of the sustainable innovation studies literature, and on our own accumulated experiences working at research-policy-business interfaces in the UK energy system over the past decade.[1] The next section maps the development of accelerated energy innovation in the UK since 2005; this is followed by a review of the development of sustainable innovation studies, especially 'quasi-evolutionary', niche-led theories of change (Transitions Studies and Technological Innovation Systems theory); after this, an account is offered of the experiences of research-policy exchange in sustainable innovation studies in the Netherlands and the UK, and then a survey of recent debates in innovation studies on transition dynamics and regime agency, and also wider academic debate on accelerated energy innovation; the final section concludes and outlines a research agenda for accelerated energy innovation.

Accelerated Energy Innovation: The UK Case

The Emergence of Urgent Change Imperatives

The UK was one of the first countries to liberalise and privatise its energy sector. For a period of around twenty years, from the late-1980s to the late-2000s, the system was governed mainly by market actors (Helm, 2003; Skea et al., 2011). Over the course of the 2000s, market-based governance was gradually weakened as public policymaking re-emerged, but in the early-2000s, policy and regulatory interventions were modest. At the beginning of the decade the UK's Royal Commission on Environmental Pollution identified climate change as a radical challenge for the energy sector, and called for a 60% target reduction in UK CO_2 emissions (relative to 1990 levels) by 2050 (RCEP, 2000). Soon after, in the first comprehensive statement on UK energy policy since privatisation, the Government committed itself to this target (DTI, 2003).

The '60% by 2050' decarbonisation commitment, though it re-legitimised long-term steerage of the energy system by public policy, was modest in its political, economic and institutional implications over political and commercial time horizons. The Royal Commission and UK Cabinet Office both presented scenarios suggesting that it could be met largely by a gradual roll-out of energy efficiency measures and renewable energy technologies (RCEP, 2000; PIU, 2002). Deployment programmes for large-scale technologies such as nuclear power and carbon capture and storage (CCS) were *not* seen as central strands of the required policy response at this time, at least over the short to medium term. The UK's renewable energy policy ambition also remained relatively modest (20% of electricity consumed by 2020), and seen as likely to impose only marginal added system costs (Gross et al., 2006). Together, decarbonisation and renewables deployment policies exerted only moderate pressures for change at this time.

In the second half of the 2000s more urgent imperatives for energy system change emerged. While there is some dispute about the extent to which these were 'real' changes, as opposed to perceived changes reflecting interest-based politics (as discussed under 'Research-Policy Exchange in the UK', below), they nevertheless brought about significant changes in the style of energy policymaking – and energy innovation dynamics. In 2006, a UK parliamentary committee listed a confluence of international and domestic forces suggesting the need for more urgent and material policy interventions: internationally, rapidly growing carbon emissions and investments in fossil fuel generation technology, despite growing scientific evidence of climate change risks; domestically, stalled progress in emissions reductions and an emerging reliance on imported oil and gas, at a time of increasingly volatile international markets (HCSTC, 2006).

Reflecting this changed context the Government commissioned another major policy review. This review (DTI, 2006) and the policy statement that followed (HMG, 2007) both conveyed a much greater sense of urgency than their counterparts earlier in the decade. While maintaining the '60% by 2050' decarbonisation commitment, the Government now identified energy security as a key policy driver. Substantial private sector investment in generation plant and network infrastructure was now considered necessary over the relatively short term to 2020, as old generating plant stock was retired and the need for new infrastructure arose, and within this, prominent roles were now suggested for carbon capture and storage (CCS) and new nuclear power stations.

In 2008, the Labour Government increased the UK's decarbonisation commitment from 60% to 80% by 2050 (HMG, 2008), reflecting growing international concerns about climate change (the higher target was linked to an identified need for a 50% global emission reduction by 2050; CCC, 2008). An '80% by 2050' target implied a significantly more challenging decarbonisation trajectory, even over the short to medium term: scenarios suggested that it required the UK electricity system to become almost carbon-free by 2030 (CCC, 2008). At the same time, under the European Commission's *Renewable Energy Directive* (CEC, 2009), the UK agreed to a highly ambitious target of 15% of all energy consumed to be produced by renewables by 2020. Because renewable technologies are more readily deployable at scale in electricity generation than in transport or heating, scenarios for complying with the Directive involved renewables providing well over 30% of electricity produced in the UK by 2020 (HMG, 2009b).

Together, the *Climate Change Act* and *Renewable Energy Directive* heralded a significant move away from two decades of market-based governance toward policy-directed change. The Government's now set out the proposed means for policy delivery in a *Low Carbon Transition Plan* and *Renewable Energy Strategy* (HMG, 2009a; 2009b); both made clear the urgency of the energy system challenge, with over 30GW of new renewables capacity needed by 2020, mostly from onshore and offshore wind farms. After 2020, major supply-side contributions were anticipated from wind, nuclear power and fossil fuel plant using CCS, and also, an expanded, 'smarter' electricity grid. To enable these, the

Government proposed planning reforms for 'swifter delivery', and also, expanded domestic supply chains to capture local economic benefit (HMG, 2009a).

At the start of the 2010s, the UK's energy policy ambitions were pursued in broadly unaltered form by a new centre-right coalition government, despite a deepening economic crisis and large cutbacks in public spending. Indeed, the new Government reinforced the UK's decarbonisation commitment by accepting the Climate Change Committee's recommended target of a 50% reduction in greenhouse gas emissions by 2025, and an 'envisaged' 60% reduction by 2030 (HMG, 2011a). Detailed Government proposals for institutional and regulatory reform of the energy sector now came forwards – proposals with real consequence over political and corporate planning horizons (DECC, 2011a). The package of reforms was aimed at supporting around £110 billion investment in electricity generation and transmission by 2020 – more than double existing rates of investment.

Decarbonisation and renewables deployment targets, and the closure of old generation plant stock (partly driven by European emissions control regulations), suggested the need for almost 60GW of new electricity capacity by 2025 – equivalent to almost three-quarters of the UK's existing power generation plant stock (DECC, 2011b). In this context, the Government concluded that there was 'no reasonable alternative' to a massive re-investment in the UK's national, centralised system of electricity generation and transmission: '[we do] not believe that decentralised and community energy systems can lead to significant replacement of larger-scale infrastructure' (DECC, 2011b: 24).

Accelerated Innovation and the UK Energy Innovation System

More urgent drivers for energy system change did not translate automatically to an 'accelerated innovation' policy agenda. In practice, however, the absence of any readily deployable technologies at a rate or scale to realise the UK's energy policy ambitions meant that accelerated innovation became a corollary of accelerated system change, prompting the wholesale remaking of the

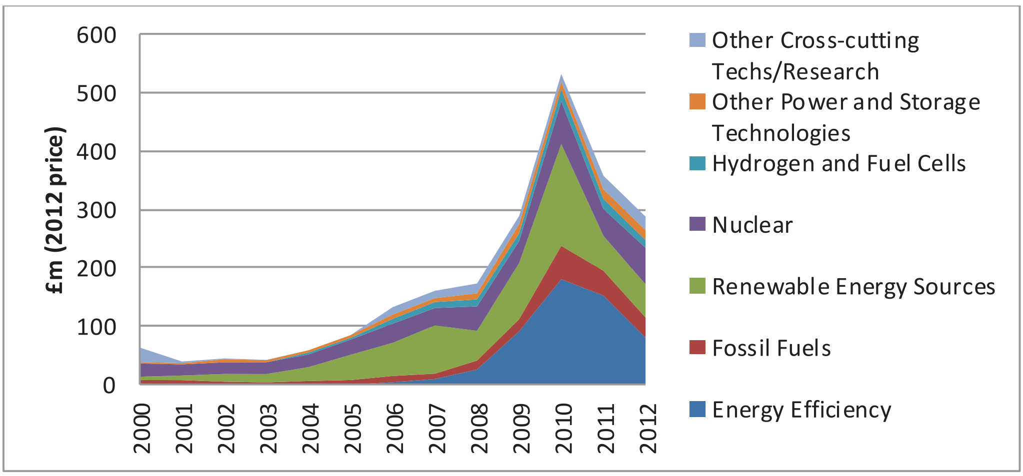

Figure 1. UK Public Spending on Energy Research, Development and Deployment (RD&D) (2000 to 2012) (IEA, 2013).

UK's energy innovation organisations and networks.

This remaking started from a very low base. The playing-out of market liberalism from the mid-1980s saw the dismantling of much of the UK's energy innovation system that had developed under public ownership. The privatised utilities had only a marginal strategic interest in technological innovation, and in the 1990s there was very little public investment in energy technology innovation (Figure 1); other than in the oil and gas sector, the same applied for the private sector (BIS, 2009).

As new policy drivers emerged in the 2000s, new energy innovation organisations and networks were created, but in the first half of the decade these were essentially grafted-on to an energy system which retained its orientation to short-run market imperatives (Winskel et al., 2006). The incentives and agencies established in this period, such as the Carbon Trust (CT), were oriented mainly to immature, long term technology prospects such as marine energy, consistent with then moderate wider policy ambitions (Scrace & Watson, 2009). As Kern (2012b: 308) noted, 'the dominant philosophy was to focus on competitive energy market governance at the regime level and to provide some funding for small-scale renewable niche technologies.'

In 2001 a Government Energy Research Review Group (ERRG) called for UK public spending on RD&D to be raised to bring it in line with that of European competitors, and also, for improved research co-ordination (ERRG, 2001). In practice, public spending levels remained low, and focussed mainly on longer term prospects rather than more readily deployable technologies; for more mature technologies, technology-neutral market-pull support was seen as the appropriate policy approach. Research co-ordination also remained weak: as the ERRG had suggested, a national Energy Research Centre was established, but as a small, distributed academic consortium rather than a single-site national centre. This was an essentially niche-based approach to energy innovation system building.

In the mid-2000s the UK's energy innovation system was more substantially remade in response to more urgent imperatives. Public investment began to rise (Figure 1) and a much greater role emerged for the private sector and public-private partnerships. An Energy Research Partnership (ERP) was set-up as a public-private strategy forum; an early ERP report called for clearer strategic vision, stronger coordination and more emphasis on technology demonstration (ERP, 2007). The late-2000s also saw the creation of the Energy Technologies Institute (ETI), a public-private partnership with significant resources, whose investments focussed on large scale engineering challenges such as offshore energy technology. The Technology Strategy Board (TSB), a public body with significant private sector representation, moved from an advisory role to become an investment agency; the TSB aims to 'accelerate economic growth by stimulating and supporting business-led innovation' (TSB, 2011a). It made energy innovation an early priority, spending on areas such as carbon capture and storage and offshore wind, and sponsoring the setting up of national innovation centres (known as 'Catapult Centres') for strategic technologies such as offshore renewables. The TSB defined the Centres' missions as 'provid[ing] an accelerated path for technologies to move from concept towards commercialisation (TSB, 2011b: 5).

The ETI and TSB also assumed important strategic roles in the newly-emerging energy innovation system. The Government described the ETI's remit as not only 'to accelerate the deployment of new low carbon energy technologies' but also, to provide strategic focus for the wider innovation system, including 'direction and pull' for university-based research supported by the Research Councils (DTI, 2007: 224-225). To help prioritise its investments, the ETI set about its own analysis of innovation priorities – undertaken largely in confidence to protect the interests of its private partners. The TSB also developed its own set of funding criteria, prioritising technologies which combined domestic industrial capability with global market opportunities (TSB, 2008).

In the late 2000s the energy industries' regulatory body, Ofgem, also built-up an internal analytical capability to consider the regulatory and investment implications of the Government's energy policy commitments (Ofgem, 2010a). Soon after, Ofgem's Low Carbon Networks Fund began sponsoring innovation projects for the renewal of the UK's national electricity and gas networks, marking a step-change in innovation spending on network infrastructure renewal (Ofgem, 2010b).

By the early 2010s, the UK energy innovation system had been aligned with the wider policy agenda for rapid system change. The remade innovation system (Table 1) was directed mainly at cost-reduction for the large-scale supply technologies seen as the main contributors to envisaged system change, and under the auspices of the TSB, cost reduction 'Task

Table 1. Main UK Public Funding Bodies for Energy Innovation (compiled by authors from multiple sources).

Organisation (date of inception)	**Stated Mission**	**Major Investments**	**Overall Spending**
Research Councils' Energy Programme (RCEP) (2006)	To position the UK to meet its policy targets and goals through high quality research and training.	Nuclear, conventional sources, renewables, end-use demand.	Research grants to universities and other institutions. £110m p.a. (2011-12).
Technology Strategy Board (TSB) (2008)	To stimulate innovation in areas which offer the greatest scope for UK growth and productivity.	Fuel cells, hydrogen; offshore renewables; grid; buildings; transport; materials	Grants to multi-partner collaborations, up to £35m p.a. on energy (2012-13).
Energy Technologies Institute (ETI) (2008)	To accelerate the development, demonstration and deployment of a portfolio of energy technologies.	Offshore renewables; networks; buildings; storage and distribution; heat; CCS, transport; bio-energy.	£60m p.a. (2008-18) from public and private funding.
Department of Energy and Climate Change (DECC) (2008)	To bridge the 'valley of death' between a technology being ready and it being widely deployed.	CCS; buildings, offshore renewables; manufacturing.	£50m p.a. from 2011.
Ofgem's Low Carbon Networks Fund (LCNF)(2010)	To help network operators provide security of supply at value for money in the move to a low carbon system.	Electricity and gas distribution networks.	Up to £100m p.a. (2010 – 2015).

Forces' were established for offshore wind and carbon capture and storage. This was a directed mission, charged with preparing the ground for wider system transition; as spelled out by the Government: 'in the 2020s we will run a technology race, with the least cost technologies gaining the largest market share. Before then, our aim is to help a range of technologies bring down their costs so they are ready to compete' (HMG, 2011: 1) The emphasis was on larger, co-ordinated efforts aimed at leveraging incumbent interests: in contrast with earlier initiatives, a regime-led innovation system.

Wider economic crises and a UK Government priority on debt recovery and growth now impacted on UK energy innovation spending and strategy. The National Audit Office reported a dramatic decline in total UK public spending after a 2010 high point (NAO, 2013). Increasing concern about the affordability of low carbon technologies was linked by some to a belief that natural gas could continue to have a prominent role in UK energy futures (e.g. Helm, 2012). This carried possible implications for innovation strategy and governance, with calls for reduced focus on innovation for large scale technology deployment, and more emphasis on long term R&D (Moselle & Moore, 2011). By 2013, in a context of reduced political consensus, the role of innovation in energy system change was increasingly contested.

Sustainable Innovation Studies

This section focuses on two prominent strands of sustainable innovation studies: firstly, the Multi Level Perspective (MLP) and Transition Management (TM) (together referred to hereafter as Transitions Studies), and secondly, Technological Innovation Systems (TIS). The focus here on these 'quasi-evolutionary theories' (Suurs & Hekkert, 2012), as opposed to others, such as national innovation systems or innovation management theories, reflects their detailed attention to the socio-technical processes, institutions and interactions involved in innovation and wider socio-technical system change – what Markard, Raven and Truffer (2012: 956) described as their 'systematic view of far-reaching transformation processes of socio-technical systems'. There are now large research literatures on both Transitions Studies and TIS, and this section samples them for points of most relevance, notably on the dynamics of system change and the role of regimes (for fuller overviews, see van den Bergh et al., 2011; Markard et al., 2012; Verbong & Loorbach, 2012).

Transitions Studies

Though described as 'appreciative theory' (Geels, 2002: 1259), in that it draws on concepts and evidence from a number of disciplinary traditions (see Geels, 2004a; Geels & Schot, 2010), Transitions Studies' origins can perhaps be traced most strongly to constructivist social theory (Geels, 2004b), particularly the *social construction of technology* (SCOT) (Pinch & Bijker, 1984).[2] Responding to limited representations of technological change in 'modern' sociology, SCOT translated sociology of science constructivist theory to describe technological change in terms of the varied interpretations and enrolment strategies of different social groups. SCOT's focus on social agency and on the early stages of technology development met with criticism from proponents of more structurally-informed accounts of innovation (e.g. Russell, 1986; Winner, 1993), leading to calls for greater attention to the intermediate *meso* level, where the influence of established organisations and institutions could be analysed, alongside alternative niches (Sørensen & Levold, 1992).

Transitions Studies was conceived to cover this wider socio-technical canvas. It emerged in the Netherlands in the late-1990s, building on a tradition in Dutch innovation studies and research-policy exchange, following-on from approaches such as Constructive Technology Assessment (Rip et al., 1995) and Strategic Niche Management (Kemp et al., 1998).[3] From its beginnings, the Transitions Studies research field has involved co-evolving strands of on the one hand, theoretical and empirical development, often through historical case studies of socio-technical system development (the MLP strand), and on the other hand, research-policy exchange and policy application (the TM strand). A later section reviews the implementation of Transitions Management in Dutch policymaking; the focus here is on conceptual foundations.

Transitions Studies understands sociotechnical change as an outcome of the interaction of three distinct levels of socio-technical structuration: micro-level *niches*, meso-level *regimes* and macro-level *landscapes*. Within this, 'system innovations' (or transitions) – defined as those innovations most influential on system make-up and performance – are understood to originate mainly in niches:

> 'regimes generate incremental innovations, radical innovations are generated in niches … [so] system innovations start in … niches' (Geels, 2004b: 35, 42).

Regimes are defined as the 'dominant rule-sets supported by incumbent social networks … embedded in dominant artifacts and prevailing infrastructures' (Verbong & Loorbach, 2012: 9). Regimes are seen as being 'dynamically stable' (Elzen et al., 2004); for Markard, Raven and Truffer (2012: 957) a regime 'imposes a logic and direction for incremental socio-technical change along established pathways of development'. System innovations are understood as being emergent rather than tightly planned, with lengthy periods of experimentation, learning and network building (Geels & Schot, 2010: 80). This is associated with an iterative, reflexive policy style, aimed at 'bending' innovation dynamics in the direction of policy objectives, rather than imposing more direct control (Elzen et al., 2004). Transitions Studies' niche-led perspective is intertwined with its interest in sustainable innovation: niches provide vital 'incubation spaces' where more sustainable technologies can be created and nurtured (Kemp et al., 1998).

Transitions Studies offered a systematic, intelligible way to frame the complex structures and dynamics of socio-technical change, and in the early-2000s it started to gather increasing attention in academic and policy circles, especially in western Europe. By the mid-2000s, its rising status in sustainable innovation studies started to meet with some critical attention. In one prominent critique, Berkhout, Smith and Stirling (2004) identified a need to challenge the niche-led account, and called for greater attention to the way landscape pressures, such as policy directives, market reforms and public opinion could place direct pressure on regimes – and to regimes' adaptive capacities under such pressures.

Soon after, Geels accepted a 'bias towards novelty' in the MLP (Geels, 2005: 85), and subsequent theoretical contributions have acknowledged that niches alone are incapable of system innovation. Geels and Schot (2007) offered a typology of 'transition pathways' based on different niche-regime-landscape relationships, some of which admit a more proactive role for regime agency: in the *transformation pathway*, new regimes grow out of old ones under moderate landscape pressures; in the *reconfiguration* pathway, incumbents' adoption of components developed in radical niches triggers a subsequent system innovation. Even so, system innovations were still seen as arising in niches, with regimes to be either enrolled or overthrown (Geels & Schot 2007; 2010).

Technological Innovation Systems

Rather than the sociology of technology, the conceptual origins of Technological Innovation Systems (TIS) studies lie more in 'evolutionary economic' theories of technology variation and selection. Evolutionary economics is more attendant to structural aspects of innovation than constructivist sociology – its pioneers introduced the concept of 'technological regimes' (Nelson & Winter, 1982). Even so, evolutionary economics also offers an essentially niche-led account of innovation dynamics, with technology variation and selection operating mainly through firms and markets (Nill & Kemp, 2009).

Over the past two decades evolutionary economics has spawned a number of innovation systems frameworks, focussing variously on nations, sectors, regions and technologies. Within this, *technological* innovation systems framings have a particular orientation to niche-led change. Carlsson and Stankiewicz (1991: 112) distinguished their technological systems analysis from the national innovation systems approach by its 'greater emphasis on microeconomic aspects … than on institutional infrastructure'. Looking back at the development of both national and technological IS approaches in the 1980s and 1990s, Carlsson, Elg and Jacobsson (2010) contrasted the top-down national innovation systems approach (developed by the OECD) with the bottom-up technological systems approach articulated in parts of Swedish academia; they noted rival theories were tools in a 'political struggle over the nature of science and technology policy' (Carlsson et al., 2010: 162).

Weber and Hoogma (1998: 546, emphasis added) contrasted the attention to 'macroscopic' factors in national innovation systems studies with their micro-level technology systems perspective, which involves '*assuming* that new technologies typically become established on the basis of bottom-up processes'. Criticising the perceived failings of national innovation systems analysis for its 'institutional determinism', Hekkert et al. (2007: 414-415) made clear that in developing their TIS framework – which has been influential in academia and policymaking over the past decade – their concern was to 'take the firm, or the entrepreneurial project, as a starting point'.

Two broad phases of development are often identified in TIS Studies: an initial, *formative* phase characterised by the trialling and testing of novel designs, establishing niche markets and building-up societal legitimacy for a new technology; and a subsequent *market expansion* phase, characterised by market growth, learning-by-doing and scale economies (Jacobsson & Bergek, 2004; Jacobsson et al., 2004). Much TIS research has focussed on the formative phase, and TIS theoreticians have stressed the need for long periods of interactive learning and network building in this period. Jacobsson et al. (2004) suggested that 'several decades' of formative phase learning were typically needed, often with little to show by way of deployment over the first few decades; they added that policy support in the formative phase should emphasise 'variety rather than volume' – i.e. small-scale experiments rather than scale economies.

Later versions of TIS theory have analysed innovation dynamics as a group of several interacting system *functions* (e.g. Hekkert et al., 2007; Bergek et al., 2008). This functional framing retains an emphasis on micro-level agency as an engine of system development, especially firm-level entrepreneurship. Positive feedback loops between functions – 'motors of sustainable innovation' – are seen as the mechanism for accelerated innovation system development (Suurs & Hekkert, 2012).

The TIS view of innovation dynamics has been criticised for offering a 'point source' narrative, with the wider world understood mainly as an enabler of (or barrier to) emergent system growth (Geels, 2007; Markard & Truffer, 2008). Nevertheless, and despite some ontological tensions between Transitions Studies and TIS (Geels, 2010) they are seen by some as complementary (Markard & Truffer, 2008) and there have been recent efforts to combine them together (e.g. Meleen & Farla, 2013). According to Suurs and Hekkert (2012: 154) for all 'quasi-evolutionary theories' (strategic niche management, MLP, TM and TIS) 'a transition is regarded as a regime shift … through an accumulation of niches that interact with a destabilizing regime'.

Applying Sustainable Innovation Studies: Research-Policy Exchange

Transitions Management[4]

From its beginnings, Transitions Studies has been concerned to interact with and inform policy; Kuhlman et al. (2010) noted their 'basic assumption' that practice, policy, research and theory formed an interactive, learning 'dance floor' – a metaphor that perhaps best resonates in the Netherlands (Rotmans et al., 2001; Rotmans & Kemp, 2003). From the outset, energy systems were a key domain for testing out Transitions Studies in practice, and there are now a number of 'insider' retrospective accounts of the implementation of Transitions Studies approach in Dutch energy and environmental policy (e.g. Kemp & Rotmans, 2009; van der Loo & Loorbach, 2012), and also reviews from interested 'outsiders' (e.g. Kern & Smith, 2008; Meadowcroft, 2009; Kern, 2011; 2012a).

As these contributions make clear, Transition Management – the strand of Transitions Studies concerned with policy application and research-policy exchange – involved close collaboration between policymakers and researchers. Kern (2011) traced the origins of TM to a small group of researchers, policymakers and consultants with shared 'firm beliefs' on the need for transformational long term changes in socio-technical systems. While there was substantial informal co-operation within this group, business actors were less involved. Although in some ways a radical movement – van der Loo and Loorbach (2012: 220) describe TM as an attempt to 'radically transform a dominant regime', it also resonated with a long-established Dutch 'polder' model of deliberative, consensus-based politics (Kern, 2011).

Initial interest in Transitions Studies among Dutch policymakers reflected perceived shortcomings of earlier environmental policies. TM offered a promising alternative to, on the one hand, more direct planning and control approaches (which were thought too disruptive) and, on the other hand, to the use of economic incentives (which were thought too weak) (Rotmans et al., 2001). However, the appeal of TM also reflected ongoing changes in the institutional context of energy and environmental policymaking in the Netherlands – especially, its promise to allow policymakers to retain influence at a time of Dutch energy sector liberalisation (Kern, 2011). Van der Loo and Loorbach, (2012: 223) noted that TM 'fitted nicely in the ongoing policy debate'.

There are now several studies reporting the limited impact of TM on Dutch energy policy and energy system change. For Kern and Smith (2008), these limitations reflected over-optimism about the prospects of radical change, and the neglect of powerful political and commercial forces. Van der Loo and Loorbach (2012: 221) conceded that over the course of the 2000s, the Dutch Energy Transition Project had 'not …been able to change the dominant energy regime'. They traced these failings to the loss of early radical ambitions as the project became institutionalised, and they concluded that 'the dominant regime appears to slow down the energy transition effort, if not overtly countering it' (van der Loo & Loorbach, 2012: 243). These problems have not been restricted to the Netherlands: Heiskanen et al. (2009) reported TM's sceptical reception and limited impact in Finland, in terms of the 'huge distance … [to] prevailing policy realities', including a high level of conflict on energy policies.

There is no agreement about the implications of the limited impacts of Transition Management within the Transitions Studies community. For some, the lesson drawn is for a changed tactical response: for example, redirected efforts on cities and regions to escape the resistance of incumbent national regimes (Markard et al., 2012). Weber and Rohracher (2012) argued for a blending of Transition Studies' radical, 'transformation-oriented' (but weakly influencing) agenda with the more conventional, 'structurally-oriented' (but more policy-friendly) agenda of TIS.

For others, the implication is for reflection on the conceptual tenets and strategic ambitions of Transitions Studies and TM. Meadowcroft (2009) noted the inescapably complex and contested nature of sustainable energy transitions. One aspect of this complexity is *technological ambiguity*, in that the transformative potential of technologies such as carbon capture and storage – a technology dismissed by some transitions scholars as a short-term technical fix (e.g. Rotmans & Kemp, 2003) – cannot be known in advance. Even if it was possible to categorise CCS unambiguously as an 'incremental' technology, Meadowcroft (2009) added, it may still be judged desirable in a context of urgency and fossil fuels lock-in. Meadowcroft concluded that 'we should probably avoid getting too hung up on 'system change' … our concern should be solving societal problems, not tilting at 'systems'' (Meadowcroft, 2009: 336).

Research-Policy Exchange in the UK

Unlike the Netherlands, there have been few tangible links between UK energy policy and innovation studies over the past two decades. This contrast reflects very different political and institutional settings. In the UK, the re-emergence of public energy policymaking in the early-2000s happened well after the privatisation and liberalisation of the energy industries. As Kern (2012b) has noted, UK recent energy policy interventions have been led by Government and business interests, with only a minor role for academics, and weak analytical capacity within the UK civil service. In the Netherlands, the rise of climate change concerns coincided with energy sector liberalisation, and academic framings such as Transitions Studies offered the promise of a still-important role for public policymakers.

Nevertheless, the gathering policy drivers provided some opportunities for research-policy exchange, and there is evidence that parts of the energy policymaking community in the early 2000s was receptive to (if not prepared to explicitly reference) the radical, niche-led perspective associated with Transitions Studies.[5] This was most manifest in the UK Cabinet Office's Performance and Innovation Unit's *Energy Review* (PIU, 2002). In her insider account Mitchell (2008: 71) suggested that the PIU Review, in its transparency and accountability, 'represented a fundamental move away from the paradigm principles in place in the UK'. MacKerron (2009: 79) also suggested that the policymaking style of the early-2000s was a radical departure from UK technocratic traditions, 'less incremental … [and] more inclusive' (MacKerron, 2009: 83). Soon after, according to Mitchell, resistance to change developed and subsequent policies, including 2003 and 2007 policy statements, 'returned energy policy to … the large scale, few large companies, centralized route' (Mitchell, 2008: 122).

A more centralised and authoritarian policy style had quickly re-emerged. MacKerron (2009: 87) concluded that by the end of the 2000s, faced by trade-off between *urgency of response* and *societal legitimacy*, UK energy policymaking had 'largely abandoned the search for legitimacy'. For Scrace and Watson (2009), the changed style of UK energy policymaking over this period reflected the revised perceptions of policymakers and regime incumbents (large utilities, power equipment suppliers, construction companies, fossil fuel companies and industry associations). Similarly Kern (2012b) noted that powerful vested interests made for an 'technocentric, supply-side' policy style, and he called for 'systematic uncovering of the institutional biases and resistances' involved. Mitchell drew a clear lesson from this experience, in terms of the need to break the institutional 'band of iron' holding the UK energy system together: 'regime change … has to occur if a sustainable energy system is to develop … the current political paradigm … has to be broken' (Mitchell, 2008: 88, 202).

In the Netherlands, the term 'transition' became a shared construct of researchers and policymakers (Kern, 2012b). In the UK, while some transitions terminology entered policy language – most prominently the Government's *Low Carbon Transition Plan* – the substantive focus quickly reverted to large scale technology-based solutions. The Transition Plan, though ambitious in its scale and speed of envisaged change, articulated an essentially non-radical, scaled-up version of system architecture and institutions: 'by 2050 virtually all electricity will need to come from renewable sources, nuclear or fossil fuels where emissions are captured … electricity is likely to be used more extensively for heat and transport, so we will probably need more than today' (HMG, 2009a: 169). It is also focussed on the relatively short term: while the Plan articulated a detailed 'route-map' to 2020, post-2020 change was portrayed essentially as a follow-on problem.

Discussion: Accelerated Energy Innovation and Sustainable Innovation Theory

Recent Debates in Transitions Studies: Transition Dynamics and the Role Of Regimes

The characterisation of transitions as radical and disruptive remains an important theoretical starting-point for many transitions scholars; as van der Vleuten and Högselus (2012: 99) noted, 'despite several studies suggesting regime-internal capacity for change, by far most transition research continues to define and study regimes exclusively as a site of resistance to change'. There are many examples; for Voß, Smith and Grin (2009: 277, 282-3, emphasis added), transition management '*presumes* radical innovation in governance priorities … the radical transformation of socio-technical systems … is considered necessary'. Verbong and Loorbach (2012: 7, 14) agreed that 'radical, structural change is needed to erode the existing deep structure (incumbent regime) of a system and ultimately dismantle it'. This upfront framing carries powerful policy implications; for Voß, Smith and Grin (2009: 284), it means "breeding' and 'growing' sustainable systems from niches'; for Smith, Voß and Grin (2010: 445) it implies the destabilisation of incumbent regimes and the promotion of radical green niches. Turnheim and Geels (2012: 49) agreed that 'destabilisation is a relevant focus for advocates of sustainability transitions'.

Alongside these positions, however, are a number other contributions – some empirical, some conceptual – which describe a more proactive account of regime agency in transition dynamics. Raven (2007) differentiated between *niche accumulation* and *regime hybridisation* dynamics; the latter, in which incumbent firms were 'driving actors', were thought particularly important for infrastructure technologies, given their tight coupling and high entry barriers. Raven added that in some situations novel innovations could be incubated in regimes rather than niches. Konrad et al.'s (2007) study of cross-regime dynamics for prospective transitions led to their questioning any ex-ante presumption of niche-led change: 'we should not presuppose that a regime shift is necessarily the one best way' (Konrad et al., 2007: 1192). Geels (2010; 2011) acknowledged that incumbent agency may go beyond reactionary and defensive responses to niches, conceding that many MLP studies have presented homogeneous, monolithic accounts of regimes, under-attending to their 'internal tensions, disagreements and conflicts of interest' (Geels, 2011: 31). Verbong and Geels (2012: 207–8, 217) noted that:

> early multi-level studies suggested that radical innovations emerge in niches, break through and overthrow the existing regime … this pattern … is less likely in infrastructural systems, like the electricity system … due to the enormous sunk investments and the ongoing and planned activities to expand and reinforce existing grids, it does not seem very likely that the electricity system will change as dramatically as some visionaries want us to believe.

Based on a study of different patterns of energy governance across the European Union, Nilsson (2012: 315) concluded that it was 'an open question whether a low carbon energy transition is really contingent on regime destabilization … given the need for large-scale systems, and investments, many mechanisms of the transition appear facilitated, and even dependent, on the current regime'. Similarly, van der Vleuten and Högselus' (2012: 98) analysis of European energy network operators 'challenge[d] the dominant assumption in early transition research that incumbent regimes resist radical change'. Van der Vleuten and Högselus called for a recalibrated approach to transitions research: 'regime analysis should not *take for granted* the 'conservative' nature of regimes and their resistance to major change … we call for a symmetrical analysis of regime stability and change' (van der Vleuten & Höglesus, 2012: 78, emphasis added).

The Multiform Dynamics of Energy Innovation

The emergence of accelerated innovation in the UK energy system and ongoing debate in sustainable innovation studies on the necessarily disruptive nature of transitions invites consideration of the possibility of continuity-based energy system change. There is some historical evidence that continuity-based, incremental innovation has been a significant driver of energy system change. For example, reviewing US federal government energy innovation efforts, Newell (2011) noted the importance of incremental innovation in several areas, such as resource extraction and processing, internal combustion engine efficiencies, industrial process efficiencies and nuclear power capacity factors. Efforts at breakthrough innovations, such as on synthetic fuels, tended to have much less impact. For Newell, the success of incrementally-oriented innovation programmes derived from their ability to leverage incumbent interests and resources. Similarly, Solomon and Krishna (2011) identified incumbent support (and central planning), as key elements in the resilience and growth of Brazilian sugarcane fuel and French nuclear power programmes. In the UK electricity system, incremental innovation (conversion efficiency improvements and technology substitution & fuel switching) had a significant impact – reducing effective CO_2 emissions by over 36% between 1990 and 2009 (DECC, 2010).

There is also evidence that regime incumbents may be more dynamic than is often presupposed. Christensen's (1997) account of the challenges of disruptive innovation for incumbents has been accused of a selective reading of empirical evidence and for overstating the innovative inertia of incumbents (Danneels, 2004; Macher & Richman, 2004). This is borne out by some historical evidence. In the UK electricity sector, incumbent organisations proved highly responsive to disruptive threats associated with industry privatisation, and transformed their long-established technology strategies in a few months (Winskel, 2002). Bergek et al. (2013) found some incumbents in the automotive and energy sectors capable of driving and absorbing disruptive innovation– challenging received assumptions in the strategic management literature: 'we identify over-optimism regarding new entrants' abilities to disrupt established industries, *partially generated by [management] theories*' (Bergek et al., 2013: 1210, emphasis added).

Other evidence highlighted a range of incumbent strategies to landscape pressures. Stenzel and Frenzel (2008: 2645) found both proactive and defensive responses by utilities to the challenge of renewables development: 'although incumbents are usually seen as being resistant to change … some utilities proactively drove change'; they concluded that co-opting incumbents into the policy process could lead to 'virtuous circles of technology diffusion and capability development' (Stenzel & Frenzel, 2008: 2656). In recent UK debates on electricity market reform, different utilities have aligned themselves with alternative policy support mechanisms, according to their technology assets and strategic interests – such that a UK parliamentary committee observed that 'low-carbon generation must not be viewed as a homogenous category' (HCECC, 2012: 31).

Prescriptions for Accelerated Energy Innovation

As energy system change has become a priority for energy policymakers and strategists, it has attracted the interest of wider sections of the academic community. The result has been a burgeoning number of prescriptions for accelerated system change and energy innovation. A recurring (though often underlying) theme in this debate is the relative merits of different innovation styles (or governance arrangements) innovation. While a number of different terms and typologies have been introduced[6], distinctions can be drawn between advocates of *niche-led* change (dominated by relatively decentralised, emergent, bottom-up and discontinuous dynamics); *regime-led* change (dominated relatively incremental and continuous dynamics); and *breakthrough* change (dominated by centrally co-ordinated, top-down dynamics).

For example, Mowery, Nelson and Martin (2010) advocated an essentially niche-led approach: decentralised, diverse, with long periods of niche-based learning; they concluded that emergent nature of energy system change meant that it was ‘difficult if not impossible to plan or predict the structure of the overall R&D effort in any detail’ (Mowery et al., 2010: 1020). Others have cautioned against niche-led disruptive change. Unruh (2002) concluded that given deep levels of energy system lock-in, established development pathways, aligned with incumbent corporate and political interests, were likely to offer more effective responses to urgent change imperatives. Similarly, for Hargadon (2010), the high upfront costs and long asset lifetimes of energy technology implied a continuity-based approach: ‘eschewing the transformational potential of a technology precisely because its technical artefacts, patterns of production and consumption, experiences, labor etc. exist already may preclude the very attributes that enable rapid scaling and broad adoption’ (Hargadon, 2010: 1026). Rather than novelty, Hargadon called for a focus on bottlenecks affecting existing technologies.

However, while he advocated a regime-led continuity-based response, Hargadon (2010) cautioned against centrally-planned breakthrough efforts, citing the historic failings of US energy innovation in this regard. Indeed, while breakthrough metaphors have been prominent in US energy innovation policy efforts (Anadón, 2012) few academic contributors have advocated such a response. In one such contribution, however, Perrow (2010) argued that although decentralised approaches were appropriate for some parts of the energy system (such as energy efficiency) a centralised top-down approach *was* appropriate for large-scale generation technologies such as carbon capture and storage.

Conclusion and Future Research: Accelerated Energy Innovation Studies

This paper has traced the emergence and manifestation of ‘accelerated energy innovation’ in the UK energy system – and considered its possible implications for sustainable innovation research. Our underlying philosophy – shared with others in the sustainable innovation studies community – is that policy, practice and theory should be seen as co-evolving, interacting domains with aspirations of mutual shaping over time.

In the late-2000s, under urgent drivers for energy system change – decarbonisation, supply security, affordability and business growth – the UK energy innovation system was remade around the ‘accelerated innovation’ imperative (Table 2). This remaking involved a prominent role for the private sector and for public-private partnerships, to relatively short-term innovation dynamics around deployment and cost reduction, and to the scaling-up or renewal of existing technologies and infrastructures.

Table 2. UK Energy Innovation System Development since 2000.

Period	Economic and Political Context	Institutional Setting	Governance Style
Early-2000s	Benign economic context. Decarbonisation driver emerges, though overall energy system driven by market actors.	Growing but still small innovation spending. Public sector-led small-scale initiatives.	*Niche-based*. Marginal role of innovation in energy system change, focus on long-term transition.
Late-2000s	Benign economic context. Long-term decarbonisation commitment, but growing security and business development drivers.	Rapidly growing public spending. Emphasis on mainstream business-led initiatives and public-private partnerships.	*Shift to continuity-based.* Innovation re-oriented to regime organisations and closer alignment to overall system goals.
Early-2010s	Economic / financial crisis; Statutory commitments on decarbonisation and renewables, but strong cost reduction / growth drivers.	Rapidly fluctuating public spending. Business-led agenda, but reduced policy / political consensus.	Mostly *continuity-based.* Focus on cost reduction for short term policy targets, but uncertain outlook and growing conflict.

The UK provided a dramatic case of energy innovation system remaking, reflecting the hollowed-out institutional base over which accelerated change imperatives exerted their influence. The private sector had a powerful role in this process, with marginal roles for some public bodies – although public-private partnerships have created many recent opportunities for the public energy research community. The manifestation of accelerated energy innovation in other national and international settings – and the extent to which the UK case is highly particular, or illustrative of wider trends – is an important research issue.

The paper also reviewed recent developments in sustainable innovation studies, especially 'quasi-evolutionary' theories. A number of recent contributions here have recognised the prospects of more continuous, incumbent-led dynamics in energy innovation and system change – perhaps reflecting the emergence of accelerated innovation imperatives, and also, the limitations of Transition Management in practice. Our paper was intended as a contribution to this ongoing debate; rather than *advocating* regime-led change, our aim has been to recognise accelerated energy innovation as an important recent phenomenon in the UK, and reflect on its implications for research and research-policy exchange.

As yet, accelerated energy innovation remains more of a policy and strategy phenomenon than a material influence on wider energy system change (in terms, for example of reduced technology cost or accelerated deployment of large scale technologies). Indeed, the technologies identified as major contributors to accelerated system change in the UK – nuclear power, offshore wind and carbon capture and storage – have all recently experienced cost escalations and/or delayed roll-out. While ongoing regulatory changes are aimed at addressing these issues (HMG, 2013), their impact has yet to be seen, and in the meantime the prospects for accelerated innovation are uncertain and contested, with some analysts calling for a reduced coupling between energy innovation strategy and deployment imperatives in the shorter term, and a refocused emphasis on longer term radical innovation. In this context, efforts at regime-led system change may be considered the first phase of a sequence of transition types, with regime-displacing change to follow on under sustained landscape pressures (see Geels & Schot, 2007: 413; Geels & Schot 2010b: 77).

Even under an uncertain outlook, however, the working-out of the accelerated innovation imperative has already seen the wholesale remaking of the institutions, governance and spending patterns of the UK energy innovation system. Organisations manifesting the imperative such as the Energy Technologies Institute and Technology Strategy Board have transformed energy innovation practice in the UK – not just among their private sector interests, but also for much of the public energy researcher base. Accelerated innovation forces have not only driven the remaking of energy innovation policy and strategy – they have reshaped innovation practice, and redefined the role of innovation in wider socio-technical system change.

As such, we have argued, the accelerated energy innovation phenomenon invites critical reflection within sustainable innovation studies, attending to the dissonance between sustainable transition theories and energy innovation policy and practice. For example, within the established Transition Studies' typology, moderate landscape pressures are associated with relatively continuous, regime-led responses, and stronger or more acute pressures with more discontinuous, niche-led changes. In the UK case, however, gradual landscape pressures were relatively accommodating of emergent, niche dynamics, while more acute pressures prompted a shift to continuity-based dynamics. The extent to which regime reinforcement is a characteristic response to urgency is another key research question.

In the wider research literature, alternative styles of energy innovation have been articulated, with differing degrees of emphasis on incremental and disruptive innovations. Some advocate a portfolio of styles, combining short term continuity with long term disruption (e.g. Weiss & Bonvillian, 2009; Lester & Hart, 2012). The social and technical interdependencies of energy systems are likely to present difficulties here, in terms of calls to break-up incumbent interests while rapidly progressing established technologies, while the suggested migration from incremental to radical solutions will encounter new lock-ins created by efforts to meet short term targets. While some of the contributions to these wider debates may lack theoretical underpinnings, or draw questionable analogies with other sectors, they at least suggest a heterogeneity of possible responses to urgent change imperative, and the need further research.

The sustainable innovation studies community has tended to neglect the research agenda associated accelerated energy innovation. In the meantime, other disciplinary perspectives, such as organisational studies, strategic management and risk studies have offered insights, for example, on the relative merits of planned or adaptive management styles (Lenfle, 2011), on energy technology innovation as corporate strategy propositions (Bowen, 2011), and on the socio-technical risk profiles of different energy technologies (Millar & Lessard, 2008). Geels (2011) has recognised the prospective added value for transitions studies from wider disciplinary contributions, and Markard, Raven and Truffer (2012) set out how the field could be 'enriched and challenged' by opening it up to disciplines such as economic geography, political science and the philosophy of science. As well as these wider contributions, there is also prospective value from drawing on neglected strands of innovation studies, such as large technical systems theory (Hughes, 1983; Summerton, 1994; Coutard, 1999).

Sustainable innovation studies has provided many important contributions to knowledge and research-policy exchange: revealing the dynamic interplay of multi-level structures and agents, and the value of diversity and experimentation in early stage innovation. Such contributions – and innovation studies' underlying commitments to reflexive and critical enquiry – have continuing value, especially given the risks and pitfalls of efforts at accelerated innovation. At the same time, however, there is a need to reflect changed drivers, contexts and responses. In striving for co-evolution with policy and practice, sustainable innovation studies should more fully address the multiform dynamics and governance of energy systems under urgency, across a broad spectrum of continuity-based and disruptive change.

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References

Anadón, L. (2012) 'Missions-oriented RD&D institutions in energy between 2000 and 2010: A comparative analysis of China, the United Kingdom, and the United States,' Research Policy 41(10): 1742-1756.

Anadón, L., E. Mielke, H. Lee, M., Bunn & V. Narayanamurti (2010) Transforming the Energy Economy: Options for Accelerating the Commercialization of Advanced Energy Technologies: Framing Statement Energy Technology Innovation Policy (Boston: Harvard Kennedy School).

Bergek, A. & S. Jacobsson (2002) 'The Emergence of a Growth Industry: A Comparative Analysis of the German, Dutch and Swedish Wind Turbine Industries,' in S. Metcalfe & U. Canter, U. (eds), Change, Transformation and Development: Schumpeterian Perspectives (Heidelberg: Physica/Springer): 197-228.

Bergek, A., S. Jacobsson, B. Carlsson, S. Lindmark & A. Rickne (2008) 'Analyzing the functional dynamics of technological innovation systems: A scheme of analysis,' Research Policy 37(3): 407-429.

Bergek, A., C. Berggren, T. Magnusson, M. Hobday (2013) 'Technological discontinuities and the challenge for incumbent firms: Destruction, disruption or creative accumulation,' Research Policy 42(6-7): 1210-1224.

Berkhout, F., A. Smith & A. Stirling (2004) 'Socio-technical regimes and transition contexts,' in B. Elzen, F. Geels & K. Green (eds), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy (Cheltenham: Edward Elgar): 48-75.

BIS (Department of Business, Innovation and Skills) (2009) R&D Scoreboard (London: Department of Business, Innovation and Skills).

Bowen, F. (2011) 'Carbon capture and storage as a corporate technology strategy challenge', Energy Policy 39(5): 2256-2264.

Carlsson, B. & R. Stankiewicz (1991) 'On the nature, function and composition of technological systems', Journal of Evolutionary Economics 1(2): 93-118.

Carlsson, B. Elg, L. & S. Jacobsson (2010) 'Reflections on the Co-evolution of Innovation Theory, Policy and Practice: The Emergence of the Swedish Agency for Innovation Systems', in R. Smits, S. Kuhlmann & P. Shapira (eds), The Theory and Practice of Innovation Policy, (Cheltenham: Edward Elgar): 145-166.

CCC (Committee on Climate Change) (2008) Building a Low-Carbon Economy: The UK's Contribution to Tackling Climate Change (London: TSO).

CEC (Commission of the European Communities) (2009) Directive 2009/28/EC of the European Parliament on the promotion of the use of energy from renewable sources (Brussels: Commission of the European Communities).

Christensen, C. M. (1997) The Innovators' Dilemma : When New Technologies Cause Great Firms to Fail (Boston: Harvard Business School).

Coutard, O. (ed.) (1999) The Governance of Large Technical Systems (London: Routledge).

Danneels, E. (2004) 'Disruptive technology reconsidered: a critique and research agenda', Journal of Product Innovation Management 21(4): 246-258.

DECC (Department of Energy and Climate Change) (2010) Energy Trends: March 2010 (London: National Statistics and DECC).

DECC (2011a) Planning Our Electric Future: A White Paper for Secure, Affordable and Low Carbon Electricity (London: Department of Energy and Climate Change).

DECC (2011b) Overarching National Policy Statement for Energy (EN-1) (London: The Stationery Office).

DTI (Department of Trade and Industry) (2003) Our Energy Future: Creating a Low Carbon Economy (London: Department of Trade and Industry).

DTI (2006) The Energy Challenge: Energy Review (London: Department of Trade and Industry).

DTI (2007) Meeting the Energy Challenge: A White Paper on Energy (London: Department of Trade and Industry).

Elzen, B., F. Geels & K. Green (2004) 'Transitions to sustainability: lessons learned and remaining challenges', in B. Elzen, F. Geels & K. Green (eds), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy (Cheltenham: Edward Elgar): 282-300.

ERP (Energy Research Partnership) (2007) UK Energy Innovation (London: Energy Research Partnership).

ERRG (Energy Research Review Group) (2001) Recommendations to Inform the Performance and Innovation Unit's Energy Policy Review (London: Office of Science and Technology).

Geels, F. (2002) 'Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study', Research Policy 31(8-9): 1257-1274.

Geels, F. (2004a) 'From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory', Research Policy 33(6-7): 897-920.

Geels, F. (2004b) 'Understanding system innovations: a critical literature review and a conceptual synthesis, in B. Elzen, F. Geels & K. Green (eds), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy (Cheltenham: Edward Elgar): 19-47.

Geels F. (2005) Technological Transitions and Systems Innovations (Cheltenham: Edward Elgar).

Geels, F. (2007) 'Feelings of discontent and the promise of middle range theory for STS: Examples from technology dynamics', Science, Technology & Human Values 32(6): 627-651.

Geels, F. (2010) 'Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective', Research Policy 3 (4): 495-510.

Geels, F. (2011) 'The multi-level perspective on sustainability transitions: Responses to seven criticisms', Environmental Innovation and Societal Transitions 1(1): 24-40.

Geels, F. & J. Schot (2007) 'Typology of sociotechnical transition pathways', Research Policy 36 (3): 399-417.

Geels, F. & J. Schot (2010) 'The dynamics of transitions: A sociotechnical perspective', in J. Grin, J. Rotmans & J. Schot, J. (eds), Transitions to Sustainable Development: New Directions in the Study of Long term Transformative Change (New York: Routledge): 9-101.

Gross, R., P. Heptonstall, D. Anderson, T. Green, M. Leach, M. & J. Skea (2006) The Costs and Impacts of Intermittency: An Assessment of The Evidence on the Costs and Impacts of Intermittent Generation on the British Electricity Network (London: UK Energy Research Centre).

Grubb, M., N. Haj-Hasan and D. Newberry (2008) 'Accelerating innovation and strategic deployment in UK electricity: applications to renewable energy', in M. Grubb, T. Jamasb & M. Pollitt (eds), Delivering a low-carbon electricity system: Technologies, Economics and Policy, (Cambridge: Cambridge University Press).

Grubler, A. F. Aguayo, K. Gallagher, M. Hekkert, K. Jiang, K., L. Mytelka, L. Neij, G. Nemet and C. Wilson, C. (2012) 'Policies for the Energy Technology Innovation System (ETIS)', in Global Energy Assessment: Toward a Sustainable Future (Cambridge: Cambridge University Press and Laxenburg, Austria: the International Institute for Applied Systems Analysis): 1665-1743.

Hargadon, A. (2010) 'Technology policy and global warming: Why new innovation models are needed', Research Policy 39(8): 1024-1026.

HCECC (House of Commons Energy and Climate Change Committee) (2012) Electricity Market Reform, Fourth Report of Session 2010-12 (London: House of Commons Energy and Climate Change Committee).

HCSTC (House of Commons Science and Technology Committee) (2006) Meeting UK Energy and Climate Needs: The Role of Carbon Capture and Storage. (London: House of Commons Science and Technology Committee).

Hekkert, M., R. Suurs, S. Negro, S. Kuhlmann & R. Smits (2007) 'Functions of innovation systems: A new approach for analysing technological change', Technological Forecasting and Social Change 74 (4): 413-432.

Heiskanen, E., S. Kivisaari, R. Lovio & P. Mickwitz (2009) 'Designed to travel? Transition Management encounters environmental and innovation policy histories in Finland', Policy Sciences 42(4): 409-427.

Helm, D. (2003) Energy, the State and the Market: British Energy Policy since 1979 (Oxford: Oxford University Press).

Helm, D. (2012) The Carbon Crunch: How we are getting climate change wrong, and how to fix it (New Haven CT: Yale University Press).

Henderson R. & R. Newell (2011) (eds) Accelerating Energy Innovation: Insights from Multiple Sectors (Chicago: Chicago University Press).

HMG (Her Majesty's Government) (2007) Meeting the Energy Challenge: A White Paper on Energy (London: DTI).

HMG (2008) Climate Change Act (Norwich: TSO).

HMG (2009a) The UK Low Carbon Transition Plan: National Strategy for Climate and Energy (Norwich: TSO).

HMG (2009b) The UK Renewable Energy Strategy (Norwich: TSO).

HMG (Her Majesty's Government) (2011a). Implementing the Climate Change Act 2008: The Governments Proposal for Setting the Fourth Carbon Budget (Norwich: TSO).

HMG (2011b) The Carbon Plan: Delivering Our Low Carbon Future (Norwich: TSO).

HMG (2013) Energy Act 2013 (Chapter 32) (Norwich: TSO).

HMT (Her Majesty's Treasury) (2011) National Infrastructure Plan 2011 (Norwich: TSO).

Hughes, T. (1983) Networks of Power: Electrification in Western Society 1880-1930 (Baltimore MD: John Hopkins University Press).

ICEPT (Imperial College Centre for Energy Policy and Technology) (2003) Innovation In Long Term Renewables Options in the UK: Overcoming Barriers and Systems Failures (London: Imperial College).

IEA (International Energy Agency) (2010) Energy Technology Perspectives 2010: Scenarios and Strategies to 2050. International Energy Agency, Paris.

IEA (2011) Good practice policy framework for energy technology RD&D, International Energy Agency, Paris.

IEA (2012) Energy Technology Perspectives 2012: Pathways to a Clean Energy System, International Energy Agency, Paris.

IEA (2013) Energy Technology Research and Development Database (Edition: 2013) (Manchester: University of Manchester).

Jacobsson, S. & A. Bergek (2004) 'Transforming the energy sector: the evolution of technological systems in renewable energy technology', Industrial and Corporate Change 13(5): 815-849.

Jacobsson, S., B. Andersson & L. Bångens (2004) 'Transforming the Energy System: the Evolution of the German Technological System for Solar Cells', Technology Analysis and Strategic Management 16(1): 3-30.

Jacobsson, S. & A. Bergek (2011) 'Innovation system analyses and sustainability transitions: Contributions and suggestions for research', Environmental Innovation and Societal Transitions 1 (1): 41-57.

Kemp, R., J. Schot & R. Hoogma (1998) 'Regime Shifts through processes of niche formation: The approach of strategic niche management', Technology Analysis and Strategic Management 10(2): 175-195.

Kemp, R. & J. Rotmans (2009) 'Transitioning Policy: co-production of a new strategic framework for energy innovation policy the Netherlands', Policy Sciences 42(4): 303-322.

Kern, F. & A. Smith (2008) 'Restructuring energy systems for sustainability? Energy transition policy in the Netherlands', Energy Policy 36(11): 4093-4103.

Kern, F. (2011) 'Ideas, Institutions and Interests: explaining policy divergence in fostering 'system innovations' towards sustainability', Environment and Planning C: Government and Policy 29(6): 1116-1134.

Kern, F. (2012a) 'An International perspective on the Energy Transitions Project', in G. Verbong & D. Loorbach (eds), Governing the Energy Transition: Reality, Illusion or Necessity? (Abingdon: Routledge): 277-295.

Kern, F. (2012b) 'Using the multi-level perspective on socio-technical transitions to assess innovation policy', Technological Forecasting and Social Change 79(2): 298-310.

Konrad, K., B. Truffer, B. & J-P. Voß (2008) 'Multi-regime dynamics in the analysis of sectoral transformation potentials: Evidence from German utility sectors', Journal of Cleaner Production 16(11): 1190-1202.

Kuhlmann, S., P. Shapira & R. Smits (2010) 'Introduction: A Systemic Perspective: The Innovation Policy Dance', in R. Smits, S. Kuhlmann & P. Shapira (eds),The Theory and Practice of Innovation Policy (Cheltenham: Edward Elgar): 1-46.

Lenfle, S. (2011) 'The strategy of parallel approaches in projects with unforeseeable uncertainty: The Manhattan case in retrospect' International Journal of Project Management 29(4): 359-373.

Lester, R. & D. Hart (2012) Unlocking Energy Innovation: How America can build a Low-Cost, Low-Carbon Energy System (Cambridge, MA: MIT Press).

MacKerron, G. (2009) 'Lessons from the UK on Urgency and Legitimacy in Energy Policymaking', in I. Scrase & G. MacKerron (eds), Energy for the Future: A New Agenda (Basingstoke: Palgrave Macmillan): 76-88.

Macher, J. & B. Richman (2004) 'Organisational Responses to Discontinuous Innovation: A Case Study Approach', International Journal of Innovation Management 8(1): 87-114.

Markard, J. & B. Truffer (2008) 'Technology innovation systems and the multi-level perspective: Towards an integrated framework', Research Policy 37(4): 596-615.

Markard, J. R. Raven & B. Truffer (2012) 'Sustainability transitions: An emerging field of research and its prospects', Research Policy 41(6): 955- 967.

Meadowcroft, J. (2009) 'What about the politics? Sustainable development, transition management and long term energy transitions', Policy Sciences 42(4), 323-340.

Meelen, T. & J. Farla (2013) 'Towards an integrated framework for analysing sustainable innovation policy', Technology Analysis & Strategic Management 25(8): 957-97

Millar, R. & D. Lessard (2008) 'Evolving strategy: Risk management and the shaping of mega-projects' in Priemus, in H. Flyvberg, B and van Wee, B (eds), Decision-making on Mega-Projects: Cost Benefit Analysis, Planning and Innovation (Cheltenham: Edward Elgar): 145-172.

Mitchell, C. (2008) The Political Economy of Sustainable Energy (London: Palgrave / Macmillan).

Moselle, B. & S. Moore (2011) Climate Change Policy: Time for Plan B. (London: Policy Exchange).

Mowery, D., R. Nelson & B. Martin (2010) 'Technology policy and global warming: Why new policy models are needed (or why putting new wine in old bottles won't work)', Research Policy 39(8): 1011-1023.

Nelson, R. & S. Winter (1982) An Evolutionary Theory of Economic Change (Cambridge MA: Harvard University Press).

Newell, R. (2011) 'The energy innovation system: a historical perspective', in R. Henderson & R. Newell (eds), Accelerating Energy Innovation: Insights from Multiple Sectors (Chicago: Chicago University Press): 25-47.

Nill, J. & R. Kemp (2009) 'Evolutionary approaches for sustainable innovation policies: From niche to paradigm?', Research Policy 38 (4): 668-680.

Nilsson, M. (2012) 'Energy Governance in the European Union: Enabling Conditions for a Low carbon Transition,' in G. Verbong & D. Loorbach (eds), Governing the Energy Transition: Reality, Illusion or Necessity? (Abingdon: Routledge): 296-316.

Ofgem (Office of Gas and Electricity Markets) (2010a) Project Discovery: Options for Delivering Secure and Sustainable Energy Supplies. Office of Gas and Electricity Markets (London: Ofgem).

Ofgem (2010b) RIIO: a new way to regulate energy networks (Factsheet 93) (London: Ofgem).

Paredis, E. (2011) 'Sustainability Transitions and the Nature of Technology,' Foundations of Science 16 (2-3): 195-225.

PCAST (US President's Council of Advisors on Science and Technology) (2010) Report to the President on Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy (Washington DC: PCAST).

Perrow, C. (2010) 'Comment on Mowery, Nelson and Martin,' Research Policy 39(8): 1030-1031.

Pinch, T. J. & W.E. Bijker (1984) 'The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other' Social Studies of Science 14(3): 399-441.

PIU (Performance and Innovation Unit) (2002) The Energy Review (London: Cabinet Office).

Raven, R. (2007) 'Niche accumulation and hybridisation strategies in transition processes towards a sustainable energy system: An assessment of differences and pitfalls,' Energy Policy 35(4): 2390-2400.

Rotmans, J., R. Kemp & M. van Asselt (2001) 'More evolution than revolution: Transition management in public policy,' Foresight 3(1): 15-31.

Rotmans, J. & R. Kemp (2003) Managing Societal Transitions: Dilemmas and Uncertainties: The Dutch energy case-study (Paris: Organisation for Economic Co-operation and Development).

RCEP (Royal Commission on Environmental Pollution) (2000) Energy: The Changing Climate (London: RCEP).

Rip, A., T. Misa & J. Schot (eds) (1995) Managing Technology in Society: The Approach of Constructive Technology Assessment (London: Pinter).

Russell, S. (1986) 'The social construction of artefacts: a response to Pinch and Bijker,' Social Studies of Science 16(2): 331-346.

Scrase, I. & J. Watson (2009) 'CCS in the UK: Squaring coal use with climate change?,' in: J. Meadowcroft J. & O. Langhelle (eds), Caching the Carbon: The Politics and Policy of Carbon Capture and Storage (Cheltenham: Edward Elgar): 158-185.

Skea, J., P. Ekins & M. Winskel (2011) 'UK Energy Policy and Institutions' in J. Skea, P. Ekins and M Winskel (eds) Energy 2050: Making the Transition to a Secure Low-Carbon System (London: Earthscan): 41-66

Smith, A., J.-P. Voß, & J. Grin (2010) 'Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges,' Research Policy 39(4), 435-448.

Solomon, B. D. & K. Krishna (2011) ,The coming sustainable energy transition: History, strategies, and outlook,' Energy Policy 39(11): 7422-7431.

Stenzel, T. & A. Frenzel (2008) 'Regulating technological change: The strategic reactions of utility companies towards subsidy policies in the German, Spanish and UK electricity markets,' Energy Policy 36(7): 2645-2657.

Stern, N. (2007) The Economics of Climate Change: The Stern Review (Cambridge: Cambridge University Press, Cambridge), especially Chapter 14: Accelerating Technological Innovation.

Summerton, J. (ed) (1994) Changing Large Technical Systems (Boulder, CO: Westview Press).

Suurs, R. & M. Hekkert (2012) 'Motors of Sustainable Innovation: Understanding transitions from a technological innovation systems perspective', in G. Verbong & D. Loorbach (eds), Governing the Energy Transition: Reality, Illusion or Necessity? (Abingdon: Routledge): 152-179.

Sørensen, K. & N. Levold (1992) 'Tacit Networks, Heterogeneous Engineers, and Embodied Technology', Science, Technology, and Human Values 17 (1): 13-35.

Turnheim, B. & F. Geels (2012) 'Regime destabilisation as the flipside of energy transitions: Lessons from the history of the British coal industry (1913–1997)', Energy Policy 50 (Special Section, November 2012): 35–49.

TSB (Technology Strategy Board), 2008. Energy Generation and Supply: Key Application Areas 2008–2011(Swindon: Technology Strategy Board).

TSB (Technology Strategy Board) (2011a) Concept to Commercialisation: A Strategy for Business Innovation, 2011-2015 (Swindon: Technology Strategy Board).

TSB (Technology Strategy Board) (2011b) Technology and Innovation Centres: Closing the gap between concept and commercialisation (Swindon: Technology Strategy Board).

Unruh, G.C. (2002) 'Escaping carbon lock-in', Energy Policy 30(4), 317-325.

Unruh, G.C. & J. Carrillo-Hermosilla (2006) 'Globalizing carbon lock-in', Energy Policy 34(10): 1185-1197.

van den Bergh, J. , B. Truffer & G. Kallis (2011) 'Environmental innovation and societal transitions: Introduction and overview' Environmental Innovation and Societal Transitions 1(1): 1-23.

van der Loo, F. & D. Loorbach (2012) 'The Dutch Energy Transition Project (2000-2009)', in G. Verbong, & D. Loorbach (eds), (2012), Governing the Energy Transition: Reality, Illusion or Necessity? (Abingdon: Routledge): 220-250.

van der Vleuten, E. & P. Högselus 'Resisting Change: The transnational dynamics of European energy regimes', in G. Verbong & D. Loorbach (eds), Governing the Energy Transition: Reality, Illusion or Necessity? (Abingdon: Routledge): 75-100

Verbong, G. & F. Geels (2012) 'Future Energy Systems: visions, scenarios and transition pathways', in G. Verbong & D. Loorbach (eds), Governing the Energy Transition: Reality, Illusion or Necessity? (Abingdon: Routledge): 203-219.

Voß, J-P, A. Smith & J. Grin (2009) 'Designing long-term policy: rethinking transition Management', Policy Sciences 42(4): 275-302.

Weber, K. & R. Hoogma (1998) 'Beyond National and Technological Styles of Innovation Diffusion: a dynamic perspective on cases from the energy and transport sectors', Technology Analysis and Strategic Management 10(4): 545-566.

Weber, K. & H. Rohracher (2012) 'Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework', Research Policy 41(6): 1037-1047.

Weiss, C. & W. Bonvillian (2009) Structuring an Energy Technology Revolution (Cambridge MA: MIT Press).

Winner, L. (1993) 'Social constructivism: opening the black box and finding it empty', Science as Culture 18(3): 427-452.

Winskel, M. (2002) 'When systems are overthrown: the dash for gas in the British electricity supply industry', Social Studies of Science 32(4): 565-599.

Winskel, M., A. McLeod, R. Wallace, R. & R. Williams (2006) 'Energy policy and institutional context: marine energy innovation systems', Science and Public Policy 33(5): 365-376.

Winskel M., G. Anandarajah, J. Skea & B. Jay (2011) 'Accelerating the Development of Energy Supply Technologies: The Role of Research and Innovation', in J. Skea, P. Ekins & M. Winskel (eds), Energy 2050: Making the transition to a secure low carbon energy system (London: Earthscan) 187-218.

Notes

1 The first author was Research Co-ordinator of the UK Energy Research Centre (2009-14); the second author was Head of the Analysis Team at the UK Energy Research Partnership (2008-13); both positions involved regular liaison with UK energy policymakers, researchers and other stakeholders.

2 As Paredis (2011) noted, Transitions Studies retains an essentially constructivist orientation.

3 Schot and Geels (2008: 539) described Strategic Niche Management (a close relation of the MLP) as 'an attempt to import insights from constructivist science and technology studies into evolutionary economics'.

4 The focus in this section is on Transitions Studies / Management, rather than TIS, because of the greater availability of reviews of MLP-TM use in policy. This is not to discount the policy impact of TIS: Suurs and Hekkert (2012) reported that TIS became 'the dominant paradigm in evaluating and steering societal innovation programmes in the Netherlands' (Suurs & Hekkert, 2012: 177).

5 UK policymakers also showed explicit interest in the TIS perspective in this period – most notably in the UK Government's Renewables Innovation Review (ICEPT, 2003; Winskel et al., 2006)

6 Unruh and Carmillo Hermosilla (2006) differentiated between *end-of-pipe* solutions (such as carbon capture and storage), *continuity approaches* (such as large scale renewables adopted in centralised networks); and *discontinuity approaches* (such as network reconfiguration, and 'strategic niche management').

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The Governance of Innovations in the Energy Sector:
Between Adaptation and Exploration

Gerhard Fuchs

The field of electricity supply has slowly evolved over a long period of time. Electricity supply constitutes an example of a large technical system resistant to sudden changes or reorientations. The essential incentives for changes have come from the so called oil-price shocks in the mid ninety-seventies of the last century, the Chernobyl accident and the resulting critical attitude towards nuclear energy in many countries, the liberalization of markets driven forward by the European Commission, discussions about climate change and finally the Fukushima catastrophe. Such external events can lead to changes in governance structures. The standard operating procedure is to have the incumbent actors deal with external challenges in the established way of doing things (structures and actors). We assume that changes in the governance structure are not an immediate reaction to external shocks, but rather these external shocks have to be interpreted, mediated by new, skilled actors and perceived as a chance to see things differently and organize and build coalitions around these new frames. For a successful transformation, a change in the relevant power constellations which supports the incumbent governance structure is required. Processes of change in the end deal with the following question: which actors can achieve what aims under what conditions? The article will analyze four prominent cases in the energy sector to illustrate this point: the governance of the carbon dioxide capture & storage technology in Germany and Norway and the governance of photovoltaics development in Japan and Germany.

Keywords: energy technologies, governance, innovation, strategic action fields

Governance of Innovations: Structural Stability and Change

Over the last couple of years, research on governance has made much progress. We are now better able to understand how markets work, what mechanisms account for the functioning of industrial sectors and how technological developments come about and influence industrial activities (Ugur, 2013). In all these areas, coordination problems have to be solved in order to allow for a smooth operation of activities (Hall & Soskice, 2001; Beckert, 2009). Coordination problems are dealt with by a varying mix of private and public actors in a more or less organized manner. Governance in this context can be defined as all forms and mechanisms used for the coordination of actors, whose actions are interdependent, i.e. they can support each other in achieving specific aims or prevent them from happening (Benz et al., 2007: 9). The reflections on the importance of governance structures are theoretically usually informed by institutionalist thinking (Werle, 2012) and predominantly analyze specific regulatory structures (Mayntz, 2004). Research has thus been concentrated on the more static and structural aspects of governance. Most of the governance literature focuses on the internal operation of governance structures and presupposes that they are working in a more or less self-sufficient manner. At least as important, however, is the challenge to analyze the *change* of existing governance structures. It has been sufficiently discussed that structures, institutions as well as organizations are characterized by a specific immobility (Scott, 2001). Path dependence - among other factors - plays a significant role in making more radical change difficult (see Fuchs, 2012; Fuchs & Shapira, 2005). Verbong and Loorbach (2012) have recently established that especially in the field of energy infrastructures, "transition" to a new state is hard to come by. This is the effect of the inertia inherent in established governance structures. If we assume that to fight climate change, significant changes in the way our established system of electricity generation works have to be made, it is paramount to ask, whether the existing governance structures are fit for that task or whether we need to look for new forms or structures of governance to ensure a transition towards a more sustainable infrastructure. Studies employing an institutionalist framework or studies that are informed by one or the other strand of evolutionary theory have repeatedly and successfully attempted to show that changes especially of a fundamental nature will be the result of "external" demands (Meyer & Rowan, 1977) or major crisis and shocks emanating from the environment (Gould, 2002). Fundamental changes furthermore are not driven forward by the incumbent actors in a specific field, sector, organization or policy domain, but by challenger groups. The transformation of a field is linked to the successful realization of radical innovations as opposed to incremental innovations. Incremental innovations improve on existing ways, activities, conceptions and purposes of doing things, while radical innovations change the ways things are done. Under this definition, the key to classifying something as a radical innovation is the degree to which it reverberates out to alter the interacting system of which it is a part (cf. Padgett & McLean, 2006). How do radical innovations then come about and can we analyze the preconditions of stability and change with the same analytical apparatus? The present paper tries to make the suggestion that the Theory of Strategic Action Fields provides just such an analytical approach (Fligstein & McAdam, 2011; 2012). The potential usefulness of the approach will be demonstrated by four case studies from the field of electricity supply.

Analyzing Technologies and Sectoral Transformation

Earlier research within Science and Technology Studies and related fields has developed different analytical approaches to study sectoral transformation. Some of these will be briefly discussed here to help better understand the theoretical option we are advancing. One important line of reasoning can be associated with the so called "transition" literature heavily influenced by the work of Frank W. Geels (2005; 2011; 2012). It claims to have an analytical apparatus that would help us both understand as well support infrastructure transitions towards a more sustainable state. Research done in this tradition meanwhile shows an amazing breadth (see Truffer, 2012). Nevertheless, it faces some shortcomings. It has an implicit normative character, arguing that transition processes will and should develop in a direction towards more sustainability. We actually see transition processes as being open-ended. The outcomes of these processes are the product of a struggle between actors who define sustainability in different ways and favor different strategies and methods. A cornerstone of the transition approach is furthermore its emphasis on niches. Niches are important since they contain the seeds for transition processes. Niches therefore have to be protected, and new technologies have to be experimented with in these niches until they are ready to help transform the system. We share the view that transformation or radical change from within a system or sector is unlikely. We doubt, however, whether the niche concept provides the best analytical concept for understanding transition processes. Niches by themselves do not necessarily transform a sector. Niches are to be found everywhere. There are niche markets which thrive on the simple fact that they concentrate on niches, e.g. by offering very high-quality or specialized products or services which are relevant only for a tiny minority. Radical change in sectors such as telecommunications on the other hand was not driven forward by niche actors but by political decisions and powerful actors from outside the field. The niche argument ultimately tends to underrate actors' aspirations and strategies which may or may not aim towards sectoral transformation.

Another line of reasoning is represented by the Technological Innovation System (TIS) approach. Again, this approach has produced an impressive number of valuable studies over the recent years and we can benefit from their results (Coenen & Lopez, 2010). Pioneering work on TIS was carried out by Bo Carlsson and Rikard Stankiewicz (1991). They define TIS as follows:

> network(s) of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion and utilization of technology. Technological systems are defined in terms of knowledge or competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks. (Carlsson & Stankiewicz, 1991: 111.)

Given that technology is the common denominator in TIS, a framework can be used that is geared to studying how the configuration of actors, networks and institutions changes over time as the technology develops (Carlsson, 1997). Recently, the emphasis on a dynamic analysis of TIS has received considerable impetus by explicitly focusing on the functions, activities or processes taking place within the system of innovation (Hekkert et al., 2007; Bergek et al., 2008). It remains somewhat ambiguous, however, how exactly the boundaries of a technological domain are set in relation to its geographical and sectoral embeddedness. Markard and Truffer (2008) remain critical of the inconsistent way that empirical studies of TI systems have delineated the system, using it either in a rather descriptive way as a synonym for sector or just as a catchword. From a sociological point of view, the uses of the systems metaphor and its more or less arbitrary listing of functions as well as its treatment of the concept of institutions have been criticized.

Recent theorizing in the social sciences in general has stressed the importance of the meso-level and especially of meso-level social orders where actors (who can be individual or collective) interact with knowledge of one another under a set of common understandings about the purposes of (in our case) a specific sector, a field, the relationships there (including who has power and why) and the sectors' rules (cf. Martin, 2003; 2011). This is an interesting parallel to the Multi-Level Perspective, which has a similar aim. Observing actions in meso-level social orders has already been implied in the various versions of institutionalist thinking. Meso-level orders have been called sectors, organizational fields, games, fields or networks. Most of this theorizing, however, is very static. It is difficult to use the insights produced by these studies to investigate change. Concepts like, for example, "institutional" or "organizational logic" are well suited for analyzing periods of stability, but not for the study of processes of (potential) transformation.

Interdisciplinary innovation research, finally, has also stressed the importance of the meso-level. One important strand of research has been done under the label of "Sectoral Systems of Innovation" (Malerba, 2004). This research, however, also suffers from an under-conceptualization of processes of change and transformation. In the institutional tradition, processes of transformation are described as "periods of mismatch" (Dosi et al., 1988: 11) or as "periods of considerable confusion" (Henderson & Clark, 1990: 12). Thus a more thoroughgoing analysis is necessary that highlights the interplay between incumbent, stabilizing and changing forces.

In our view, the Theory of Strategic Action Fields (TSF) provides an analytical framework that enables the analysis of dynamic developments, is not normatively based and is also not technology-centered. We conjecture that a strategic action field is dominated by a set of incumbent actors who share a common belief about what the field is all about, how specific positions are attributed to actors, what the aims of the field are and the legitimate ways to pursue these aims. From a plentiful supply of empirical evidence and theoretical considerations, we can safely assume that incumbent actors will try to oppose demands for change that will destabilize their position in the field and the dominant ways of doing things. Change will therefore be driven forward mostly by challenger actors, less powerful actors within the strategic action field under analysis or from outside actors "invading" the field. The success of the challenger actors depends on their ability to frame the problems the field is concerned with in a novel manner, to organize around this new frame and implement new innovative measures, which eventually might change the rules of the game into their favor. These groups of actors can benefit from developments apart from the field, which are of relevance to internal field processes. The developments could concern political decisions such as the Energiewende decision in Germany or the liberalization of energy markets; changes in macro-cultural discourse such as the growing awareness of the dangers of climate change; or widespread external opposition against specific technological options such as nuclear energy. For significant change to take place, these external developments have to pose significant threats or provide opportunities for the realization of collective interests. Those delivering the threats or opportunities must have command over sufficient significant resources in order to be able to generate and sustain action. Under normal conditions, the formidable resource advantages – material, existential/symbolic and political – enjoyed by incumbents are simply hard to overcome on the basis of internal dynamics alone. Significant changes to a field will also require the use of innovative and new – possibly previously prohibited – forms of collective action. The role of individual or corporate skilled actors is paramount. They need not only to fight for a new interpretation of what the field is all about, but they will also have to forge new coalitions and compromises reaching beyond the initial set of challenger actors. Analyses of processes of sectoral transformation have shown that such processes as well as their outcomes are difficult to predict and might take different forms, such as: (a) a re-imposition of the old regime with some adjustments; (b) the breakdown into unorganized social space; (c) the partitioning into several spaces (e.g. renewable vs. traditional electricity generation); (d) the development of a wholly new regime (cf. Mahoney & Thelen, 2010; Fligstein & McAdam, 2011). We reserve the term "transformation" for the last option.

The theory of strategic section fields shares many concerns and ideas with the Multi-Level Perspective as developed by Frank W. Geels. One main difference is that the theory of strategic action fields aims to be a general social theory that should be able to be applied to the analysis of a wide array of sociologically relevant problems and thus communication across the many sub-fields of social sciences could be made easier. From an STS point of view, the challenge is to show whether the approach can also be usefully addressed to the analysis of technology-related problems. To help with this task, within the theory a set of hypotheses have been formulated that can be tested by doing quantitative as well as qualitative studies. A hallmark of the theory without any doubt is its concept of fields and the linkages to the present vibrant discussion in sociology on this topic (cf. Martin, 2011). Epistemologically, the TSF in its empirical analyses tends to follow a realistic approach. Aspirations of actors are taken as a starting point and the limits of fields, which might develop out of these activities, are determined not abstractly but by the problem-oriented activities of the actors themselves.

New Technologies, Governance and the Energy Sector

In most developed countries, the organization of electricity supply in the past had been shaped by a small group of industrial actors along with political and regulatory decision makers (Viktor, 2002). Electricity supply constitutes a prime example of a large technical system (Mayntz & Hughes, 1988; Mayntz, 2009) characterized by a substantial degree of institutional inertia. The more intensive the organizational needs and the more complex and empowered a socio-technical system's structures are, the more demanding and protracted a substantial transformation will be. This is especially true for the tightly knit networks and the capital-intensive organization that exist in the electricity supply system. In many countries, decisions on the use of specific technologies (e.g. nuclear energy, renewable energies) have not been the result of the activities of profit-maximizing economic actors. The essential incentives for changes in the energy sector have come from the so called oil-price shocks in the mid ninety-seventies of the last century, the Chernobyl accident and the resulting critical attitude towards nuclear energy in many countries, the liberalization of markets driven forward by the European Commission, the Fukushima catastrophe and discussions about climate change. Large energy infrastructures are the precondition for economic development. But the dominant ways of generating electricity by extracting it from fossil fuels (coal, oil, gas) have been made responsible for the human-induced part of climate change. Insofar an important element of fight against climate change is the improvement of old technologies to make them more climate-friendly or the development of new technologies, which promise to be climate-neutral from the start. The variety of existing technological solutions can be aligned on a continuum between adapting existing technologies and exploring new ways of generating electricity. In the following I will analyze the so called Carbon Dioxide Capture and Storage (CCS) technology as an example for the "adaptation" option, which is aiming at making conventional power plants work more climate-friendly. The CCS technology is considered by the International Energy Agency as the only viable and available technological option if societies want to continue to use and build conventional power plants and reduce CO2 emissions at the same time. A more decisive challenge for the existing governance structure is coming in the past, present and future from the area of renewable energies. The traditional way of generating electricity has as its backbone a centralized structure with big electricity generating units, which are run by a small group of potent firms. Renewable energies on the other hand are not only vying for attention with the claim to develop a new, climate friendly and secure way of electricity generation, but also favor a decentralized design, demanding and offering new roles for entrepreneurs as well as consumers. A totally new form of governance seems possible.[1]

Applying the Theory of Strategic Action Fields, we aim to show that the success of the technologies in transforming the given field of electricity generation in order to make it more sustainable is dependent on the ability of actors from outside the field to destabilize the dominant system and organize political support. Concerns about environmental sustainability and energy security have made sustainable energy transitions a prominent political question in industrialized countries. Previous research in these areas has confirmed that external shocks and positive reinforcement dynamics are central to understanding transitions (Unruh, 2000; Jacobsson & Lauber, 2006; Lipp, 2007). Similarly, the literature on the domestic responses to international shocks emphasizes that international pressures influence national politics in variegated ways (Gourevitch, 1978; Ikenberry, 1986). However, these theories do not offer insights into the political strategies that underpin or impede sustainable energy transitions. Energy transitions linked to climate change argumentations in principle require global decarbonization (Unruh, 2000). As of yet, there is no "global solution" to be expected. One reason is that the costs of achieving emissions reductions without improved energy technologies or an overall switch to new technologies is high (Barrett, 2009). According to many commentators, a sustainable energy transition is not possible in a society unless the government intervenes by imposing binding constraints on carbon emissions, either through direct regulation or by using price instruments (Unruh, 2002; Fischer & Newell, 2008) and develops suitable frameworks for the development of new technologies. From this vantage point, sustainable energy transitions are fundamentally political.

The Development of CCS in Germany and Norway

Using the example of CCS, we will analyze what governance of technology-oriented incremental innovations in the energy sector looks like and how different actor constellations and structures in a similar sector can lead to major differences in outcome and performance: a stalling development in Germany on the one hand

and a successful implementation based on a broad social consensus in Norway.

CCS in Norway

For generating electricity, Norway uses nearly exclusively water power. The significant domestic oil and gas reserves are mainly used for export purposes. Owing to this, the discussion on CCS in Norway was advanced by actors who did not have a significant role in the domestic electricity providing system as such. Leading actors for the development of the technology and a suitable governance structure had been the oil company STATOIL and research institutes like SINTEF and the Technical University of Trondheim (NTNU). In our terms, these were not proper incumbent actors in the field. Already in the 1980s, the idea of capturing and storing CO2 had been fancied. At the same time Norway's minister president Gro Harlem Brundtland chaired the *World Commission on Environment and Development* of the United Nations. Under her chairmanship, a comprehensive report on sustainable development was published. In 1991 Brundtland in line with her thinking on sustainability introduced for Norway a CO2 tax for fossil fuels and fossil-fuel-using sectors. This tax helped increase efforts over the 1990s to push forward plans for the capturing and injection of CO2 into oil and gas fields. Initially, this happened as a pure research effort, but gradually also in the form of projects testing whether the procedure was commercially viable. The interest of the oil and gas industry is derived from two activities linked with the CCS technology: the so called EOR (Enhanced Oil Recovery) and the EGR (Enhanced Gas Recovery). By both methods CO2 is injected into off-shore oil and gas fields in order to improve the efficiency of exploitation. This framing of the technology quickly brought other actors onto the playing field and the developing actor network. Norway's biggest industrial plant constructing company Kvaerner and international oil companies contributed to the research efforts. The driving force in Norway thus has been the oil and gas industry which started R&D activities as well as partnerships with scientific institutes. Its prime interest was the injection and storage of CO2 in nearly empty oil and gas fields. The industry joined forces with the government who looked upon CCS as a way towards demonstrating that Norway cares about the environment in spite of the fact that they are a major producer of fossil fuels. The government in turn was joined by a number of NGOs who interpreted the technology of CCS in a similar way. In this way, we can see a successful example of coalition building among actors from outside of the field of electricity generation. The government's sustainability agenda did fit well with the expectations of the oil and gas industry and its industrial partners. The coalition was further enlarged by NGOs, who also evaluated CCS as a technology very favorably.

Starting in 1996 Statoil began with the first commercial use in the gas field Sleipner West in the North Sea. From 1997 onward, research activities for CCS also got public support money from the KLIMATEK program sponsored by the Norwegian government. After Kvaerner had been successful with starting its first pilot installation of a CO2 capturer, Norway's second biggest technology company, Aker, also invested in R&D for CO2 capturing. Only later on did CCS become of greater significance and interest to the Norwegian system of electricity generation. Growing electricity demand could no longer be matched by domestic water power alone and environmental concerns were discouraging the building of new water dams. At this moment, the Norwegian energy provider Naturkraft acquired a license to construct two new gas fired power plants. A lively debate on the construction of these new power plants emitting CO2 ensued. Influential environmental organizations were favoring the implementation of the CCS technology for the new power plants. It seemed to be the only option, if attempts to decrease energy consumption were not successful and if on the other hand the government wanted to stick to the political aim (in the meantime also laid down in the Kyoto Protocol) of reducing CO2 emissions.

After the private R&D activities, the Norwegian policies as well as the geological storage potentials made ever bigger research efforts possible, which were now also supported by the European Union (in spite of the fact that Norway is not a member of the EU), and CCS gained solid support among the Norwegian public and most of the active NGOs. The initial debate on whether to build new gas fired power plants turned into a debate about the pro and cons of the CCS technology (cf. van Alphen et al., 2009: 49), which was initially won by the supporters of CCS coming from different camps. In 2011 the official Norwegian policy was guided by the idea that no new concessions for gas fired power plants will be granted if the CCS technology is not used.

Norway is a world leader in CCS development. It, however, features not only the technological capacities to implement it, but also in principle the political will and the public support. That CCS is still nevertheless no success story is related to the unclear financing of the technology (how much subsidies should come from the state?) and the unclear development on the world markets that seem to make it unlikely that Norway will be able to export this technology worldwide. Insofar the industrial partners as well as the oil and gas industry have become more reluctant in supporting CCS.

In conclusion, it can be said that CCS in Norway was driven forward by a growing and broad coalition of actors coming from politics, industry and the civil society. The pressure to use this technology for electricity generation did not come from the field proper but from actors and decisions external to the field. The development of the technology did not lead to a disruptive change, but was inclusive, oriented towards existing actor coalitions and broadening them in a largely consensual manner. The government succeeded in framing the problem as one of caring for sustainable development, it largely financed the development of CCS and constructed a suitable regulatory framework. It built a broad coalition of industrial and civil society actors supporting the CCS technology.[2]

CCS in Germany

An analysis of the governance of innovation for CCS in Germany gives a strikingly different impression. First of all, coal (absent in Norway) still plays an important role for electricity generation in Germany. 24% of the energy generated in Germany has brown coal as its source; an additional 18% is derived from hard coal (UBA, 2011). The brown coal used comes nearly exclusively from domestic sources and is at the same time the only competitive domestic fossil material used for electricity generation. After a period of stagnation, coal-fired power plants are again expanding in the German market, i.e. most running or planned construction projects are coal-fired power plants (cf. Pahle, 2010). As buyers of power plant technologies, the German utilities have a substantial interest in technological innovation that would allow them to continue running the coal-fired plants and build new ones. This refers to a further improvement of technology already in use to increase efficiency, but it also elicited an interest in CCS, which could significantly lower CO2 emissions. In the early years of the new millennium, politicians, industry and research shared the conviction that the pressure to reduce emissions would continue and this belief was further strengthened by the fact that the German Government committed the country to an ambitious climate policy (40 % CO2 reduction target by 2050 announced by the Federal Government). CCS therefore seemed to be a suitable solution if one wanted to continue running coal-fired power plants and reduce emissions at the same time.

The importance of coal is also highlighted by the fact that Germany is considered to be a worldwide leader in the development of technologies relevant for the running of coal-fired power plants (Weimer-Jehle et al., 2010). If CCS was to become a technological development with a worldwide appeal (especially in countries like China and India), German industry and research needed to jump on the bandwagon. Innovation activities in the area of coal-fired power plants and CCS in Germany were executed by a limited number of predominantly big actors. These were multinational companies like Siemens, Alstom and Hitachi Power Europe, which as dominant constructors of power plants build technically highly developed components like turbines, boilers and generators, producing them in a more or less identical manner for the German as well as the world market. Innovations are driven forward in clusters of research networks in which extra-university research institutions (e.g. Research Center Jülich), big university institutes, the R&D departments of the producer companies and the R&D departments of the customers, usually the four big energy providers RWE, E.ON, Vattenfall and EnBW are represented (cf. Rogge & Hoffmann, 2009: 7) – sometimes all of them at the same time. Driving actors in the development of CCS and the spread of its idea in Germany therefore are the firms constructing power plants, the domestic brown coal industry and the big energy providers, which operate the majority of the German coal-fired power plants and who were worried about the emission trade schemes and resulting increased costs. The support coalition included the government, which was concerned both with CO2 reduction aims and the competitiveness of the domestic industry. It was a coalition consisting of the incumbent actors in the field. These were the same actors which already in the past had worked in a cooperative manner to establish a stable field.

Given the importance of construction firms from an industrial policy point of view, early R&D activities were supported by the Federal Government, as mentioned. The leading actor in this respect was and still is the Ministry of Economic Affairs (BMWi). Within the so called COORETEC initiative for the promotion of research and development of future oriented power plants with fossil fuels, research projects and pilot installations for the capturing of CO2 were supported. At the site *Schwarze Pumpe* in Brandenburg, a big and traditional brown coal extracting area, the worldwide first trial installation for a CO2-poor brown-coal-fired power plant based on the Oxyfuel procedure was built. The pilot installation started to work in 2008 and was run by the energy provider Vattenfall. The aim was to test and further develop the technology in order to make it commercially viable. In a parallel effort Vattenfall also developed a 300 MW demonstration project, which was supposed to start operation in the years to come. It was planned to be again situated in Brandenburg, this time at Jänschwalde. In contrast to the Norwegian situation, the driving forces for the development of CCS clearly came from the incumbent actors of the field. Insofar innovation activities followed an established incremental course typical for this type of field, based on the interests of the incumbent actors and their networks. It soon became clear, however, that the second step in the CCS development process (looking for suitable sites to store the captured CO2) ran into difficulties. For this part, no established mechanisms were available and the approval of other actors became necessary, which hitherto did not play any role in the calculations of the coalition driving forward CCS. The commercial exploitation of CCS at the end had to cope with severe acceptance problems which threatened the success of the whole innovation process. Massive resistance against the exploration of possible storage sites became organized. Various citizen initiatives came into existence, which gradually gained the support of environmental organizations, but also of other associations, like the Farmers' Association and the Association of Water Power Companies (Schulz et al., 2010). After massive protests, the regional (state) governments became reluctant in their support for the Federal Government's plans to push CCS. Especially the resistance of the state government of Schleswig Holstein made it impossible to pass a federal law on CCS. As a consequence, the energy provider RWE stopped its plans for building a demonstration power plant using the CCS technology in Hürth (Northrhine Westphalia). Even before this decision RWE had failed in its attempt to gain EU support for the project. The EU gave as a justification for its decision the public opposition against the search for storage sites in Germany. The only existing legal approval for the exploration of potential commercial CO2 sites, two sites in the state of Brandenburg, was based on state regulations, given the absence of federal rules. The permission was granted, however, with the expectation that a new federal law would soon be passed, which would then grant legitimacy to the state's actions. Since the federal law did not materialize, the state government announced that the exploration permit can only be considered as temporarily valid. After long negotiations a new federal law was finally passed. It put the responsibility for accepting the technology in the hands of regional governments, which for political reasons at the moment do not have any interest in supporting CCS. Lobbying by the incumbent actors for a different solution was hardly visible. This was due to the changing field environment: neither the worldwide spread of CCS nor the expected attempts to charge CO2 emissions materialized. Insofar there is now not a national nor a world market for the technology and in addition no political will for regulatory actions. It is no wonder that at the moment (2014) Germany is increasing its CO2 emissions and burning more coal then before. As such the technology implementation process looks doomed.

In sum, the technology development process was advanced by established industrial actors, based on political decisions favoring the technology. Unlike in Norway, however, CCS did not succeed in building a solid support coalition reaching beyond the established field actors. Decision-making took place in closed circles until the necessity arose to go public in the search for storage sites. Local protests against CCS storage sites became quickly organized, national NGOs became active in the opposition against CCS and soon there was a vibrant nationwide discussion. The field of CCS in Germany at the moment can thus be best described as an unorganized social space. Actors are unsure what to do and how to proceed.

The Governance of Photovoltaics in Germany and Japan

Contrary to the more incremental innovations for coal and gas fired power plants, the development and diffusion of renewable energies includes a variety of new actors – especially in Germany. These new actors encompass new producers, electricity traders as well as owners of decentralized electricity generating units. Discussions about global warming and general environmental concerns have led to political attempts to create and manage a new energy market and the newly developing energy mix. New political instruments were developed and at least in Germany new actor constellations can be observed, which in consequence have led to the development of a specialized governance structure for renewable energies.

Photovoltaics (PV) Development in Japan

The beginnings of PV research in Japan date back to the 1960s. The company Sharp was engaged in the development of solar cells for space research. As a result of the oil crisis in the 1970s, which struck Japan fuels especially hard due to its near complete dependence on the import of fossil, the government in 1973 initiated a first political program, the so called "Sunshine Program", with the aim to explore possibilities to reduce the dependence on energy imports. A small part of the overall program, ca. 6 million USD, was devoted to PV research for terrestrial applications.

At the center of the Japanese innovation system is a small number of big, vertically integrated as well as diversified companies that specialize in incremental innovations in products and production processes. The second-most important actor for the governance of innovation is the government. It is much more directly involved and makes more direct attempts to coordinate innovation processes than its counterpart in Germany, for example: "Japan and Germany clearly display different social systems of innovation and this is why these countries showed contrasting patterns of evolution during the last quarter of the twentieth century" (Boyer, 2003: 148). Vogel points out that

> the German government merely facilitates private-sector coordination, whereas the Japanese government organizes and guides the private sector more directly. The German government has codified its economic model into law, whereas the Japanese model relies more on informal norms and standard practices. (Vogel, 2006: 308)

The Japanese government has interfered actively in the development of the energy sector with a variety of measures and strategies. This can be shown for the energy sector in the whole but also very clearly for the case of PV. Following the 2nd oil price shock of 1979, the government in 1980 created the *New Energy Development Organization* (NEDO) with the aim of reducing Japan's dependence on foreign oil. NEDO is an adjunct to the Ministry for International Trade and Industry (MITI), which was also responsible for energy questions. In 1988 NEDO was renamed to the *New Energy and Industrial Technology Development Organization* and thus stressed even more its coordinating role for the industry (cf. Ristau, 1998: 81). Members of NEDO were recruited from the state apparatus but also from the industry. As such, the energy provider *Tokyo Electric Power Company* for example played an important role in the formulation of the energy policies and strategies of the organization.

Over the 1980s, NEDO fulfilled two important functions for the development of PV. On the one hand, it sponsored research projects for the improvement of the efficiency of solar cells. On the other hand, NEDO became also the biggest buyer of commercially produced solar cells. In the 1980s, there was neither a domestic nor an export market for PV applications. The state-sponsored demand was a decisive benefit for the Japanese industry, which was aiming at developing a world leader position in the development of this technology. With the eventual development of a world market for PV, Japan was able to satisfy the growing demand and expand its market share on the world market substantially. “In 1983 23% of the worldwide sales of modules originated in Japan. Two years later the European Solar Association calculated that the contribution had grown to 45%.” (Ristau, 1998: 81; translation by author.)

The strength of the Japanese innovation system is not only to be seen in the type of cooperative policy support, but also in the political instruments used for technology diffusion (e.g. the financing of demonstration projects, incentive programs). In order to give the industry incentives to expand production capacities, MITI initiated in 1994 the so-called 70,000 roofs program (*Monitoring Program for Residential PV Systems*; Shum & Watanabe, 2009: 3536). It was implemented by the *New Energy Foundation* (NEF). Within the scope of this program, the government financed 50% of the installation costs for PV modules of private households. Under specific conditions firms could also participate in the program. The financing of the overall program was done with the help of a surcharge on regular electricity tariffs. The energy providers furthermore were obliged to buy PV-electricity at market prices. In 1997 a new energy law was passed (*Law on Special Measures to Promote Use of New Energies*). It consisted of a broad mix of subsidies and other policy measures to support the spread of PV and other renewable energies. A clear target for the expansion of PV was also stated. PV was supposed to grow from 500 MW to 5,000 MW before the year 2010 (*Long-term Energy Supply/Demand Outlook*). Other laws naming targets for the spread of PV ensued as well as a number of projects, which were especially supposed to boost public demand for PV (e.g. installations on public buildings). The Ministry of Education for example passed the *ECO School Project*, the Ministry for Infrastructure Development the *Green Government Office Project* and between 1992 and 1998, a *Field Test Project on Photovoltaic Power Generation for Public Facilities* was carried out, which later on was merged into the *Field Test Project on Photovoltaic Power Generation for Industrial and Other Applications* (Anderson et al., 2006: 26). The public expenditure for the support of PV in the 1990s was significantly higher than in all other comparable nations. The public budget in 1997 for the support of PV amounted to 150 million Euro. In Germany at this time no public money of any significance was spent on this purpose. Less than half of the Japanese support money went into R&D support; the bigger part was used for the stimulation of demand (Ristau, 1998: 92). Since 1997, the support was extended with a further *Program for the Development of the Infrastructure for the Introduction of Residential PV Systems*. In the following years (from 1997 to 2001) the support grew from 11,11 milliard Yen to 23,5 milliard Yen (Shum & Watanabe, 2009: 3536). The technology developed and implemented in Japan resembled a standardized mass product without any significant adaptations to the needs of specific customer groups (Shum & Watanabe, 2009: 3540). The dominant Japanese type of an integrated innovation process can thus be observed for the case of PV. This included the integration of the “last mile”: the installation or de-installation of PV modules by artisans and architects. Shum and Watanabe refer in their analysis of the Japanese governance of PV innovations to the image of a “closed development” (Shum & Watanabe, 2009: 3540).

The development of PV in Japan therefore resembled other comparable innovation processes in Japan. In the center of attention is the cooperation between the incumbent actors from government and industry. They are aiming at developing products that can also be exported and sold on the world market and thus help the domestic industry. For the realization of the aim, PV development established channels and methods of cooperation were used, in order to push the innovation forward in an incremental and piece-meal fashion. In spite of the first-mover position of Japan with respect to technology and commercial development, a position which Japan could hold on for quite some time, the amount of installations realized in Japan was not overwhelming. Up to the Fukushima accident, the contribution of renewables to the overall energy mix actually decreased. In this regard, it is important to understand that Japan did not succeed in creating a real domestic market for PV installations. PV installations are primarily to be found on public buildings. The incumbent actors, the same companies that were doing for example nuclear power development, were also installing PV, but had their prime orientation towards exporting products and did not favor a significant change of the domestic technology mix. The composition of the coalition deciding on the further development of the energy sector remained stable, new challenger groups (e.g. from civil society) did not play a significant role and as such more wide-ranging changes were not envisioned. In Japan, the type of coordination used for PV therefore resembled the established patterns in the electricity-generating field. The development was towards a technological add-on option, but was not intended or used to break up the existing practices. The actors concentrated on strategies that would not endanger their existing position and business models, which were dominantly oriented towards developing and using nuclear energy.

PV Development in Germany

The German PV development in contrast to the Japanese case is characterized by severe conflicts, radical innovations and marked breaks and changes in governance. In the already discussed examples (CCS and PV), we detected more or less continuous efforts to sustain R&D and support efforts based on coordinated and cooperative efforts of the main actors from government, science and industry. The German PV picture looks different. In Germany, government support was and is again rather reluctant, difficult to predict, liable to sudden changes and shifting priorities. In contrast to Norway and Japan as well as the CCS development in Germany, the momentum for the development of PV was kept alive by so called non-conventional actors. In this case the social movement character of governance change becomes clearly visible.

As a result of the oil crisis, Germany started first programs related to PV and other new energy options in the 1970s. At this point in time, the responsibility for promoting PV was with the Ministry of Research and Technology. With the ensuing decline of oil prices and following a change in the composition of the federal government – it was now led by the conservative party - the programs to support PV were severely curtailed. The first programs for PV nevertheless had certain successes. The big industrial partners (AEG-Telefunken, Siemens-Solar) having received most of the public money, succeeded in establishing a competitive expertise and technological prowess. The German PV research could be established and gained an internationally leading position along with Japan and the US. Unlike in Japan, however, the little public money available was widely dispersed, experiments with various technologies and procedures were supported and universities as well as applied research centers like the Fraunhofer Institute for Solar Energy Systems (ISE) (founded in Freiburg in 1982) participated. Research projects became financed that were not evaluated from the side of the funding institution with respect to what technological option would be the most desirable one and what would be the best option for industry, society or both. In the end, the efforts were seriously hampered by the fact that technologies were developed up to a pre-market stage, but given the lagging or non-existent domestic demand combined with little political interest in supporting an uptake of the technology, this led to a stalemate and no significant role for the technology in electricity generation could be established. On the contrary: the further development of the technology was opposed by the incumbent actors of the electricity supply system, equipped with good networks and contacts to political and administrative decision-makers. Clear policy guidelines were furthermore difficult to establish due to conflicting positions of key relevant ministries. In particular, the Ministry for Economic Affairs claimed responsibility for market-oriented support schemes and until the present day sees PV very critically, while the Ministry for Research and Technology had and has a more favorable view of PV (Ristau, 1998: 44ff.).

The general support for technology development therefore was rather weak and divided. The support coalition for PV mainly consisted of concerned scientists who wanted to develop an alternative way of generating electricity. Their engagement very often had grown from of an opposition to nuclear energy. The Association for Solar Energy (DGS) (founded in 1975) tried to pool their interests and became more important due to external events. The Chernobyl accident in 1986 made nuclear energy very unpopular and initiated a new search for alternative energy resources and discussion about the future outlook of the energy system as a whole restarted. Within two years, the opposition against nuclear energy among the population at large rose from 50 to 70% (Jahn, 1992). The scientists favoring PV tried to influence the public discussion and put PV on the agenda as a possible new option, as an important element of a transformed energy system. PV was labeled as a clean, environment-friendly source of energy. This made it possible to merge the interests of different social groups: the anti-nuclear power movement and environmental groups could quickly agree on such an option, which made it also possible for them not only to be against something, but to be in favor of a true alternative option. In comparison to other countries, the social movements and the general opposition to nuclear energy after the Chernobyl accident was more wide-spread and also found a political support in the green party Die Grünen. Given this changing environment, the federal government felt obliged to offer some carrots in the form of a first, small market-oriented program for supporting PV. In 1991, the *1,000 Roofs Program* began. It was financed by a state controlled bank (Kreditanstalt für Wiederaufbau) and offered loans to private households interested in participating in a big test of PV installations connected to the electricity grid. NGOs like the aforementioned DGS as well as the Association for the Promotion of Solar Energy and Eurosolar used this situation to influence the political agenda. They developed various models for the financial support of PV and the technical options for connecting decentrally generated solar energy to the general grid.

Besides these national developments, other institutional innovations on the global and the European level were important and affected the German PV scene. On the European level, the deregulation of the energy system was driven forward by the European Commission. The global discussion about climate change led in its turn to the Kyoto protocol (1997). Both shifts altered the framework within which PV could be developed. The groups favoring solar energy became more firmly organized and built up new political coalitions especially on the local and regional levels. On the federal level, however, things looked different. After the heavily over-subscribed 1,000 Roofs Program was terminated, the demand for PV installations plummeted again and decreasing energy prices seemed to make PV an economically unviable solution. The market nearly disappeared and the relevant industry threatened to or actually left Germany to move to locations that would provide a more stable regulatory framework. It became clear that without a long-term regulatory strategy and support scheme, no significant demand for PV could develop in Germany.

In this situation, the role of non-conventional actors proved again decisive. Greenpeace paid the independent public Ludwig Bölkow Foundation for doing a study on the feasibility of constructing a production facility for PV modules in Germany. The study came to the conclusion that it would in fact be economically viable to produce and use PV modules in Germany. Considering economies of scale and an automatisation of production processes, the price for PV installations could be reduced by 40%. Even a small production unit with the capacity to produce only 2,000 PV units would be able to work profitably. These results were used by Greenpeace to look for people interested in helping to finance such a plant. Within a short period of time, 4,000 people showed their interest. Greenpeace then put adverts in leading newspapers to look for entrepreneurs to realize their plans and suitable persons actually showed up. The major importance of Greenpeace's activities was in sensitizing to the potential demand of PV and showing ways for a viable implementation of a PV production strategy. It had become clear that PV installations could be produced more cost-efficiently than previously thought and the discussion thus also gained an industrial policy component (cf. Fuchs & Wassermann, 2012).

Once it had become clear that PV modules could be produced more cost-efficiently than initially thought, medium sized companies in particular became interested in PV – such as RAP Microsystems in Wernigerode or the Solar Factory in Freiburg (Ristau, 1998: 57). The new small and medium-sized PV companies concentrated from the beginning on grid-connected installations. They began to produce modules, mounting frames for roofs and inverters. In this way the activities instigated by the various social movements, mentioned above, led to the development of a new innovation path and strengthened the specific characteristics of PV development in Germany (Jacobsson & Lauber, 2006: 266). Many of the new PV startups had their origins in PV research institutes. The close networking between science, environmental groups and small, initially environmentally and energy politically motivated entrepreneurs was especially valid in the case of PV.

In 1998, the development received a new push. A change in the composition of the Federal Government brought a red-green coalition into power. The window of opportunity was now wide open and the expanding PV support coalition saw its chance. It no longer needed any lobbying work from the outside. Members of the PV coalition could now effectively influence policies from the inside. The aim that resulted was an institutionalization of the support for renewable energies. The red-green coalition in fact initiated two new policy instruments for the support of PV. Firstly a successor to the terminated 1,000 Roofs Program was started, now called *100,000 Roofs Program*, demonstrating the new emphasis and importance of promoting PV. The program was passed in 1999 and it was again administered by the bank KfW. It offered cheap loans covering a period of ten years. In 2000, secondly, a new electricity feed-in law was passed (*Renewable Energies Law*). It set conditions under which generated electricity could be fed into the grid and also regulated the issue of financial compensation. The Federal Government was trying to establish a broad support for the new law, but nevertheless some of the energy providers and their trade associations went to the courts and tried unsuccessfully to block the law. When the 100,000 Roofs Program terminated in 2003, a new amendment to the Renewable Energies Law increased the compensation for individuals generating electricity from PV modules, making PV even more interesting from a commercial point of view. When in 2005 a new shift in the composition of the Federal Government took place (now a coalition led by the conservative party with the social democratic party as a junior partner), no fundamental changes were put in place. Originally opposed to PV promotion schemes, the conservatives at least for some time looked more favorable to PV. This was essentially due to the influence of regional politicians from the Eastern parts of Germany, where most of the new PV companies had set up business and were also attracting foreign direct investment.

The next political change in 2009 (a conservative-liberal coalition took office) has made the further development of PV unpredictable. Various regulatory changes were implemented and opinions – especially voiced again from the Ministry of Economics, the four energy providers and network operators – gained importance, claiming that PV is not a suitable option for the German electricity system. Prior to the Fukushima catastrophe, the operating times for nuclear power plants were prolonged and contracts made by the previous governments were cancelled – damaging the prospects of PV. After Fukushima, an end to nuclear energy was proclaimed, but up until now the conditions for the promotion of PV have not become stable and calculable again. Just like in the mid-nineties the German PV industry is suffering both from the uncertain regulatory environment and new competitors especially from China. PV modules which constituted a small niche market in the late nineties have now become a mass market in which economies of scale are important.

Conclusion: Governance of Innovations in the Energy Sector

In this contribution, we have traced the development of two technological innovations in three countries. The emphasis, on the one hand, was on analyzing how technological developments are embedded in specific national and sectoral contexts for which we used the concept of governance. On the other hand, we have put the emphasis on a process perspective. The process perspective is informed by the Theory of Strategic Action Fields by Neil Fligstein and Doug McAdam. We started with the assumption that a change in governance structures has to find its expression in a change within the dominant actor constellations. Changes in actor constellations are the product of a period of contention. Actors from neighboring fields or the state attempt to change the existing field consensus and thus the position of the incumbent actors. Incumbent actors (like the four big energy providers in the German PV case) will try to defend their position and to damage the position of the challengers. The outcome of such a process cannot be easily predicted. It depends on the ability of the actors to frame the situation in a light that is beneficial to their strategy, to organize around this frame and develop (innovative) instruments for pushing forward their aims even against resistance. For the case of Germany, we could show that the development of PV was dependent on the establishment of a new support coalition, which against the opposition of incumbent actors and interests, created a new form of governance for the promotion of renewable energies. The support coalition gradually broadened and consists meanwhile of a diffuse group of actors. We can observe the development of a governance structure from bottom up.

The CCS technology in Germany on the other hand was supposed to be executed "from above" with the help of the established actors and networks consisting of energy providers, research institutes, hardware producers and political actors. They tried to push through a technological option against growing public opposition. The eventual failure to commercialize CCS is signified by the successful attempts of the opponents of CCS to organize and a lacking capacity of the established actors to co-opt them (like in Norway). The result is unorganized social space. In Norway, the CCS development was driven forward by a broad coalition of actors which initially came primarily from outside the electricity-generating sector. Successful co-optation strategies brought together a coalition of actors from neighboring fields, the general public and the incumbent actors.

PV development in Japan was on the one hand successful insofar as the main aims for spreading PV within Japan were realized. The aims were to promote the use of PV without any fundamental changes to the governance structure and the position of the incumbent actors. Of prime interest was to develop a new technology for export, which for establishing a point of reference, was also to be used in Japan. The effect, however,

Table 1. Summary of results.

	CCS/Norway	**CCS/Germany**	**PV/Japan**	**PV/Germany**
External event	Brundtland report, oil and gas industry business options	CO2 reduction targets, potential world market developments	Oil price shock, search for new export markets	Anti-nuclear movement, Chernobyl accident
Coalition	Government, NGOs, industry	Government, incumbent industry actors	Government, incumbent industry actors	Concerned scientists and citizens, local politicians
"Innovative" actions	Tax, funding of research	Funding of research and demonstration projects	Coordinated technology development, public procurement	Local experiments, law on renewable energies
Role of government	Regulatory activism	Arbiter	Coordinator	Enabler
Field development	Proactive adaptation	Unorganized social space	Adaptation	Transformation
Technology development	Preconditions available	Stopped	According to plan	Dynamic

has been a constant, but comparatively slow development of domestic PV. PV before Fukushima played a negligible role for electricity generation in Japan and no stable new market developed.

Within the scope of this article the case studies could only be presented in a highly stylized way. They hopefully served the purpose, nevertheless, to show the validity of a new analytical approach to study energy transitions.

References

Alphen, van, K., J. van Ruijven, S. Kasa, M. Hekkert & W. Turkenburg (2009) 'The Performance of the Norwegian Carbon Dioxide, Capture and Storage Innovation System,' Energy Policy 37(1): 43-55.

Anderson, K., L. R. Nottage, L.T. Wolff & W. Yamanaka (2008) 'Japan's Gradual Transformation in Corporate Governance,' Research Paper No. 08/29 (Sydney: Sydney Law School).

Beckert, J. (2009) 'The Social Order of Markets,' Theory and Society 38 (3): 245-269.

Benz, A., S. Lütz, U. Schimank & G. Simonis (eds) (2007) Handbuch Governance. Theoretische Grundlagen und empirische Anwendungsfelder (Wiesbaden: VS Verlag).

Bergek, A., S. Jacobsson & M. Hekkert (2008) 'Functions in Innovation Systems: A Framework for Analysing Energy System Dynamics and Identifying Goals for System-Building Activities by Entrepreneurs and Policy Makers,' in T. Foxon, J. Köhler & C. Oughton (eds), Innovation for a Low Carbon Economy: Economic, Institutional and Management Approaches (Cheltenham: Edward Elgar): 111-79.

Boyer, R. (2003) 'The Embedded Innovation Systems of Germany and Japan: Distinctive Features and Futures,' in K. Yamamura & W. Streeck (eds), The End of Diversity? Prospects for German and Japanese Capitalism (Ithaca: Cornell University Press): 147-183.

Carlsson, B. (ed) (1997) Technological Systems and Industrial Dynamics (Boston, Dordrecht, London: Kluwer Academic Publishers).

Carlsson, B. & R. Stankiewicz (1991) 'On the Nature, Function and Composition of Technological Systems,' Journal of Evolutionary Economics 1(2): 118-93.

Coenen, L. & F. J. Diaz Lopez (2010) 'Comparing Systems Approaches to Innovation and Technological Change for Sustainable and Competitive Economies: An Explorative Study into Conceptual Commonalities, Differences and Complementarities,' Journal of Cleaner Production 18(12): 1149-1160.

Dosi, G., C. Freeman, R. Nelson, G. Silverberg & L. Soete (eds) (1988) Technical Change and Economic Theory (London, New York: Pinter).

Fligstein, N. & D. McAdam (2011) 'Toward a General Theory of Strategic Action Fields,' Sociological Theory 29(1): 26-1.

Fligstein, N. & D. McAdam (2012) A Theory of Fields (Oxford: Oxford University Press).

Fuchs, G. (2012) 'Path Dependence and Regional Development: What Future for Baden-Württemberg,' in G. Schryögg & J. Sydow (eds), The Hidden Dynamics of Path Dependence. Institutions and Organizations (Houndmills: Palgrave Macmillan): 178-196.

Fuchs, G. & P. Shapira (eds) (2005) Rethinking Regional Innovation (New York: Springer).

Fuchs, G. & S. Wassermann (2012) 'From Niche to Mass Markets in High Technology: The Case of Photovoltaics in Germany,' in J.M. Bauer, A. Lang & V. Schneider (eds), Innovation Policy and Governance in High-Tech Industries (Berlin, Heidelberg: Springer): 219-244.

Geels, F.W. (2002) 'Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case-Study', Research Policy 31(8-9): 1274-1257.

Geels, F.W. (2005) Technological Transitions and System Innovations: A Co-evolutionary and Socio-Technical Analysis (Cheltenham: Edward Elgar).

Geels, F.W. (2012) 'A Socio-Technical Analysis of Low-Carbon Transitions: Introducing the Multi-Level Perspective into Transport Studies', Journal of Transport Geography 24: 471-482.

Gould, S. J. (2002) The Structure of Evolutionary Theory (Cambridge: Harvard University Press).

Hall, P. & D. Soskice (eds) (2001) Varieties of Capitalism (Oxford: Oxford UP).

Hekkert, M., R. Suurs, S. Negro, S. Kuhlmann & R. Smits (2007) 'Functions of Innovation Systems: A New Approach for Analyzing Technological Change', Technological Forecasting and Social Change 74(4): 413-432.

Henderson, R. & K. Clark (1990) 'Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Existing Firms', Administrative Science Quarterly 35(1): 9-30.

Jacobsson, S. & V. Lauber (2006) 'The Politics and Policy of Energy System Transformation – Explaining the German Diffusion of Renewable Energy Technology', Energy Policy 34(3): 256-276.

Jahn, D. (1992) 'Nuclear Power, Energy Policy and New Politics in Sweden and Germany', Environmental Politics 1(3): 383-417.

Mahoney, J. & K. Thelen (2010) 'A Theory of Gradual Institutional Change', in J. Mahoney & K. Thelen (eds), Explaining Institutional Change: Ambiguity, Agency, and Power (Cambridge: Cambridge University Press): 1-37.

Malerba, F. (ed) (2004) Sectoral Systems of Innovation (Cambridge: Cambridge University Press).

Markard, J. & B. Truffer (2008) 'Technological Innovation Systems and the Multilevel Perspective: Towards an Integrated Framework', Research Policy 37(4): 596-615.

Markusson, N., S. Shackley & B. Evar (2012) The Social Dynamics of Carbon Capture and Storage: Understanding CCS Representations, Governance and Innovation (London: Routledge).

Martin, J. L. (2003) 'What is Field Theory', American Journal of Sociology 109 (1): 1-49.

Martin, J. L. (2011) The Explanation of Social Action (Oxford: Oxford University Press).

Mayntz, R. (2004) 'Governance Theory als fortentwickelte Steuerungstheorie', MPIfG Working Paper 04(1) (Max Planck Institut für Gesellschaftsforschung: Köln).

Mayntz, R. (2009) 'The Changing Governance of Large Technical Infrastructure Systems', in R. Mayntz (ed), Über Governance: Institutionen und Prozesse politischer Regulierung (Frankfurt, New York: Campus): 121-150.

Mayntz, R. & T.P. Hughes (eds) (1988) The Development of Large Technical Systems (Frankfurt a. M.: Campus).

Meadowcroft, J. & O. Langhelle (2011) Caching the Carbon. The Politics and Policy of Carbon Capture and Storage (Cheltenham: Edward Elgar).

Meyer, J.W. & B. Rowan (1977) 'Institutionalized Organizations: Formal Structure as Myth and Ceremony', American Journal of Sociology 83(2): 340-63.

Padgett, J. & P. McLean (2006) 'Organizational Invention and Elite Transformation: The Birth of Partnership Systems in Renaissance Florence', American Journal of Sociology 111(5): 1463-1568.

Pahle, M. (2010) 'Germany's Dash for Coal: Exploring Drivers and Factors,' Energy Policy 38(7): 3431-3442.

Ristau, O. (1998) Die solare Standortfrage. Der technologische Wettstreit zwischen den USA, Japan und Deutschland (Bad Oeynhausen: Bröer-und-Witt-Solarthemen).

Rogge, K. & V. Hoffmann (2009) 'The Impact of the EU ETS on the Sectoral Innovation System for Power Generation Technologies – Findings for Germany,' Paper submitted to DIME Workshop on Environmental Innovation, Industrial Dynamics and Entrepreneurship May 10–12 2009 (Netherlands: Utrecht).

Schulz, M., D. Scheer & S. Wassermann (2010) 'Neue Technik, alte Pfade? Zur Akzeptanz der CO2- Speicherung in Deutschland,' GAIA 19(4): 287-296.

Scott, W.R. (2001) Institutions and Organizations. 2nd edition (Thousand Oaks, CA: Sage).

Shum, K.L. & S. Watanabe (2009) 'An Innovation Management Approach for Renewable Energy Development – The Case of Solar Photovoltaic (PV) Development,' Energy Policy 37(9): 3544-3535.

Ugur, M. (ed) (2013) Governance, Regulation and Innovation. Theory and Evidence from Firms and Nations (Cheltenham: Edward Elgar). Verbong, G.P.J. & D. Loorbach (eds) (2012) Governing the Energy Transition: Reality, Illusion or Necessity? (New York: Routledge).

Victor, D.G. (2002) 'Electric Power,' in B. Steil et al. (eds), Technological Innovation and Economic Performance (Princeton: Princeton University Press): 385-415.

Vogel, S.K. (2006) Japan Remodeled: How Government and Industry are Reforming Japanese Capitalism (Ithaca: Cornell University Press).

Werle, R. (2012) 'Institutions and Systems: Analysing Technical Innovation Processes from an Institutional Perspective,' in J. Bauer & A. Lang & V. Schneider (eds), Innovation Policy and Governance in High-Tech Industries (Heidelberg, Berlin: Springer): 23-47.

Notes

1 The present paper draws on the results of four research projects dealing with the development and prospects of CCS and PV. The projects used document analysis, expert interviews and discussions, scenario analysis and agent based modeling as methods. The projects were supported by the Volkswagen Foundation, the German Federal Ministry for Environmental Affairs, the University of Stuttgart and the Helmholtz Association.

2 More detailed accounts of the CCS story can be found in Meadowcraft and Langhelle (2009) and Markusson et al. (2012).

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Constructing Expectations for Solar Technology over Multiple Field-Configuring Events:
A Narrative Perspective

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The existence of positive expectations is of particular importance for emerging clean energy technologies that are not yet competitive on the market in terms of cost or performance. The sociology of expectations literature studies how expectations can further technological fields. We contribute to this literature by studying expectations work through multiple "field-configuring events" in an effort to map out field development over time. Our analysis demonstrates six narrative themes and the evolvement of expectations work to further solar technology. We suggest that event-based expectations work is fruitful for exploring complementary visions and expectations for a new technology. Rather than explicitly aligning expectations, events can lead to an initially narrow storyline gradually spreading into multiple narratives upon which to build a field's future and, thereby, guide and strengthen the advocacy. This form of guidance is especially important in early phases of field formation.

Keywords: expectations work, field-configuring events, emerging clean energy technology

Introduction

Solar energy is a promising emerging clean energy technology that is anticipated to play an important role in the future energy system due to its great availability and minimal environmental effects (cf. Solangi et al., 2011: 2150). Especially, solar photovoltaic (PV) technology is a rapidly growing business sector internationally that contains possibilities for technology companies working with the technology. Yet in several countries the solar technology field is in its early development in terms of energy supply and technology business. As a technology is not yet competitive against established energy sources and a range of market criteria is still unstable, it is important for field development that there is an active 'technological community' (cf. Rappa & Debackere, 1992) promoting it and creating positive expectations concerning its future performance.

The sociology of expectations literature studies how expectations can further emerging fields (e.g. van Lente, 1993; Brown & Michael, 2003). Studies have accentuated the importance of expectations work and the alignment of visions and expectations for novel fields (van Lente, 1993; Borup et al., 2006; Brown, 2003). The significance of events for the configuration of new fields has been recognized by a number of articles in organization and management studies (e.g. Garud, 2008; McInerney, 2008), pointing towards the need to address the phenomenon of event-based expectations also within the expectations literature. Insight is needed into how expectations work evolves through multiple 'field-configuring events', i.e. seminars or other gatherings where technology proponents come together. Such examinations are valuable in mapping out the development of a new field and assessing the ways in which event series may aid in promoting technology.

This article contributes to the expectations literature by investigating how expectations work was carried out for a new energy technology through multiple events. In this study the term 'event' is used to describe field-configuring events, i.e. seminars where "... people from diverse social organizations assemble temporarily with the conscious, collective intent to construct an organizational field..." (Meyer et al., 2005: 467). In particular, we carry out an 'analysis of narratives' (Polkinghorne, 1988) of the presentations and discussions taken place at events for the Finnish solar cluster in 2010-2013; an example of a non-established technological market. Based on observations and written material gathered from ten events altogether, we seek to explicate what type of common narrative themes were put forth by the proponents and how the expectations work evolved within the examination period. We suggest that event-based expectations work is fruitful for exploring complementary visions and expectations for a new technology. Whereas prior studies highlight the importance of explicitly aligning visions and expectations (Brown & Michael, 2003; Bakker et al., 2011), we found that event series can lead to an initially narrow storyline gradually spreading into multiple narratives upon which to build a field's future. Thereby, events can guide and strengthen the advocacy for a new clean technology. In our view, guidance through the multiplication of expectations is especially important for new and unsettled fields, whose priority lies in building credibility and legitimacy for the field as a whole.

The paper proceeds as follows. In the next section we summarize prior research concerning (a) expectations work conducted by 'technological communities' (b) the role of narratives in innovation processes and (c) the role of field-configuring events for organizational fields. Then we present the methods and empirical data. The section after that depicts the events that were investigated in this study and discusses their interconnections. Then we illustrate the six narrative themes that emerged from the data, as well as the evolvement of the expectations work in the course of the event series. Finally, we discuss our findings in reference to extant research and draw conclusions from the analysis.

Creating Expectations for Emerging Technology

Expectations Work by Technological Communities

The existence of positive expectations is of particular importance for emerging clean energy technologies that are not yet competitive against established energy sources and face uncertainty concerning future market criteria. (e.g. van Lente, 1993;

Borup et al., 2006; Konrad et al., 2012).Van Lente's (1993) pioneering work in sociology of expectations points to how expectations, promises and political ideographs function in technology development. His research demonstrates expectations as significant for i) bringing actors together and generating a common purpose ii) attracting resources like finances for R&D and political support for institutional and regulatory change iii) providing meaning and orientation for scientists and engineers and iv) reducing the perceived uncertainty of decision-making (van Lente, 1993). Also Borup et al. (2006) have found expectations to be important for stimulating, steering and coordinating field development. Furthermore, van Lente (1993) has recognized ideographs as central for legitimizing new technology, as they serve as additional symbolic and cultural resources. Ideographs, such as 'technological progress' are "... high order abstraction[s], representing collective commitments to particular but equivocal and ill-defined normative goal[s] ..." (McGee, 1980: 15).

The expectations literature has also paid attention to the formation of collective expectations, referring to expectations that are shared by many actors or widely known and referred to (Konrad, 2006; van Lente & Rip, 1998; Borup et al. 2006). Because of this, they form prospective structures for actors in a field (van Lente & Rip, 1998) and both enable and constrain innovative activities. Also, it has been acknowledged that aligning visions and expectations is important to new fields (Brown & Michael, 2003), as robustness of expectations is needed to mobilize resources for a field as a whole. Technology proponents can create generic expectations referring to expectations that further a technological field as a whole (c.f Pollock & Williams, 2010 with respect to promissory organizations). On the other hand, actors can also promote particular expectations around proposed technological developments containing actor-specific agendas and interests. This may lead to the contestation of expectations against each other in so-called "arenas of expectations" (Bakker et al., 2011, discussed in more detail in the last section of the literature review).

Finally, studies have addressed the "dynamics of expectations" and pointed out how unmet expectations may lead to harmful disappointment cycles with respect to field development (Brown & Michael, 2003; Konrad, 2006). This wide range of research has helped to establish clarity with respect to the role of expectations work in furthering new technology. As noted above, particularly the notion of event-based expectations work has not been clearly articulated within the expectations literature.

The concept of 'technological community' is useful for understanding expectations work at events that are inclusive by nature and allow multiple narrators and perspectives to be taken into account. The term has been used to understand inter-organizational behaviour in innovation and it has been defined as "a group of scientists and engineers, who are working towards solving an interrelated set of technological problems and who may be organizationally and geographically dispersed but who nevertheless communicate with each other" (Rappa & Debackere, 1992). Within a technological community, a distinction is made especially between the expectations work conducted by scientists and industrial actors. While scientists lay emphasis on legitimizing their field of research, industrial actors are generally interested in economically viable business on a shorter time horizon (Bakker et al., 2011). Furthermore, research organizations and technology companies are usually engaged with certain technological applications making them natural proponents of these applications, in particular (Bakker et al., 2011). Technological communities may also include policy and other public bodies and industry associations acting in various supporting roles to the community. These tend to take interest in developing the field as a whole. In sum, the concept points out the role of actors of technology development and underlines both differences and similarities between different members of the community (Rappa & Debackere, 1992).

The Role of Narratives in Innovation Processes

The role of narratives in innovation processes has been discussed e.g. in the expectations literature (Eames et al. 2008), in innovation studies (Bartel & Garud, 2009) and in the sustainability transitions literature (Garud & Gehman, 2012). Studies have shown narratives to serve as spaces where diverging interests and agendas can be promoted (Eames et al., 2008) or, as Bartel and Garud (2009) have put it, as boundary objects that can generate interpretive flexibility. Furthermore, narratives have been claimed to co-ordinate innovation activities within organizations (Bartel & Garud, 2009). They have also been found useful in sustainability journeys. An organization may need to re-narrate its identity and purpose according to the ups and downs occurring on the way towards sustainability so as to remain credible to key stakeholders (Garud & Gehman, 2012) Finally, narratives are seen as a means of creating protective spaces for new technologies and enhancing a technology's competitive position on the market (Smith & Raven, 2012; Verhees et al., 2013).

Several studies have also paid attention to the narrative means of furthering emerging clean technologies with findings pointing to general themes present in technology promotion. The studies have discovered themes like 'ecotopia,' 'inevitability and technical progress' and 'staying in the race' with respect to the hydrogen economy (Eames et al., 2008: 363-368) or 'urgency and threat of climate change' and 'ecological modernization' in relation with the societal debate around wind farms (Barry et al., 2008). With respect to solar technology Laird (2003) discovered that it was promoted through business values by conventional advocates and social and ecological values by non-conventional advocates. Altogether, the themes detected in prior research can be roughly summarized into three categories: one pointing to technological progress and scientific evidence, another pointing to economic issues like business potential and employment and a third one emphasizing ecological sustainability. These themes seem common to clean energy technology discourse in general.

The Role of Field-Configuring Events in the Emergence of Organizational Fields

Bakker et al. (2011) regard the formation of collective expectations to occur in so-called 'arenas of expectations.' In these, enactors voice competing expectations that are assessed by selectors like policy makers and investors. This is a collective social process taking place at conferences, in journals and the wider media, to name a few. The particular role of conferences and other events for the emergence of organizational fields has also been addressed by several authors in organization studies (e.g. Garud, 2008; Oliver & Montgomery, 2008; McInerney, 2008). Especially, the role of events as loci for contestation and selection between different accounts has been emphasized (e.g. Garud, 2008; Bakker et al., 2011), but also their function as arenas for shared cognitive sense-making (Oliver & Montgomery, 2008) and for conventionalizing accounts has been identified (McInerney, 2008). For example, McInerney depicts a process where institutional entrepreneurs of a social movement create legitimacy for their accounts by anchoring them to “situationally-approapriate orders of worth” (2008: 1111) and by convincing powerful actors on the field to accept and promote them further.

These studies have also specifically addressed the functions of events. Garud (2008) has suggested events to serve as (i) forums for actors to meet, interact and exchange information (ii) contestation and selection environments between competing visions and (iii) spaces for creating legitimacy for one approach over another and bringing about institutional closure. Furthermore, events have been found helpful in aiding loose networks of individuals and organizations to transform into cohesive fields with an established institutional identity (McInerney, 2008), and in in the creation of explicit conclusions among actors (Oliver & Montgomery, 2008). Generally, it is thought that events have a crucial role in field change and evolution and that they, thus, merit close investigation (Lampel & Meyer, 2008). Also Garud (2008) has argued that events with experts and other stakeholders provide a fruitful arena for investigating, how a new field is generated in real time.

Analytical Framework

In this paper we analyse ‘event-based expectation work’ for an emerging sustainable energy technology. This means that we investigate how expectations are mutually constructed in a series of field-configuring events. In our understanding at the core of event-based expectations work is that visions and expectations are likely to evolve over time and, thereby, influence the development of a new field. We place particular focus on the the narrative means of furthering emerging technology (c.f. Eames et al., 2008). Furthermore, we use the concept “technological community” (Rappa & Debackere, 1992) to point out that, at the studied events, a range of different proponents were present, promoting their own perspectives and interests. Thus, the expectations work is understood as inter-organizational, communicative behavior within the community.

Empirical Data and Methods

We studied ten events organized between February 2010 and February 2013 in Finland as an effort to support the field emergence of solar technology. Table 1 provides a list of the events, participants and the types of data collected at each event. Our data consists of field-notes of the presentations and discussions, the in-print presentation slides (ca. 1250 slides), brochures distributed at events and video material shown at one event (ca. 15 minutes of expert interviews). Some of the events included workshop sessions, which were also noted and analysed. Observation data was gathered at six of the ten events and it covers 50 out of the 80 presentations. In half of the events field-notes were taken by two or more persons. In our notes we gave particular attention to arguments and phrases, yet we also took notes on general atmosphere and other interactions. Specific attention was paid to how the events evolved over time.

Our empirical analysis is grounded in narrative inquiry (Kramp, 2004). Narrative inquiry consists of a range of qualitative approaches that share an interest in how people give meaning to things and events in a narrative or storied form (Kramp, 2004: 108; Riessman, 2005: 1). The guiding thought behind these approaches is that people create meaning by connecting events, actions, and experiences and moving them through time (Kramp, 2004: 110). As defined

Table 1. Studied field-forming events 2010–2013: Organizing party, date and data used for the analysis.

	Phase 1		Phase 2			Phase 3					
Event number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Organizing party	Tekes	Tekes	Tekes	Tekes	Cleen & Finpro	Tekes	Aalto University	Tekes	Tekes	Aalto University & ATY	
Date	16.2.2010	15.2.2011	28.4.2011	8.12.2011	31.1.2012	7.2.2012	27-28.3.2012	21.6.2012	11.2.2013	4.5.2013	
Observation data available	no	no	yes	yes	yes	no	yes	no	yes	yes	
Presentations by different types of narrators	Number of presentations by different types of narrators[1]										Major narrators in each category
Manufacturing equipments for the solar industry			1	1		1			1		Beneq
Components for solar power and heat systems		2	1	4+1		1		1	1		ABB, The Switch, Luvata (later on Aurubis Finland)
Solar PV products			1	2			1	1	1		Naps Systems, Suntrica
Solar heat products		1		2+3			1		2	1	Savo-Solar, Oilon
Importers and installing businesses									2	1	Finnwind, Sonnenkraft
Energy companies				1+1				1	1	1	Fortum, Helsingin Energia (municipal energy company)
Construction business and their customers				3+3				5	5	1	Ruukki, Järvenpään mestariasunnot, TA.fi, City of Helsinki
Universities and research institutes			3	1+2			2		3		Aalto University, VTT, Tampere University of Technology

Table 1 cont.

	Phase 1		Phase 2			Phase 3					
Event number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Organizing party	Tekes	Tekes	Tekes	Tekes	Cleen & Finpro	Tekes	Aalto University	Tekes	Tekes	Aalto University & ATY	
Date	16.2.2010	15.2.2011	28.4.2011	8.12.2011	31.1.2012	7.2.2012	27-28.3.2012	21.6.2012	11.2.2013	4.5.2013	
Observation data available	no	no	yes	yes	yes	no	yes	no	yes	yes	
Presentations by different types of narrators	Number of presentations by different types of narrators[1]										Major narrators in each category
Industry associations				2+1			1		1	1	European Photovoltaic Industry Association (EPIA), European Solar Thermal Industry Federation (ESTIF)
Consulting organizations				3	1		1			1	Pöyry
Investors	1	1		2							VNT Management, Cleantec Invest, China Energy, Finnvera
Innovation & energy policy bodies				1+3						1	Tekes, Sitra, Ministry of Employment and the Economy

by Polkinghorne (1988: 13-14) a narrative is "... a meaning structure that organizes events and human actions into a whole ..." Narratives, thus, depict the point of view of the narrator and are bound to a particular time and place (Czarniawska, 2000).

There is great variance as to how narratives are conceptualized and handled by different scholars (Rhodes & Brown, 2005: 175). Polkinghorne (1988) has suggested a distinction between 'analysis of narratives' and 'narrative analysis'. In the former the researcher proceeds inductively giving first attention to an individual narrator and after that moving on to identifying shared themes or categories that emerge out of the data. In the latter the researcher constructs a narrative of his/her own and inflicts to it meaning and order that is not apparent in the data.

In Polkinghorne's (1988) terms, we carried out an 'analysis of narratives' giving attention to emic phrases and categories used by the narrators themselves. The method can also be conceived as an inductive theme analysis (Boje, 2001). In our analysis we use the term "narrator" (c.f. Kramp, 2004: 3) and "proponent" interchangeably to refer to event participants who, by giving presentations or taking part in the discussions, engaged in imposing meaning on the issue. The term "sub-plot" is used to describe single threads (often supported by several narrators) that, when woven together, form more complex and layered narrative themes (cf. Polkinghorne, 1988).

We began by thoroughly reading the field notes and written material with a focus on the point of view of the particular narrator. After that we proceeded to distinguishing themes in the particular narratives and finally common themes across proponents. In the theme analysis we gave attention to the nuanced, narrator-specific images within a category and iterated between the particular and the common components of the themes. In our empirical analysis we gave most attention to the presentations as they dominated the events in terms of time. These were analyzed based on field notes collected at the events and written text and visual imagery of the presentation slides. Our observations concerned the ways in which written slides were presented, questions directed at the presenters, reactions of the audience and follow-up discussions. The two forms of data were regarded as equally important parts of our analysis, and we did, thus, not treat them differently.

In the second phase, we analysed the evolvement of the expectations work in the course of the event series. This was done by re-visiting the empirical data and carefully assessing at what point in time each theme arose in the expectations work. Attention was also paid to the objectives of organizing parties with regards to the events and how the events related to each other.

Field-Configuring Events for Solar Technology

The position of solar technology in Finland has traditionally been weak. Although an industry association was founded already in the 1970's and building demonstrations have been conducted since the 1980's, the field has not been able to establish credible momentum. However, the recent advancements in the international solar market seem to have given a push to market formation. For instance, a recent cluster report illustrates the status of the Finnish national field as weak but promising (Finnish Solar Cluster Report, 2012). In the national history of solar energy, the events observed in this study could be entitled as a first serious attempt to establish a field in the area.

Interestingly, the events were organized by intermediary organizations instead of the industry association or the technology developers themselves. The industry association for solar energy in Finland (ATY) is relatively weak, representing mainly solar enthusiast and small businesses. Large incumbent companies are not a part of the association, and at the beginning of the events series, they were not active in the field altogether. The intermediary organizations included the Finnish Funding Agency for technology and innovation (Tekes), the research and innovation network Cluster for energy and environment (CLEEN), The National Trade, Internationalization and Investment Development Organization (Finpro), and Aalto University (national university for technology, business and art). The seminar series thus displayed an intentional effort of these organizations to push for field formation. The events were mostly open for all. The narrators present in the events included e.g. small and medium sized solar technology companies, large power and energy technology companies, construction firms, European industry associations, innovation and policy bodies and research organizations (see Table 1). The composition of the participants evolved as the events progressed.

By and large, the event series can be conceptualized as having proceeded in three phases. The first phase was focused on supporting the export activities of high tech SME's, while in the second phase emphasis was placed on the attractiveness of the solar industry per se. In the third phase attention was brought towards home market creation.

The first two events formed the first phase of the expectations work process. These events were organized by the Funding agency for technology and innovation whose purpose is to support the growth and exports of national industries and innovation activities. The first event was a kick off-seminar of a programme on renewable energy. Most of the analysed events were organized under this programme which sought to increase the growth and export possibilities of the clean tech industry. The second event was the yearly seminar of this programme. Directly in line with the role of the intermediary organization, these events had a focus on displaying the growth potential of the national clean-tech domain. Solar companies were included among the presenters but no particular focus was placed on the solar industry as such.

The second phase laid emphasis on the solar sector and its business potential at an international level and was formed by the following three events. During this phase the Funding agency for technology and innovation stepped out of its traditional position and begun to push for field formation. The other organizing party i.e. the research network for energy seemed to follow in these footsteps. The third event "Solar energy in Finland and EU" was the first to have a clear focus on solar. As novel elements, presentations from researchers were included in the program and time was also allocated for a workshop concerning the "will of Finnish companies" with respect to solar energy. This workshop did not, however, produce any concrete results and the participants seemed quite passive with respect to the discussion in general. Event number four, the "Solar Energy Forum", raised the profile of the events to a new level. It featured keynote speakers from the European solar associations as well as all relevant Finnish companies and researchers. For the first time large energy incumbents were also present. This event also included policy makers, to whom many of the key notes seemed to be directed. Also in this event time was allocated for workshops facilitated by an outside consultant. As a concrete result, a summary of the workshop outcomes was emailed to all participants. The fifth event was a workshop entitled "Innovating for Solar

Energy", and it was a direct continuation of the previous grand event with similar participants. An important goal was to establish understanding about whether the organizing institution should start a novel research program concentrated on solar energy. However, no concrete conclusions were reached.

Finally, the third phase created movement towards home market formation. Emphasis was now laid on convincing participants of the potential of solar technology even in the challenging conditions of Finland, combined with the practical goal of enabling connections between the supply and demand side participants. The last four events were positioned in this phase. While the sixth event made a temporary return to the traditional approach and featured only presentations from well-known export companies in the renewables field, already the seventh event, a course on solar energy, made a clear move to this direction. It was explicitly directed at the building construction industry and laid focus on solar as a small-scale distributed solution for Finland. The eighth event was a solar-energy workshop in which the construction companies and large incumbents were the most visible participants. The ninth event held in February 2013 had a taste of the same greatness as the grand event attracting first-line experts from business, academia and industry organizations and featuring stands from solar companies. However, it did not produce any concrete outcomes. Finally, the tenth event was organized in collaboration with the national university and the industry association. This event was strongly centered on home market creation, and the presentations and discussions followed this theme.

In general, the three stages make visible the transition in the roles of the intermediary organizations hosting the events. In the course of the events these enlarged their agendas to facilitate field formation. At large, the events seemed to serve the three crucial processes of field formation proposed by Geels & Deuten (2006, 273), that is (i) the establishment of a social network and community (ii) the emergence of intermediary actors that speak for the field and (iii) the creation of a knowledge infrastructure that enables the circulation of experiences and the emergence of common knowledge and vision. In the following we will demonstrate the narrative themes and their evolvement that we distinguished in the expectations work.

Narrative Themes in Expectations Work

Six interrelated narrative themes emerged from our analysis. These are Solar as (1) Progression and Modernization (2) Sustainability (3) Booming Business (4) Convenience and Usability (5) National Competitive Advantage and (6) Distributed Production. The themes should not be taken as clear entities – although they have been conceptualized as such for reasons of clear communication. Each theme contains sub-plots reflecting certain aspects of the theme and shared among multiple narrators as well as expectations typical for single narrators. Furthermore, many of the themes raised concerns that were brought up especially in the discussions following presentations. Four out of the six themes were supported by strong ideographs; claimed important for legitimizing new technology.

Table 2 summarizes the detected narrative themes including sub-plots, main narrators, theme related concerns and important ideographs. In the following we first depict the detected themes after which we analyze the evolvement of the expectations work. The themes are presented in the order of their appearance during the three phases of the event series.

Table 2. Narrative themes in expectations work.

Narrative Themes	Sub-plots	Main Proponents	Theme-Related Concerns	Ideographs
1. Progression and Modernization	- A natural consequence of scientific work and technological development - Coming along with other “smart” technologies - Part of modern architectural design	- SME’s - Research organizations - Innovation and policy bodies - Industry associations		- Technological progress
2. Sustainability	- Sustainable energy source - Ecological lifestyle choice - Expansion of renewables - Ethically and morally right choice - Abundance compared to other energy sources	- Most narrators		-Sustainability
3. Booming Business	- Exceptional regional successes in international markets - Cost reduction and approaching grid-parity - Natural flow of finances to solar	- Innovation and policy bodies - Large technology and energy companies - Venture capitalists	- Price competition due to Asian suppliers -Low ability of national organizations to be a part of the success	- Technology-led economic growth - Employment
4. Convenience and Usability	-Usability in extreme conditions - Fitting well to natural and built environment - Contributing to energy challenges in developing countries and secluded areas	-Technology companies - Municipalities -Industrial organizations		
5. National Competitive Advantage	- National know-how in technical engineering - Success of national solar companies - Feasibility of solar in the Northern sphere	-Technology companies -Research organizations -Innovation and policy bodies	- Lacking commercial ability of Finnish companies - Lack of a home market - Negative attitudes locally - Insufficient policy measures	- Staying in the race - Scientific know-how
6. Distributed Production	- Consumer empowerment - Potential of building-integrated solar -Bringing about a new economic system based on solar energy	- Technology companies - Innovation and policy bodies - Energy incumbentss	- Existing bureaucracy related to connecting distributed solutions to the grid - Need to bring system integrators and turnkey solutions to the market	.

Solar as Progression and Modernization

Since the very beginning solar technology was presented as ’progressive’ and an integral part of modern future. Technological development seemed to be thought of as unavoidable, almost like an “inevitable self-evident logic along a single, pre-ordained path” (cf. Stirling, 2007: 290). Thus, solar was perceived as a natural consequence of scientific work. This was fortified with the use of ‘technical convincing’ (cf. Reuss, 2008) by many narrators, which meant that often the broader context and exact meaning of technical details remained unexplained and impossible to understand for non-experts. The values of innovation and technological progress thus seemed to be taken as self-evident by the narrators. Stirling (2007: 292) has also noted this tendency, stating that expert language often capitalizes on universal pro-technology and pro-innovation arguments whilst the content and meaning are left undifferentiated. Also Schatzberg (1994) has argued that technology advocates frequently project progress onto the promoted technology whereas Eames et al. (2006: 366) have recognized the theme ‘inevitability and technical progress’ used to further the ‘hydrogen economy’.

This theme was visible especially in the presentations by the SMEs, the research organizations, policy bodies and the industry associations. For example, Beneq, a supplier of production and research equipment for thin film coating, presented pictures demonstrating modern laboratory equipment and microscopic images of solar application materials. The research organizations illustrated extensive amounts of technological information on research projects accompanied by wiring diagrams and graphs on cell performance. We also observed people getting deeply engrossed in technical detail. For instance, people would show enthusiasm related to exhibited technical applications or refer to some technical specifics as ‘real eye-openers’. Alternatively, some presentations evoked questions and counter-arguments concerning technological performance.

Many narrators used future- and progression-oriented phrases in their presentations. Thus, the narrators talked about “future emerging technologies” (Tekes), “innovative cell processes” (Aalto University) and “next generation applications” (ABB). Some envisioned a more distant future. A spokesperson for Tekes appeared hopeful for the future beyond 2020 to bring surprising advancements like “ultra low cost technologies”, “very high efficiency approaches” and “integration concepts for very high levels of PV penetration”. Frequently, solar was understood in connection with other emerging technologies. The narrators talked about “nano cells”, “hydrogen and fuel cells” (Aalto University) and “the terrestrial use of space photovoltaics” (Tekes) as areas of up-coming research. They also presented possible side-products of and diffusion supporting technologies for solar technology. Solar was seen to come along with a range of other ’smart‘ technologies such as energy-efficient “smart living” (Fortum), “smart heating” (ESTIF), “smart metering” (ABB) and, of course, the “smart grid” (e.g. ABB, VTT, EPIA), which is an established term to describe emerging electricity grids that use information and communication technology to improve grid performance.

At times solar technology appeared as a part of futuristic architectural design. The narrators presented pictures of Asian mega-cities with solar integrated skyscrapers and other modern buildings or major solar applications internationally like the world’s first commercial concentrating solar power tower PS 10 located in Andalucia, Spain. These constellations became symbols for solar technology, more broadly, making it appear as an intellectual celebration of modern science and technology and an inevitable part of a science-based future.

Solar as Sustainability

Arguments about solar technology as an unavoidable part of a sustainable energy system and necessary for mitigating climate change started to increase from the beginning of the second phase. Current energy production was conceived as damaging the environment, and if not transformed to a more ecological direction, leading to a gloomy future. Here, solar was thus understood as an alternative energy source rather than a display of technological excellence. Sustainability seemed a largely shared ideology in the background of the proponents, whereas clear anti-environmentalist perspectives were virtually non-existent at the events. Ecological arguments are common in energy technology discourse and have been distinguished e.g. in proponent visions on hydrogen (Eames et al., 2006) and wind energy (Barry et al., 2008). The theme was widely promoted by different narrators.

For many narrators solar appeared as an ethically correct, 'good' energy source that would come along with other sustainable technologies and practices. One narrator associated solar with e.g. composting, recycling, public transport and local food, i.e. as an ecological lifestyle choice in general (Helsinki City). Furthermore, pictures of solar panels frequently purported other ecological energy technologies like wind mills, biofuel fields or geothermal generators (e.g. VNT Management, EPIA, Tekes). Also the follow-up discussions pointed out that renewables should not compete against each other but be promoted as a unified group contributing to sustainability. Some narrators appealed to the audience's sense of compassion and responsibility: Fortum, a large energy incumbent, and Järvenpään mestariasunnot, a housing company, purported the famous image of a polar bear on an ice raft with titles pointing to the urgency of acting upon climate change. Many presentations ended with slogans hinting towards the 'righteousness' of solar energy, such as "Let us work together to change the world towards the better" (EPIA) or "Power and Productivity for a Better World" (ABB).

In conjoint with the inevitability argument, many narrators highlighted resource scarcity (the limited amount of oil and gas reserves, in particular) and pointed out the abundance of solar energy in relation to other energy sources. Particularly policy and research bodies stated that a range of social institutions and policies had been established that would limit prevailing consumption patterns and increase the use of renewables. The use of solar was regarded as deriving naturally from its sheer quantity on earth. It was furthermore suggested, that great availability would eventually lead to solar energy becoming proportionally cheaper than other power sources. For instance, the energy incumbent Fortum described solar as an "infinite fuel resource". Arguments about inevitability and urgency are typical of new technology discourse, and have been recognized in previous literature, too (cf. e.g. Eames et al., 2006; Barry et al., 2008).

Solar as Booming Business

Starting from the second phase an increasing number of narrators took the internationally growing solar market as a starting point and regarded solar technology as a promising business sector. In this context global developments, like the outstanding technology diffusion in Germany and the emerging markets in China and the USA, seemed important for the proponents. Within this theme the narrators referred to powerful ideographs such as 'technology-led economic growth' and positive effects on 'employment' (e.g. Tekes, Aalto University, ESTIF). As with most new technology discourse, these themes have been found central in political discussions on energy (e.g. Teräväinen, 2010). Main narrators for this theme included innovation and policy bodies, venture capitalists and large technology and energy companies.

Graphs demonstrating the remarkable growth of the solar market internationally appeared relevant, and these were frequent in the presentations (e.g. Tekes, Fortum, EPIA). For instance Naps Systems, the pioneering Finnish solar electricity systems company, talked of market development as "exponential" and "so fast that anything I say is already outdated". In addition, the proponents seemed convinced of the approaching "grid parity", that was mostly associated with economies of scale and accumulation of experience. They also showed enthusiasm over exceptional regional successes like the job creating effect of clean energy technologies in Germany (VNT Management). However, the discussions also raised concerns related to market development like the fierce price competition on the solar panel market.

An important sub-plot was the natural flow of finances into this booming sector. Many regarded investor interest in clean technology as increasing. VNT Management portrayed graphs on the remarkable growth rates of investments in clean technology in the past and on prognoses that foresaw investment volume nearly triple within the next decade. Within this subplot also doubts were expressed with respect to investor interest in solar nationally. In one event a proponent from the audience asked how many investors were presents in the event. As no hands were raised, he laconically stated to "rest his case".

Solar as Convenience and Usability

In the second phase arguments about solar technology as convenient and highly adaptable begun to gain ground. For instance, it was illustrated as fitting well to the built and natural environment. The narrators underlined its value to the consumer and framed it as convenient to use, even in challenging conditions. Out of all the detected themes, this theme was most reflective of solar-specific promises rather than general promises of new energy technologies. Main proponents of this theme included technology companies, municipalities and the industrial organizations.

In the presentations architectural landscape pictures displayed solar as an aesthetic part of urban planning and not disturbing city scenery (e.g. Helsinki City, Aurubis). The technology company Aurubis crystallized this image in a headline stating "Solar technology becomes one with architecture". Other pictures visualized it as merging with nature. Naps Systems and the industry associations presented photography with natural elements like forests, animals and mountains coming together with solar panels. A picture by ABB demonstrated an aerial view of grass fields with a 'solar panel field' in between. Almost like an extension of nature, the solar installation formed a field-like-shape similar to the living environment.

A visible sub-lot was the usability of solar in extreme conditions. In conference handouts Suntrica, a small technology company focused on portable solar chargers, associated the technology with adventurous individuals relying on solar batteries on the go. Naps Systems expressed a similar storyline and pointed to solar as working flexibly in differing geographical settings. As a curious example the company presented a picture of the "camel fridge": a portable solar-panel-fridge carried on the back of a camel.

A sub-plot within this theme was the potential of solar in contributing to the energy issue in developing countries. Solar was presented as enabling energy to be provided to secluded geographical areas, thus, furthering their prosperity. Like in the 'sustainability theme', moral connotations were central here as well. Naps Systems illustrated solar as "improving the quality of life [in rural communities]" whereas Aalto University presented a topic entitled "Hope to the developing countries from solar solutions". The incumbent energy company Fortum depicted a picture of a Native African standing next to a solar panel, pointing clearly to power production in third world countries.

Solar as National Competitive Advantage

In the third phase solar technology was, to an increasing extent, regarded as a favorable business sector at the national level. In this respect the narrators spoke of the country's long tradition and great know-how in technical engineering i.e. national scientific expertise in the area. 'Science' and 'technology' have been recognized as important cultural values in Finland (Michelsen, 1999; Litmanen, 2009), and the narrators seemed to be drawing from the legitimacy of the theme in national political culture. Main proponents of this theme included technology companies, research organizations and innovation and policy bodies.

The narrators pointed out the superiority of Finnish companies compared to international competitors. Like in the 'progression and modernization' theme, 'technical convincing' (Reuss, 2008) was used to refer to national companies as globally unique and fulfilling niche market demands. Representatives of Tekes characterized e.g. the small solar thermal company Savosolar as "world's only company capable of equipping their collector with a selective absorption coating" and reported on how Finnish companies had succeeded in international competitions with headlines such as "Finnish Innovations in the Final". Finnish technical know-how was understood as boosting the rise of the solar sector internationally, and statements like "Finnish technology empowers the rise of solar energy" were given.

A sub-plot within this theme centered on displaying confidence in the feasibility of solar energy in Nordic conditions. The narrators underlined the sufficiency of radiation in Finland and presented this as an important factor supporting the emergence of home markets and, thus, the establishment of the field altogether. A common argument was that "In Southern Finland, where most people live, the sun shines [per annum] as much as in North-Germany".

However, the follow-up discussions raised concerns over the capability of national companies to capitalize on business opportunities. For instance, the absence of a home market, general attitudes towards solar technology at the national level, and the insufficiency of policy measures raised concerns. The concerns were largely related to the ability of Finland to 'stay in the race'. One company (Beneq), for instance, stated that "Not many companies have time to wait around until the home market proves the product successful – the train passes, let's hope that Finnish innovations are on board." 'Staying in the race' is a common ideograph used to promote technological change and innovation, irrespective of the technology in question. It has played a role in the promotion of hydrogen (Eames et al., 2006) and is also highly visible e.g. in Finland's roadmap for furthering wind energy (cf. Teknologiateollisuus, 2009).

Solar as Distributed Production

Some narrators perceived solar technology as promoting distributed small-scale energy and consumer empowerment, as it allows households to gain access to power production. The theme was further strengthened in the follow-up discussions, where participants pointed out the great role that distributed energy has had in the German energy transition. However, the discussions also brought to light concerns related to this theme, as the narrators pointed out the bureaucracy and the pragmatic problems related to connecting distributed applications to the grid. Argumentation about empowerment is common for clean energy discourse and, for instance, Eames et al. (2006) and Laird (2003) have recognized similar arguments in their empirical studies. The main proponents of the theme included technology companies, innovation and policy bodies and an energy incumbent.

A sub-plot within the theme lied in the potential of building-integrated solar energy. The proponents seemed to conceive successful demonstrations conducted nationally as important, considering the frequent references to them. For instance, they presented the net zero-energy apartment and the passive-energy-house (Helsinki City, Luvata, VTT). Obviously, these appeared as a source of credibility by "grounding [the technology] in local contexts" (cf. Eames et al., 2006: 361). This particular sub-plot presented solar as it appears in the Long-Term Climate and Energy Strategy of the Finnish Government (Ministry of Employment and the Economy, 2008: 38). In it solar technology is advocated a role only in heating, at least in the short run. Other technologies that are conventionally furthered in the same manner include i.e. heat pumps, biofuels and wood pellets.

The energy incumbent Fortum (with production from nuclear- and hydro power as well as fossil fuels) represented an exceptional case among the narrators. Recently the company has created a business unit for solar energy and started to campaign visibly on the topic. In its presentations it depicted a vision of the 'Solar Economy': a 'deep green' energy system combining several renewable energy technologies to achieve "inexhaustible and emissions-free, solar-based production". In 'Solar Economy' consumers were purported as operating as co-producers in a distributed system. Solar was thus regarded as a 'technical fix' (cf. Eames et al., 2006: 364) that would not only provide inexhaustible energy but also lead to profound social benefits. Fortum's vision was crystallized in a picture portraying the shift from today's energy system to the 'Solar Economy'. In the picture the traditional energy system was presented on the left, situated low in the horizon and painted in dark colors. Next, the picture portrayed the "transition phase" including nuclear power plants and other low-emission plants. These were purported almost as if leading the way from the 'valley of darkness' towards the emerging solar economy, positioned on a hill on the far right and portrayed in bright colors. It seemed that with its depiction of "Solar Economy" the company was investing effort into re-narrating its past accomplishments and purpose (c.f. Garud & Gehman, 2012) in order to fit solar into its profile and to frame itself as a legitimate actor in renewable energy. Towards the end of the events it had launched a solar panel package to private households and, later on, invested also in a large solar power plant in India. Fortum's campaign carried the same title as the visionary book by Scheer (2004): 'The Solar Economy'. In the book Scheer foresees an energy system in which fossil fuels and nuclear energy are replaced by renewables, leading to benefits alike the ones presented here.

Evolvement of Expectations Work

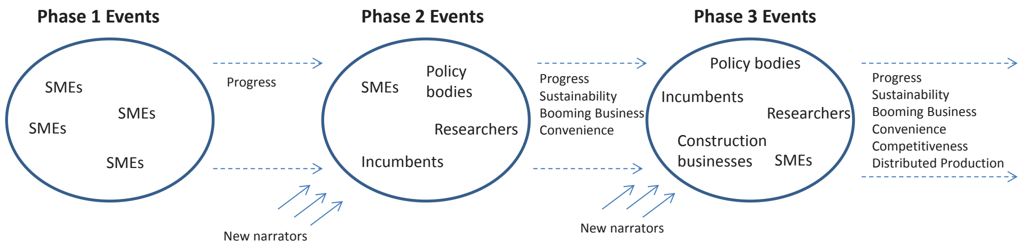
As indicated above, the narrative themes evolved in conjunction with the three phases of the field-configuring events. The categorization of the themes to the phases is not unambiguous, but reflects the points in time where the themes started to gain considerable ground in the expectations work. As the events progressed, previously emerged themes matured and took new forms.

The theme (1) Progression and Modernization was dominant in the first phase, as the events were mostly adhering to the purpose of the mediating organization instead of creating expectations for the solar field as such. As can be seen from Table 1, the range of narrators was limited and the theme was mainly visible in the presentations by the solar SMEs purporting company products as a part of advanced technologies and themselves a part of progressive industries.

The themes (2) Sustainability (3) Booming Business and (4) Convenience and Usability appeared in the second phase, as attention shifted towards portraying the business potential of solar at an international level. At this stage researchers and policy bodies joined the events opening up new perspectives to the field, such as sustainability concerns. Also new SME companies specialized in adaptable solutions entered and emphasized the convenient use of solar solutions The theme 'Booming Business' emerged as a strong theme and was further fortified as large companies, including energy incumbents, joined the events and pointed to developments in leading markets. The 'Progression and Modernization' theme got further strengthened during the second phase as innovation-focused events were organized and the research community was invited to participate.

The third phase introduced the two latter themes (5) National Competitive Advantage and (6) Distributed Production. At this point the focus shifted from the attractiveness of the international markets towards domestic developments, and especially the last event was centered on home market formation. Also the national building construction companies became more visible in the last stage focusing on solar as a small-scale energy source. In the last phase the themes Sustainability, Booming Business and Convenience matured and became more diverse, as new narrators like, for example an NGO and another energy incumbent, gave their presentations on the issue.

Hence, the expectations work evolved gradually as an exploration of complementary visions and expectations for the technology. The narrators started off with a fairly narrow storyline defined by the rationale of the intermediary organization. In the course of the events, this storyline spread into multiple narratives upon which to build the field's future. This happened as the event series progressed with more diverse and solar-focused events taking place and, the intermediary organizations stepping outside their primary roles and inviting new narrators to join. In general, the evolvement of the expectations work represents a widening of the narrative space for different expectations and benefits of solar technologies. The storyline moved from a high-tech export focus towards a more diversified set of arguments and conceiving solar as interesting for several societal reasons. During the events, focus also shifted closer towards the Finnish society and home market creation, and led to a wider range of national actors to identify with the field. Picture 1 presents the evolvement of the expectations work throughout the event series.



Picture 1. Evolvement of Expectation Work.

Discussion and Conclusions

The main purpose of this study was to investigate how expectations work was carried out for a new clean energy technology through a series of field-configuring events. This is an important perspective in mapping out the development of an emerging field over time and understanding the nature of expectations work conducted through an event series. While the sociology of expectations literature has emphasized the importance of expectations for field emergence (e.g. Bakker et al, 2011), the notion of event-based expectations work has not been articulated in this context. The present study helps in understanding the evolution of event-based expectations work in early phases of field formation. Our analysis of narratives offers an empirical starting point for addressing the phenomenon within the expectations literature and invites additional theoretical and empirical discussion on the topic.

We suggest that event-based expectations work is fruitful for exploring complementary visions and expectations for a new technology. Whereas prior findings highlight the importance of explicitly aligning visions and expectations for the development of new fields (Brown & Michael, 2003; Bakker et al., 2011), our study shows that event series can lead to an initially narrow storyline gradually spreading into multiple narratives upon which to build a field's future. In this manner, events can guide and strengthen the advocacy for a new clean technology, even if they do not lead to immediate concrete results. We found this to happen as the expectations work evolved through three stages, each of which was focused on particular aspects of field-configuration. The expansion of the narrative themes was enabled as the intermediary organizations enlarged their agendas from their core purpose towards a more explicit effort on field formation, invited a more diversified group of participants to join the events and came up with new event topics. Also the events were allowed to be increasingly focused on the networking of different actors in this field. Consequently, our findings suggest that, besides an alignment of visions and expectations, also their multiplication can be valuable.

Based on our findings it seems that guidance through the multiplication of narratives is particularly important for new and unsettled fields that have not reached the stage of contestation between different technologies and solutions. Instead, the priority of weak fields lies in building credibility and legitimacy for the entire technological community. It thus seems that at early stages of field formation as technology proponents begin to interact with each other, expectations work is likely to be focused on a mutual exploration of multiple technological opportunities. In the course of an event series participants gradually become aware of each other's standpoints and develop a sense for the presence of multiple narratives and viewpoints within them. Recently, the strategic niche management literature has found the "widening of narratives" to be important in the development of niche spaces for sustainable innovation (Smith et al., 2014). This further accentuates the significance of this phenomenon and calls for attention towards it when studying expectations work in a pre-market phase of technological fields.

Compared with previous accounts on arenas of expectations (cf. Bakker et al., 2011) and field-configuring events (cf. Garud, 2008) it is notable that contestations between different viewpoints or technologies were absent from the events studied in this paper. Instead, the proponents seemed focused on building a convincing set of arguments for furthering the field as a whole. In line with this, also the six narrative themes detected should not be understood as competing storylines for the field but as complementary visions. The themes themselves were highly flexible and did not exclude any narrator-specific standpoint from the expectations work. We perceive the themes as common denominators for different narrators at which they could create mutual understanding and connect with others. More, specifically, we found the narratives to function as reference points that were flexible enough to allow for a simultaneous advancement of generic expectations promoting the entire field and narrator-specific expectations promoting the agenda of a single proponent. Our findings, thus, complement those that have shown narratives to allow diverging interests and agendas to be advanced simultaneously (Eames et al., 2008), or to serve as boundary objects that can generate interpretive flexibility (Bartel & Garud, 2009). Our findings are complementary, as we emphasize the role of narratives in promoting two layers of expectations - generic and particular. Finally, we also found that in early phases, field-configuring events are likely to support this specific type of interpretive flexibility in expectations work. Events may provide a unifying and inclusive context for a wide range of narrators linking different perspectives to a common agenda.

More specifically, our analysis yielded six themes through which solar technology was promoted: Solar as (1) Progression and Modernization (2) Sustainability (3) Booming Business (4) Convenience and Usability (5) National Competitive Advantage and (6) Distributed Production. The themes were not explicitly referred to, but appeared as embedded in the presentations and discussions. This embeddedness made the themes look like taken-for-granted promises of new technology rather than something that should be critically scrutinized or elaborated upon. The impression was further reinforced through the use of powerful ideographs, that is, self-justifying normative goals (McGee, 1980) to which many of themes were closely connected. As suggested in extant literature ideographs like 'technological progress' or 'sustainability' may serve as additional symbolic and cultural resources for legitimizing new technology (van Lente, 1993).

The narrative themes detected in this study are rather typical of clean technology discourse and seem to be largely shared across technologies and regions. Technological arguments (pointing e.g. to technological progress), economic arguments (pointing e.g. to new business potential), and sustainability arguments (pointing e.g. to climate change) have been identified by several authors in relation to various clean energy technologies (e.g. Eames et al., 2006; Barry et al., 2008). As such, they could be seen to reside within the confines of ecological modernization (Pataki, 2009); technological optimism combined with the aim of generating sustainability within current institutional order. However, in the national Finnish context the themes represented a renewal of the social discussion on energy. In Finland, energy policy targets have traditionally focused on providing sufficient energy at affordable prices to secure the operating conditions of established industries, accompanied with objectives to mitigate climate change (e.g. Ruostetsaari, 2010). Yet, here the narrators clearly aimed to shift this approach by pointing out the importance of generating new industries and presenting the technology as an emerging value innovation. The proponents thus aimed to reposition the discussion on solar technology from a mere energy policy issue to promoting industry, innovation and energy policy targets simultaneously. Hence, the detected themes can also be perceived as an effort to re-narrate the issue in a way that would make sense in a particular context (c.f. Garud & Gehman, 2012) and to make a case for a novel approach towards energy. In the studied case, the narrators drew e.g. from the long national tradition in engineering as well as the cultural values of 'science' and 'technology' (c.f. Michelsen, 1999) to achieve this and create legitimacy for new lines of thinking.

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References

Bakker, S., H. van Lente & M. Meeus (2011) 'Arenas of expectations for hydrogen technologies', Technological Forecasting & Social Change 78: 152-162.

Barry, J., G. Ellins & C. Robinson (2008) 'Cool Rationalities and Hot Air: A Rhetorical Approach to Understanding Debates on Renewable Energy', Global Environmental Politics 8(2): 66-98.

Bartel, C. & R. Garud (2009) 'The Role of Narratives in Sustaining Organizational Innovation', Organization Science 20(1): 107-117.

Boje, D.M. (2001) Narrative methods for organizational and communication research (London: Sage).

Borup, M., N. Brown, K. Konrad & H. van Lente (2006) 'The sociology of Expectations in Science and Technology', Technology Analysis & Strategic Management 18 (3/4): 285-298.

Brown, N. & M. Michael (2003) 'A Sociology of Expectations: Retrospecting Prospects and Prospecting Retrospects', Technology Analysis & Strategic Management 15(1): 3-18.

Czarniawska, B. (2000) The uses of Narrative in Organization Research, GRI Report 2000:5, Göteborg.

Eames, M., W. McDowall, M. Hodson & S. Marvin (2006) 'Negotiating Contested Visions and Place-Specific Expectations of the Hydrogen Economy´, Technology Analysis & Strategic Management 18(3/4): 361-374.

Finnish Solar Cluster Report (2012) Pöyry Management Consulting Oy, Tekes.

Garud, R. (2008) 'Conferences as Venues for the Configuration of Emerging Organizational Fields: The Case of Cochlear Implants', Journal of Management Studies, 45(6): 1061-1088.

Garud, R. & J. Gehman (2012) 'Metatheoretical perspectives on sustainability journeys: Evolutionary, relational, durational,' Research Policy 41: 980-995.

Kramp, M.K. (2004) 'Exploring Life and Experience Through Narrative Inquiry,' in K. deMarrais & S.D. Lapan (eds), Foundations for Research: Methods of Inquiry in Education and the Social Sciences (New Jersey: Lawrence Erlbaum Associates): 103-121.

Konrad, K. (2006) 'The Social Dynamics of Expectations: the Interaction of Collective and Actor-Specific Expectations on Electronic Commerce and Interactive Television,' Technology Analysis & Strategic Management 18(3/4): 429-444.

Konrad, K., J. Markard, A. Ruef & B. Truffer (2012) 'Strategic responses to fuel cell hype and disapointment,' Technological Forecasting & Social Change 79: 1084-1098.

Laird, F. (2003) 'Constructing the Future: Advocating Energy Technologies in the Cold War,' Technology and Culture 44 (1): 27-49.

Lampel, J. & A.D. Meyer (2008) ´Field-Configuring Events as Structuring Mechanisms: How Conferences, Ceremonies, and Trade Shows Constitute New Technologies, Industries, and Markets´, Journal of Management Studies 45: 1025-1035.

Litmanen, T. (2009) 'The temporary nature of societal risk evaluation: Understanding the Finnish nuclear decisions,' in Kojo, M. & Litmanen, T. (eds), The renewal of nuclear power in Finland (London: Palgrave MacMillan): 192-217.

McGee, M.C. (1980) 'The 'Ideograph': A Link Between Rhetoric and Ideology,' The Quarterly Journal of Speech 66: 1-16.

McInerney, P-B. (2008) 'Showdown at Kykuit: field-configuring events as loci for conventionalizing accounts,' Journal of Management Studies 45(6): 1089-116.

Meyer, A.D. & V. Gaba & K. Colwell (2005) 'Organizing far from equilibrium: non-linear change in organizational fields,' Organization Science 16(5): 456-73.

Michelsen, K-E. (1999) Viides sääty, Insinöörit suomalaisessa yhteiskunnassa (Helsinki: Tekniikan Akateemisten Liitto). [The fifth class, engineers in Finnish society].

Ministry of Employment and the Economy (2008) Long-Term Climate and Energy Strategy: Government Report to Parliament 6 November 2008. https://www.tem.fi/files/20585/Selontekoehdotus_311008.pdf. 01.09.2012.

Oliver, A.L. & K. Montgomery (2008) 'Using field-configuring events for sense-making: a cognitive network approach,' Journal of Management Studies 45(6): 1147-67.

Pataki, M. (2009) 'Ecological Modernization as a Paradigm of Corporate Sustainability,' Sustainable Development 17: 82-91.

Polkinghorne, D.E. (1988) Narrative knowing and the human sciences (Albany: State University of New York Press).

Pollock, N. & R. Williams (2010) 'The Business of Expectations: How Promissory Organizations Shape Technology and Innovation,' Social Studies of Science 40(4): 525-548.

Rappa, M.A. & K. Debackere (1992) 'Technological communities and the diffusion of knowledge,' R & D Management 22(3): 209-220.

Reuss, M. (2008) 'Seeing like an engineer - Water projects and the mediation of the incommensurable,' Technology and Culture 49(3): 531-46.

Rhodes, C. & A.D. Brown (2005) 'Narrative, organization and research,' International Journal of Management Reviews 7(3): 167-188.

Riessman, C.K. (2005) 'Narrative analysis', in N. Kelly, C. Horrocks, K. Milnes, B. Roberts & D. Robinson (eds), Narrative, memory and everyday Life (Huddersfeld: University of Huddersfeld): 1-7.

Ruostetsaari, I. (2010) Energiavalta: Eliitti ja Kansalaiset Muuttuvilla Energiamarkkinoilla (Tampere: University Press). [Energy authority: The elite and the citizens on a changing energy market].

Schatzberg, E. (1994) 'Ideology and Technical Choice: The Decline of the Wooden Airplane in the United States', Technology and Culture 35(1): 34-69.

Scheer, H. (2004) The Solar Economy: Renewable Energy for a Sustainable Global Future (London: Earthscan Publications).

Smith, A., F. Kern, R. Raven & B. Verhees (2014) 'Spaces for sustainable innovation: Solar photovoltaic electricity in the UK', Technological Forecasting and Social Change 81: 115-130.

Smith, A. & R. Raven (2012) 'What is protective space? Reconsidering niches in transitions to sustainability', Research Policy 41: 1025-1036.

Solangi, K.H., M.R. Islam, R. Saidur, N.A. Rahim & H. Fayaz (2011) 'A Review on Global Solar Energy Policy', Renewable and Sustainable Energy Reviews 15: 2149-2163.

Stirling, A. (2007) 'Deliberate Futures: Precaution and Progress in Social Choice of Sustainable Technology', Sustainable Development 15: 286-295.

Teknologiateollisuus (2009) Tuulivoima-tiekartta. [Road-map for wind energy]. http://www.teknologiateollisuus.fi/fi/ryhmat-ja-yhdistykset/tiekartta.html. 24.11.2012.

Teräväinen, T. (2010) 'Political opportunities and storylines in Finnish climate policy negotiations', Environmental Politics 19(2): 196-216.

Van Lente, H. (1993) Promising technology: the dynamics of expectations in technological development, PhD thesis (University of Twente, NL: Enschede).

Van Lente, H. & A. Rip (1998) 'Expectations in Technological Developments: An Example of Prospective Structures to be Filled in by Agency', in Disco, C. & van der Meulen, B. (Eds.), Getting New Technologies Together, Studies in Making Sociotechnical Order (Berlin: Walter de Gruyter): 203-231.

Verhees, B., R. Raven, F. Veraart, A. Smith & F. Kern (2013) 'The development of solar PV in The Netherlands: A case of survival in unfriendly contexts', Renewable and Sustainable Energy Reviews 19: 275-289.

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Self-Building Courses of Solar Heat Collectors as Sources of Consumer Empowerment and Local Embedding of Sustainable Energy Technology

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Self-building courses have been identified as a stimulus for user innovations, local embedding and diffusion of renewable energy technology. In this paper we explore the Finnish solar heat collector self-building courses. Our empirical material consists of field observations, interviews with teachers and a survey of participants since the early activities in late 1990s. Our findings show that course participants have started to follow energy discussions, collect information and actively advise others. Participants view themselves as increasing capable actors in renewable energy. They have also begun to engage in energy saving and renewable energy at home on a wide front. The fact that only 41% have installed their collector points to the importance of timing but also to the way in which self-building courses serve as a first step into renewable energy. Overall our results indicate that self-building courses offer possibilities for material engagement that has outcomes beyond the immediate objectives of the course.

Keywords: solar heat collectors, self-building, material engagement

Introduction

Energy provision has been historically based on centralized systems, in which energy users have limited involvement. The current interest in micro-generation is challenging this situation. However, the adoption of new technologies and roles in diverse local contexts requires significant adaptation and transformation of both technologies and contexts. We explore solar heat collector self-building courses as sites of such transformation.

Self-building courses have been identified as a stimulus for user innovations and local embedding of the technology in Austria (Ornetzeder & Rohracher, 2006). They have also been identified as a key diffusion mechanism that at times has been comparable to the commercial supply of solar heat collectors (Ornetzeder, 2001). Apart from promoting diffusion and engaging new users for solar heat collectors, there is also literature suggesting that energy-related self-building activities can empower consumers and help them take a more active role in energy systems (Darby, 2006). More generally, courses can also be understood as sites of material engagement in which public politics is enacted. However, there is limited research on self-building courses outside the Austrian context, and particularly the wider impacts of such courses remain unclear. Hence, our research is explorative and aims to uncover the evolution of course activities in Finland, the participants' interests, experiences and changes in practices following such courses, and the potential impacts of self-building courses on local interest and uptake of solar technologies.

We conceptualize self-building courses as material settings in which politics and publics are mobilised (Marres, 2009; Marres & Lezaun, 2011). This suggests that self-building activities have impacts beyond the immediate scope of the course (i.e., the building of solar heat collector collectors for the participants). We are interested in both the way mobilization takes place at the courses and in the effects of this mobilization. The latter include changes in other household practices and changes in relations to technology as such and energy technologies in particular. Moreover, on the community level, we anticipate changes in overall engagement with renewable energy. Based on our findings, we suggest avenues for further and more specified research and experimentation.

The Finnish solar heat self-building activities lean explicitly on the Austrian experiences, and yet differ from them in important ways. The Finnish courses are not self-organised citizen initiatives, but organised by vocational schools, folk high schools and entrepreneurs. Yet, the Finnish courses lack public recognition and the institutional support. Solar heat collectors have also evolved since the Austrian courses in the 1990s and self-building might be less cost-effective today. Hence we can expect that the motivations to participate in courses as well as the outcomes in terms of wider dissemination are different in Finland from the Austrian experiences.

The paper is structured as follows: We continue by first discussing user involvement in technology development and, in particular, the role of self-building activities. Having established this background we set the research questions that address the Finnish self-building courses. Thereafter we introduce our empirical material and discuss both the development and scope of Finnish self-building activities as well as the motivation and the wider impacts of participation in these courses.

Solar Heat Collector Self-Building Courses as Sites of Material Engagement

The involvement of users in the development of new technologies is a popular topic in science and technology studies, albeit approached from different perspectives. The social construction of technology approach has focused on how particular early user groups shaped technological development paths (Bijker et al., 1986). Following from this, there have been attempts and calls for 'opening up' the early stages of technology development to a wider array of different kinds of users through various discursive forums and practices (Rip et al., 1995; Schot, 2001; Heiskanen, 2005). User involvement is stressed because different configurations of technological systems have political consequences for which kinds of users are empowered or disenfranchised.

However, diverse users can also get engaged in technology development through action rather than discussion or conventional political means (Marres, 2009). User innovation and the role of lead users who invent to meet needs that are not met by the current market offerings are one example of practical engagement (von Hippel, 2005; Ornetzeder & Rohracher, 2006). In particular, when examining the development of renewable energy technologies, practical engagement and social mobilization is viewed as crucial for the acceptance and local embedding of new technologies, as well as for their diffusion to other contexts (Raven et al., 2008). More generally, Marres and Lezaun (2011) suggest that individuals who experiment with technology form engaged material publics. The use of technology and a public report of one's material entanglements results in 'public intimacy' and in material engagement that is at the same time public and political as well as material and intimate.

What is the nature of the spaces in which political leverage is acquired and accomplished through practical and material engagement, and to what extent and in which respect might self-building activities be political? Marres and Lezaun (2011) agree on the political facet of ongoing experimentation and technology development by lead-users but also point to the efforts required in and consequences of material engagement. These efforts signal that technologies have real conditions and consequences and are 'doable' in various degrees (Marres & Lezaun, 2011). That is, the private joys and struggles of material entanglements carry a political weight when brought into public. From this perspective, experimentation refers to a sensual probing and trial of new technologies that results not (only) in new knowledge but also in a reconfiguration of socio-material entities (Marres, 2009).

Our conceptualization of self-building courses as material settings in which politics is performed suggest a particular line of research. Firstly, we understand experimentation as the sensual appropriation of new technology that involves both changes in the design of, for example, solar collectors but crucially also in the way the devices are to be talked about, understood, assembled, installed and combined with other existing technologies. This is to say that experimentation does not necessarily leave traces in the product design, and that material engagement is to be assessed not only in terms of user innovations. *Experimentation* and *assembly* are interesting also as modes of material engagement and as 'doing' or inserting the self in the technology. Secondly, one needs to understand the way that these efforts are made public. Sharing via Internet blogs (Marres, 2009) and Internet forums (Hyysalo et al., 2013) are special cases of sharing user innovations. Self-building courses imply different media and particular collegial publics that include other course participants and alumni as well as future participants.

The role of practical action by users and user movements in the political struggle over system design is particularly highlighted in the case of open source software (e.g. Holthgrewe & Werle, 2005). Here, the struggle is explicitly played out through a counter-culture that focuses on the concrete development of an alternative (and better) system to that represented by the dominant market players. In the case of open source software, the publicity of efforts is at the very heart of this activity. However, research on motivations for users to participate in open source software development reveals a mixture of interests, some of which are pragmatic, some personal, some professional and only some explicitly political (Freeman, 2007). Hence, we too approach the political nature of material engagement as emergent rather than as intentional and explicitly organized.

The topic of user-driven technological counter-cultures has re-emerged in a debate over low-carbon energy systems and the types of roles that various systems configure for users (e.g. Hoffmann & High-Pippert, 2005). Small-scale renewable energy has often been presented as a counter-force to large-scale centralized energy systems and the related economic and political systems. Indeed, user involvement and, to a degree, also collective self-building are frequent in low-tech solutions such as solar heat collectors and small scale wind turbines[1]. Recent research has also suggested that a decentralized energy system based on active user involvement – i.e., via micro-generation of energy – could serve to empower users more than the current centralized system does. This argument builds on (fairly scattered) evidence on small groups of users who produce their own heat and power and are more aware of their energy consumption than those who solely rely on the dominant centralized energy system (Keirstead, 2007).

Some of these issues have already been examined in connection with solar heat collector self-building courses. Ornetzeder (2001) and Rohracher and Ornetzeder (2006) examined the solar self-building course movement in Austria and found it had a significant role in not only early technology development, but even more in the diffusion and acceptance of solar heat collectors (self-built and commercially manufactured) in Austria. In addition to the practical skills that participants gained, the peer-to-peer learning and social exemplars set by these courses were found to be influential. Ornetzeder (2001) also points out the way that participants gained increasing scope to act and further engage new people in solar heat collector self-build courses. Yet these previous studies on self-building do not elaborate on how the courses influence participants' relations to energy and technology.

Despite extended efforts, we have not been able to locate wider research on self-building courses of renewable energy technologies. Citation databases contained no clear stream of research connected to the Austrian studies mentioned above. More generally searching for 'course', 'training' or 'hobbyist' activity in renewable energy technology with Google Scholar and in Science Direct yielded no results pertaining to organized self-building activities. There is thus an obvious need to focus on self-building courses and, in particular, on their abilities to mobilise and empower diverse participants.

The self-building courses organized in Finland represent an attempt to 'import' the Austrian experience, but have gained a distinctive local flavor, as will be shown in the following. We specify our research questions as following. In terms the relocation of self-building courses, it is interesting to see (1) *whether similar phenomena have the capacity to survive in other cultural contexts with different traditions, and whether they have the capacity to engage a wide cross-section of the population in one way or another.* One question here is whether the self-building courses in Finland rely on a relatively narrow segment of 'deep green' people, or whether they manage to offer participants some immediate and more personal benefits, as they did in Austria (Ornetzeder, 2001).

A related question pertains to the courses' capacity for survival and evolution. Ornetzeder and Rohracher (2006) stressed the importance of the self-building courses at the early stage of technological diffusion, when manufactured packages were expensive and still left room for improvement. The courses started to spread in the Finnish context at a much later stage and never reached the level of nation-wide institutionalization that was experienced in Austria. Hence, we ask: (2) *Is there a mechanism for social replication and evolution in the Finnish courses that allows them to grow, share experiences and evolve* *as the technology and market evolves and matures?*

If and when DIY courses can survive, their outcomes are of key relevance. We ask (3) *whether the courses can serve to promote acceptance and local embedding of a novel technology through peer-to-peer learning, social examples and social mobilization.* When examining social mobilization, however, we want to be sensitive to the course context and the bodily engagements, experimentation and the resulting more implicit and object-centered activism and involvement (Marres, 2009). We are thus interested in learning (4) *whether participants gain more from their practical engagement with solar heat collectors than merely a new piece of equipment and what is the nature of activism that results from the experimentation and material contacts at self-building courses.* Overall we aim to contribute to the 'decentralized energy systems' hypothesis by examining whether participants become more aware of their energy use and more capable and active in energy policy as a result of the courses and the practical engagement therein.

Empirical Material of the Study

This study is based on several types of empirical material concerning Finnish solar collector self-building courses. We started exploring the field by making initial contacts with those teachers who we could identify on the internet and those that were known to the national solar energy association. Once these contacts had been established we began to interview teachers and course organizers. Altogether six teachers and five course organisers were contacted and interviewed. Some of these teachers and organisers had been active already in the early 2000s and some were newcomers. In addition, one of the authors enrolled in a five-day course in June 2012 and interviewed and observed course participants. This course was organized in the municipality of Eurajoki and we refer to this part of the evidence as the 'Eurajoki course'.

In addition to interviewing teachers and organisers, we conducted a survey among former course participants, which was organized in the following way. We first contacted course teachers and organizers, and a total of 13 organizers agreed to help us. They delivered part of the surveys (available in both Finnish and Swedish) themselves electronically or through the post to former course participants. Some of the teachers and organizers agreed to give us the contact information, and we sent out the surveys. A total of about 700 questionnaires were distributed. The exact number is somewhat uncertain because some of the questionnaires were distributed directly by the organizers. However, this approximates the total number of people who have participated in organized self-building courses for solar heat collectors in Finland. As time has passed, especially e-mail addresses are no longer current, so some of the questionnaires might not have reached the former course participants. We gained 134 responses (112 in Finnish and 22 in Swedish). The total response rate is hence about 19%, which is likely at least partly due to outdated contact information.

In addition, two guidebooks for solar heat collector self-building from the years 2000 and 2006 have served as secondary material.

Self-Building Courses for Solar Heat Collectors in Finland

Self-building courses in Finland

Solar heat collectors remain a marginal phenomenon in Finland. While energy efficiency, renewable energy and the benefits of distributed energy generation have been discussed actively, the focus of these debates has not been on solar thermal systems. Consequently, also the share of dwellings that make use of solar heat collectors is low. According to the European Solar Thermal Industry Federation (ESTIF, 2012), the total installed capacity in Finland in 2011 was less than 33 000 m^2 and about 23 000 kW, which can be estimated to amount to about 5 000–8 000 units (assuming an average size of about 4–6 m^2). These figures point roughly to a diffusion level of 0,5% in the Finnish stock of detached houses. In spite of the low rate of adoption in general, and compared with it, the self-building courses in Finland are not a marginal phenomenon. As mentioned we came up with an address list of more than 700 course participants over a time period that starts from the late 1990s.

One of the key staring points for the Finnish courses in the late 1990s was an EU-funded research project aiming to make use of the Austrian experiences of self-building courses and trying to launch similar activities in Finland (Faninger-Lund & Lund, 2000). This resulted in purposive dissemination activities. Some of the early courses took place at Kronoby Folk High School in the Ostrobothnia region and aimed, following the Austrian example, to educate new teachers to run courses elsewhere. Furthermore, the assembly and installation of solar collectors has been documented in leaflets and guidebooks (Faninger-Lund & Lund, 2000; Lindström, 2006). A second, less documented development concerns the frequent courses organized by a single teacher who had emigrated from Germany to Finland in 1999 and had a background in counselling private households about solar heat installations. Another key teacher, an in-house tool manufacturer of a large industrial company, began his teaching activity in 2006, and has organized courses for roughly 200 participants. These two persons have taught the majority of the courses that we have been able to locate in Finland.

Motives to organise and teach courses

In Austria, Ornetzeder (2001) reports that individual courses were organised and set up by existing social groups that had traditions in collective activity. The Austrian association of renewable energy supported such local organization with knowledge and with a toolkit for manufacturing collectors. Despite an attempt to replicate the Austrian course concept, the Finnish courses are not organised based on such bottom-up initiatives of householders. Rather, folk high schools and regional semi-public energy efficiency agencies have acted as organisers and marketed the courses for individuals as they do with any other courses.

Based on our interviews with teachers and the institutions that organize these courses, it seems that enthusiastic teachers have been the main initiators for new courses. This implies that courses have been organized on an ad-hoc basis, and the continuity of the activity has been based on these individuals. Altogether, most of the schools appear to play only a minor role and the (few) teachers more of a decisive role.

However, schools have recently begun to take more strategic approaches towards solar heat collectors. The courses in Eurajoki were for example established in 2010 because they were viewed to fit the course portfolio and complement the image of the school. As the coordinator states: "These are courses that we manage to fill up, for sure. For once, the majority of participants are men unlike our other courses. And the image is progressive if you compare it with needlework and wooden boatbuilding." The way that vocational schools, folk high schools and polytechnics are perceiving solar heat collectors as a fitting part of their course activities signals a different dissemination channel from the Austrian case. However, despite the more strategic and institutionalized logic towards solar heat self-building courses, most of the organizers continue to rely on independent teachers. The availability of teachers seems to be a critical resource.

The role of regional energy agencies has been to encourage folk high schools or vocational schools to engage in organizing a course and to contribute to the theoretical teaching, i.e. basics of solar heat collectors. They appear to have been critical in triggering the involvement of the schools by drawing in public funding, providing basic knowledge and brokering teachers.

The motives and positions of the teachers involved vary. The two teachers that have run at least half of all self-building courses are both entrepreneurs who sell their services as teachers, import and sell supplies and provide counselling for system design. Teachers who have been involved for a longer period perceive a change in the role of the courses. In the early 2000s, people were motivated by the low cost of self-building. Now one of the teachers regards this era as history and rather emphasizes the need to educate participants to make good choices in the commercial markets. Consequently, he no longer runs self-building courses.

Teachers who have been involved for a shorter period of time did not perceive the low prices of commercial solutions as problematic. Rather, they anticipate wider effects of empowerment and claim that people no longer are bound to think about pay-back time or feasibility in general, but engage more whole-heartedly in the activity and are keen to collect independent and truly "free" energy, as they label solar heat. Accordingly, these teachers view the courses as fun, social gatherings during which the tasks of assembly are rotated and the collectors come about as a result of collective effort. The teacher in Eurajoki views the smooth flow of tasks as his major concern: he recognizes that people have different skills but hopes to avoid people that are "all thumbs", because then time is consumed at instruction and the work is ultimately left for others to do. Similarly, he also perceives too much theoretical interests as problematic because "collectors don't get done only by talking".

The course contents and collector types

The content of a solar heat self-building course and the learning and engagement opportunities it offers depend on the selected collector types, on the number of collectors to be built during the course and on the aims of the course in terms of wider learning. All of these have varied in the history of the courses in Finland. The first guidebook on self-built solar heat collectors (Faninger-Lund & Lund, 2000) is far more open in terms of technical solutions than the latter course book (Lindström 2006). Leaning on the Austrian course concept, Faninger-Lund and Lund (2000) review the solutions for integrating collectors in the roof structures. The dimensions of the collectors also remain flexible. In the latter guidebook of, the design is already more specified. The dimensions of the model developed in Ostrobothnia are roughly 2200mmx1000cm. It is built around an aluminium absorption element that is housed in a separate casing. The material of the casing was first wood, but changed to aluminium profile later. The heat transfer from the absorption plate to the system of water circulation is currently done with copper pipes and soldered joints, although aluminium piping and pressure joints have also been on trial. In general, it seems that the Ostrobothnia model is relatively well-fitted for the self-building course concept. The flow of assembly consists of separate tasks and erring in one point is not critical overall but can be corrected. Furthermore, the critical feature of the collector – the soldered joints – can be simply tested at the end of the process.

The above-mentioned improvements witness to a constant effort to improve the collector design. This story of the evolution of the collector also served at the Eurajoki course to create legitimacy for experimenting and collective ownership of the collector. In 2012, we were "to try out polyurethane insulation" and new tools for bending copper pipes. The collective identity and the public nature of the efforts were further prompted by site visits to and presentations given by participants of previous courses.

The courses need to attend to the elementary techniques such as cutting aluminium, drilling, soldering, riveting, painting as well as testing that are needed to bring about a collector unit. However, participants need much more knowledge of how to integrate solar collectors into other technical systems, where to install collectors, what are the proper dimensions of the collectors and how to service and maintain them. Among the course participants in Eurajoki in 2012, some participants viewed themselves as capable of also installing the collector units they had built on the course. However, participants more commonly felt that they only needed to understand solar heat well enough to instruct the plumber to do the work. Nevertheless, the basic engineering of the heating systems and the right dimensions of each element in the system seemed to rest in knowledge that was (expected to be) available through the course. Despite this, the course organisers in Eurajoki had decided during their three-year activities to teach less 'theory' during the course and use the classroom only for coffee breaks.

The length of the courses has varied. While the lengths of the courses based on the Ostrobothnia-model has been five days, the bulk of the courses that have been based on the more industrial design have been shorter. The teacher of these courses has attempted to compress the course into two days, during which Friday evening is spend on intensive theoretical teaching and Saturday on assembling one or few collectors to demonstrate the assembly. These courses aimed to exemplify solar heat rather than at the benefits of 'mass-production by amateurs', which is the case in the other courses. Apart from this matter of principle, the compressed course schedule is motivated by the fact that participants travel from long distances. Against this, the folk high schools that typically also offer lodging services have been ideal sites to organize the longer courses based on the Ostrobothnia-model.

This short view on the institutions and teachers that are involved in organizing the courses shows diverse motives. In our data, we find two distinct schools of thought and two personal histories that make a difference in how courses are run and what kinds of engagement take place. One of the teachers has immigrated with knowledge and experience of serving as an intermediary between commercial actors and the consumers. The other has brought in manufacturing skills and sought to develop a collector type that is less based on commercial components, and rather results out of the joint activities of lay people. The institutions that have played a significant role include both regional energy agencies and folk high schools. The energy agencies have a mandate to promote renewable energy and in addition they have sought to support the local economy. The schools on the other hand have been engaged in order to make good use of their ample available space as well as to gain a positive and progressive image.

The Motives and Interests for Participating in Solar Self-Building Courses

Despite the low price of commercial solutions, self-building courses still remain highly popular in Finland. This prompts the question of why people participate in self-building courses: Why to get involved in solar heat in the first place and why to join in a collective effort of self-building? We begin below with some observations from the previous literature on self-building activities, then report the insights from participant observation at the Eurajoki course and finally the results of the survey. Our survey was designed to take into account the multiple motives and rationalities that we had found in the literature and in the first-hand participant observation in the Eurajoki course and interviews with course participants, who also had a chance to comment on our survey questions.

The motives to engage in self-building

The rise of consumer home DIY, i.e., self-made home improvements, has stimulated the curiosity of social scientists: why do people who can afford to contract services choose to make improvements themselves, given that the work is not even always perceived of as enjoyable (Watson & Shove, 2008). Watson and Shove (2008) stress the recursive relation between products, projects and practices in DIY home improvement: the supply of cheap power tools has served to engage new practitioners, whereas projects once started have their own momentum. An explorative study by Wolf and McQuinty (2011) came up with several categories of motives. Some relate to the outcome itself and the desire for customized or unique products, or concerns about the quality and availability of commercial products and services, or the economic benefits of DIY. Others relate to identity enhancement: the empowerment gained from successful accomplishment of a project, personal fulfilment from craftsmanship, and belonging to a DIY community.

In the case of solar heat collector self-building group work, there might also be a broader a range of driving forces. Ornetzeder and Rohracher (2006) note that the low cost of obtaining products contributed to the popularity of the Austrian solar self-building courses, as well as the personal advertising by other users and the social motives to join a group in the neighbourhood. In addition, they stress that work in a self-building group can be tied up with broader social aims such as environmental protection or regional development. Palm and Tengvard (2011) examined the motives for the adoption of small-scale self-assembly micro-generation equipment such as solar panels and small wind turbines in Sweden. They found that some households did this to reduce fossil fuels use, others to display environmental consciousness or set an example to others, and yet others to protest against “the system” and achieve a degree of self-sufficiency.

Motives proved a mixed bunch also at the Eurajoki course. An overriding theme was the desire to be independent of big energy companies and to “harvest” or “catch free energy”. Both self-building and the very technology of solar heat collectors fit this aim as collectors are viewed as durable and maintenance free. Pushing the point, free energy was perceived as a way to “give the finger” to the large energy companies. However, the notion of “free energy” also suggested that householders wanted to keep their distance from the state. Participants thus, less provocatively, speculated about a gloomy future in which government intervenes in the collection of free energy and imposes a collector levy. It is interesting to note the mismatch between this anarchic facet of distributed energy generation and, on the other hand, climate change mitigation as a collective coordinated international effort. Strikingly, at Eurajoki there was a lot of discussion about free energy, but little if any talk about climate change or carbon footprints.

"Cheap energy" was another and distinct way to understand the motives of participants. Course participants were price-conscious, comparing the prices of different heating technologies for domestic use and the different alternatives of collecting and using solar heat. All participants seemed convinced that solar heat is an increasingly competitive and feasible technology to integrate into heating systems. Yet, at times, the argument surfaced that commercial collectors could be delivered home for the price of the materials of self-building (the material fee of the course was 350 euros/ each collector unit and the course fee 240 euros). Thus while solar energy was in general regarded as cheap, this cost calculus was not extended to the course activities. In a similar vein, the teachers and the participants downplayed efforts to improve the efficiency of the collector by more advanced manufacturing technology. Such fine-tuning of the technology and "going beyond the decimal point" was deemed irrelevant.

The logic of self-building at the Eurajoki course was also built on the merit of self-building as such. People had chosen to participate in the course because they wanted to learn more about solar heat and personally and materially engage in building the collector as a handiwork project. As the time of the course was late June, working participants were using their holidays to participate in the course. In addition there were many pensioners and self-employed people with more flexible time. Yet each participant had had to make some kind of arrangement to find room for the course, and some needed to negotiate course demands with the demands of their professional life. It was evident that the participants were also motivated to participate in the course rather than just to get the collector as the final output of the work. The social, collective nature of the course was enacted by not talking about how many collector units each participant was "making" but how many they are "taking" out of the collective achievement, ranging from one to five. Moreover, participants also made collectors for an elderly man who could not participate in the course due to an accident. Overall, the logic of self-building seems to depend both on protecting the space from overt cost comparisons, on justifying low-tech solutions and on the positive aspects of the collective work: running good conversations, excelling in skills and enjoying the efficacy of dividing work.

From a diffusion point of view, it is not only the motives as situated experiences or forward-looking aspirations that matter. It is equally interesting to look at the paths that have led people to participate and thereby follow the idea of Watson and Shove (2008) that self-building activities have momentum of their own. These paths of participation are marked by previous choices of heating systems, by infrastructure changes, by contacts in people's social networks and, among others, by occupational encounters with solar heat. The field notes from the Eurajoki course in table 1 report a wide variety of pathways.

Table 1. The occupational backgrounds and particular pathways of engagement of the course participants (pseudonyms) in the Eurajoki course.

Otto, metal worker currently driving a lorry	Has a pellet burning system. Has been working in Denmark and seen lot of houses with collectors. Has also started to collect price information in Denmark. During the course, repeatedly states that we are quickly running out of oil and need substitutes.
Aleksi, farmer	Has a pellet burning system. Has worked on a mission in Africa and seen solar collectors there. Has also been on the previous year's course and is now here for 8m2 more. Like Otto, mentions an 'extreme' solar house in the nearby city of Pori.
Johannes, retired from being an in-house proto-maker at a car factory	Has a ground source heat-pump, which he regards an excellent choice and regrets he did not do it earlier. Plans to somehow install solar heat for his summer cottage that has been recently connected to the public water supply but has no electricity supply.
Ingrid, woman entrepreneur, hairdresser	The husband recently switched jobs and could not get a leave to participate although had enrolled. The husband is an 'inventor' type. They have a wood chip burner that consumes "immensely" (100m3). Solar heat is sought for due to its convenience. Ex-neighbour has been on a previous course and talked Ingrid's husband into participating.
Oskari, retired	Has electric heating. He was not sure where or how to use the panel, and is only getting a 'half' of a single panel together with his friend Kaarle whom he convinced to participate as well. Knows a progressive solar house in the region.
Kaarle, worker at a large coal-fired power plant	Has old collectors in his garage. He has bought these from a client for whom he was making a renovation and who got new panels. Friend of the other participant, Oskari.
Tomi, restaurant chef at a cruiser ship	Has been previously at the Eurajoki school to build a wooden boat.
Elisa, woman entrepreneur, organic catering service	Lives in a house that is under a decommissioning threat. Reasons that panels are easy to take with her if she needs to move. The person who later suggests that we should install handles on the panels to make handling easier.
Arne, retired from the army	Takes lot of pride in having designed and built his house all by himself. His brother has solar heat collectors.

Motives and backgrounds documented in the survey for Finnish participants of solar self-building courses

As we stated earlier, we identified over 700 participants of solar collector self-building courses in Finland. Next we turn to our survey results and ask whether the Eurajoki experiences describe a general pattern. Among our respondents (n= 134), the average age is relatively high (Table 2), even though the youngest participant was aged 24 and the oldest 81[2]. Most of them are men: only 7 respondents were women, and this reflects the reality in the courses as far as we learned from the interviews with teachers. However, only less than one-third of the participants worked or used to work with building systems (e.g. builder, architect, HVAC installer). More commonly, people had other lines of work, such as teachers, farmers, or some other, technical occupation. Most of them lived in a detached house. At the time of our study, 44% were pensioners. Participants were active in several respects: many had previously participated in another kind of self-building course and a large share was also active in local politics. The respondents mainly (70%) consists of people who have attended the longer self-building version as opposed to the short two-day course and many of them (47%) had attended the course during the last few years, after 2009.

More than half (53%) had planned to install a solar heat collector in their own property. However, few of them had much background knowledge of solar heat before enrolling in the course: only 16% had collected information on solar thermal products in the market and only 13% had familiarized themselves with actual installed solar thermal systems.

Often, the participants come to the courses from a relatively wide area – i.e., not from the same village. Hence, the social context of the Finnish solar self-building courses is somewhat different from the Austrian ones (Ornetzeder, 2001). Most participants do not appear to have actively sought out the course, either, as only 14% found the course on the Internet. Many (50%) had found the course announcement in the daily newspaper, and almost one-third had found it in the course providers' catalogue (which are often distributed to all residents in the locality). Less than one-fifth had learned about the course from an acquaintance or friend or some other personal source. As pointed out in table 1, at Eurajoki there were several people who had some experience or knowledge of solar heat, but only one had a relative and one a neighbour as an informant. This suggests that the course organizers have an important role in raising awareness of solar heat and the possibility to self-build.

Most self-building course participants took part in the course in order to obtain a solar heat collector for their own property[3] (Figure 1). Another common reason to participate was a general desire to learn more about solar heat. Many of the participants were also spurred by the opportunity to gain a solar heat collector cheaply by making it themselves. Almost half also indicated a desire to learn about heating systems and the installation of solar panels within existing systems. This reflects our findings at Eurajoki: there were several participants who were more oriented towards learning and had no specific idea of how to make use of the collector(s) they were building. Less frequently indicated reasons in the survey were the enjoyment of doing crafts. Concerns for climate change and carbon footprints were mentioned by less than one-third of the participants. Only about 10% had some kind of professional interest in participating in the course, and there were very few who had enrolled in

Table 2. Characteristics of survey respondents (n=134).

Average age, years	58
Share of men, %	92
Occupation related to building systems, share %	27
Share living in detached houses, %	84
Share of pensioners,%	44
Share having participated in previous DIY course, %	59
Share having participated in local politics, %	79
Share having planned to install a solar heat collector in own property, %	53
Share having background knowledge before enrolling in the course, %	16
Share having acquainted themselves with existing solar installations, %	13

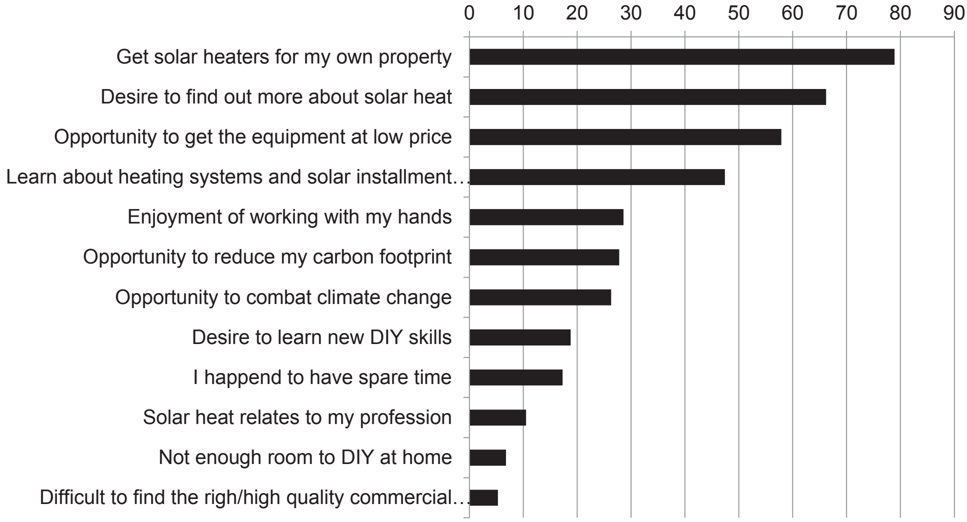

Figure 1. Motives and reasons to participate in solar heat self-building courses (n=134).

the course because of a lack of suitable commercial alternatives.

According to the survey, the course participants' interests appear to be pragmatic and relate to the content of the course rather than a general interest in crafts. Self-building and an explicit desire to get materially engaged do not appear to be the main reason for participants to enrol. Nor do the courses seem to primarily be a way to spend one's spare time. However, when observing the participants working at the Eurajoki course, it was obvious that people were enjoying the material engagement, keen to discuss the best methods of assembly, and also quick to develop suggestions for improved design. Participants were skilled and fluent in the required tasks, but clearly oriented towards solar heat collectors as an outcome of the activity and as an item to discuss while working. Moreover, in our survey, 90% of the course participants reported that they enjoyed the company of other course participants – even though only 38% expected to keep in touch with other participants after the course.

Outcomes and Impacts of Self-Building Courses

One of the expected outcomes of participation in a solar heat collector self-building course is the material product, the solar heat collector. Hence, courses may contribute to the diffusion of solar heat collectors, providing the heat collectors are subsequently installed and put to use. We found that only 41% had installed their solar heat collectors. There were multiple reasons for this, ranging from other uncompleted building projects, the need to obtain a new boiler, to simply a lack of time and, frequently, money. Many were still planning to install their solar heat collector one day. This delay resonates with the findings that many participants had done little planning beforehand and found out about the course in a less deliberate way. Among those who had installed their solar heat collectors, 85% were satisfied with their performance. Their satisfaction was also usually well-grounded, as three-fourths of these participants monitored the performance of their collector at least weekly.

However, previous literature suggests that participation in solar self-building courses might have broader outcomes than merely the accomplishment of a piece of equipment (Darby, 2006; Rohracher & Ornetzeder, 2006). The experiences from the Eurajoki course were encouraging: without a systematic interview of all the previous years' participants, we came across two active carriers of the solar heat agenda. One of them had begun to develop tools for the assembly process and the other had given presentations of his solar heating system in his local community. On the course in 2012, we also encountered a professional metal worker who was pondering about starting production activities after the course. With such positive hints, we hence explored a range of potential outcomes in our survey questions (Figure 2).

Ornetzeder and Rohraher (2006) discuss the way in which solar heat collector self-building courses have served to socially embed new technologies in several rural contexts. The visibility of solar heat collectors appearing on roofs in each village where self-building courses were organized enhanced the diffusion of solar heat in these localities. Hence, we were interested in finding out how many of the solar heat collectors were installed and the amount of attention they received by neighbours. According to the survey, as many as 59% had discussed solar heating with their neighbours. This share was even higher, 89%, among those who had installed their heat collector. Some of the teachers we interviewed also believed that their course activities have made a small but visible impact on the diffusion of solar heat in the course localities. A surprisingly large number, 47%, also reported having given others advice on or planned solar installations for other people.

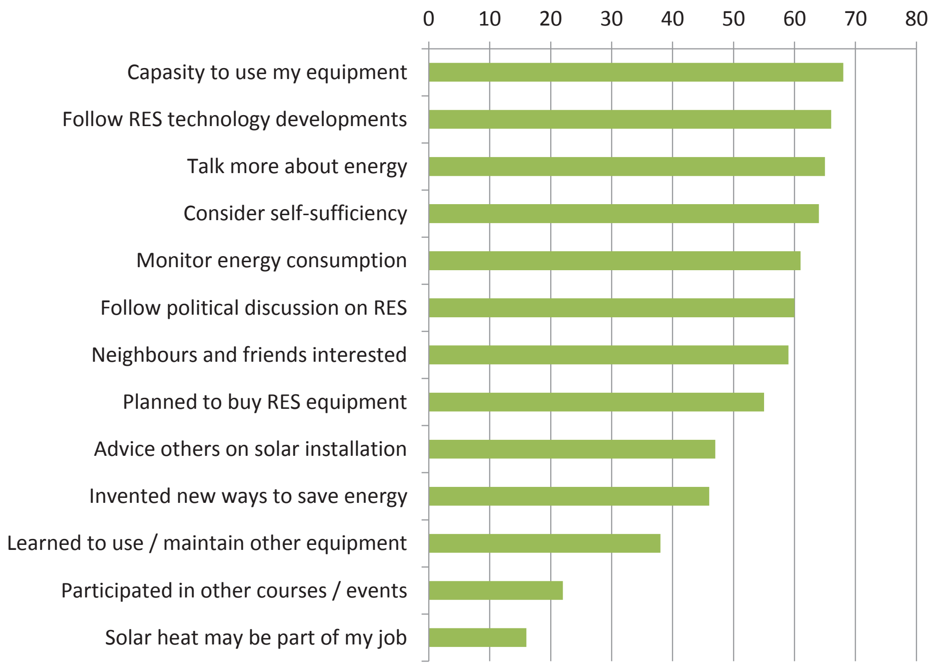

Figure 2. Outcomes of the courses experienced by course participants (%) (n=134).

Darby (2006) has examined the role of self-building activities in constructing awareness of energy issues via engagement in concrete activities and the development of tacit knowledge (i.e., skills based on personal experience). In a survey of participants in an energy-conscious village competition, she found that people with more self-building experience implemented a larger number of the actions proposed in the competition, and those who had implemented measures were more capable of processing explicit (i.e., expert-generated) knowledge. She suggests that as tacit knowledge accumulates, people become more capable of seeking out new explicit knowledge as needed, inventing solutions to problems, and sharing knowledge with others. This inspired us to ask people about changes in their energy consumption practices and engagement in other forms of energy activism.

In terms of tacit knowledge and overall energy management competences, the courses seem to have influenced a large share of the participants. Two-thirds had at least gained the capability to use their own equipment. Broader impacts were also visible: Many had started to consider the possibility of comprehensive energy self-sufficiency. A large majority had started to monitor their energy consumption more closely and about 45% had invented new ways to save energy.

The majority also had plans to make further investments in renewable energy solutions. Almost two-thirds of the participants also followed renewable energy technology developments more closely after the course, and a similar number of participants had started to talk more about energy with other people. The majority of the participants were inspired by the course to follow political debates on energy more closely than before.

We can take Darby's (2006) argument even somewhat further. For many lay people, formal energy efficiency knowledge is very confusing because of the unfamiliar technical terminology employed (Parnell & Popovics-Larsen, 2005) and because of the historical disenfranchisement of lay people from centralized systems of energy production (van Vliet et al., 2005). Self-building courses might help people to overcome such obstacles and gain a more active and empowered relation to energy technologies. In very concrete terms, the courses offer opportunities and ample time to begin to talk about energy with like-minded fellow-participants and to collect ideas and knowledge about energy related issues while involved in familiar assembly tasks. The course context – a well-trialled, simple collector design and a group of people in which skills can be pooled – seems to offer an easy, successful entry to the realm of renewable energy production.

The fact that more than two-thirds of our course participants had started talking about energy consumption more than previously suggests that they have been somehow empowered to also deal with energy issues in more explicit, verbal terms. Perhaps the fact that they are also following energy technology and policy developments suggests a similar phenomenon, as well as the widely endorsed bold ideas about energy self-sufficiency. However, contrary to our expectations, the effect of empowering participants was not any stronger on the people with no background in building systems or energy relates issues; in fact, the building professionals had become slightly more eager to discuss energy issues than the lay people had[4].

We made a closer analysis of the relation between people's background knowledge on solar heat before the course[5] and the impacts of the course. Overall, it seems that if there were differences between participants with different levels of background knowledge, these were in favour of those with greater background knowledge:

- Those who had acquaintance of an installed system before the course had more frequently (94%) gained sufficient knowledge to use and maintain their own equipment than those who had no prior acquaintance of such systems (74%).
- Moreover, those who had acquaintance of an installed system before the course had more frequently (82%) started to monitor their own consumption than those who had no prior acquaintance with solar heat collectors (66%).

These findings suggest that the course is not the only source of empowerment but previous knowledge and experience matter. However, both those with previous experience and those with none benefited from the course. For example, even among those who had no background knowledge of solar heat before the course, as many as 54% had advised or helped others in their own solar installations (compared with 50% of those who prior acquaintance with solar heat collectors).

We might also explore links between DIY as a hobby, and future occupational orientations or aspirations (Holthgrewe & Werle, 2001). Several of the course participants we surveyed had occupations (or had retired from former occupations) that were somehow linked to building, construction or building components or equipment. Moreover, we found a minority of 15% agreeing that "solar self-building competences might be a part of my future career". Interestingly, in the Eurajoki course, a few participants had decided to join the course because they had seen solar heat collectors in construction projects for clients. Hence, while conclusive evidence is still pending, our data suggest that also the pathways of solar technology diffusion can be quite complex, and self-building can be linked in various ways to diffusion via commercial or occupational channels.

Discussion

The empirical material that we draw on is somewhat scattered. However, in terms of the outcomes of the courses, our interviews with teachers, observation of course participants and the survey complement each other. Concerning the survey, we point to particular difficulties relating to the interpretation of the results. Firstly, there have been two quite different course concepts in Finland with likely differences also in terms of the types of discussions and thought processes stimulated among participants. It seems reasonable to think that the longer courses have a greater impact on the participants' overall energy awareness, apart from the immediate goal of constructing solar collectors. Secondly, the timespan between the survey and the actual participation varies from couple of months to approximately 10 years which evidently creates difficulties for analysing the effects of the course. In all cases, it is difficult to disentangle the effect of the course from other developments. Motivations to enter the course, the course itself and the activities thereafter form a continuum that is affected by many other factors as well.

Our two first research questions address Finnish solar heat self-building courses as a continuum of the success of Austrian courses (Ornetzeder, 2001; Ornetzeder & Rochracher, 2006). Our first question was whether the phenomenon has the capacity to survive in a different cultural context. The related second question that we posed is whether the Finnish courses can be seen as a collective phenomenon with the capacity to reproduce and grow.

The Finnish self-building courses differ significantly from their Austrian role-models albeit explicit effort was made to import the model into Finland. Quite crucially, educational institutions play a key role in pulling a group of participants together. Unlike in Austria, the participants in the Finnish courses do not know each other and the commitment to the collective building effort only emerges once the course starts. Furthermore, Ornetzeder (2001) reports that theory, planning and dimensioning precedes the Austrian courses hence situating course in a much more determined process of adopting solar heat. Finnish courses, on the other hand, appear as the first and often even quite haphazard instances of encountering and familiarizing oneself with solar heat. Furthermore, Finnish courses have depended on few key individuals who are professionally engaged in providing parts and teaching the courses. Altogether Austrian and Finnish courses depend on a quite different logic albeit the key technology of the simple flat plate collector is shared by the two contexts.

This difference has implications in terms of the momentum and the replication of the courses. Who could be the carriers of course activity and actively contribute to the expansion of the volume of these courses? This far, the teachers and the institutions that facilitate the courses seem not to coordinate their activities, nor to share resources or hold a collective identity. Neither does the national association of solar energy promote self-building or the courses in any explicit way. Moreover, albeit 38% of participants reported that they expect to keep in touch with others, our interviews with teachers and course organisers do not give signs of a collective mobilization. In other words, in Finland solar heat seems to lack the key ingredients of a social movement, and the potential for the extension and replication of course activity is limited at least when compared with Austrian experiences.

Our research question 3 and 4 address the impacts of these courses in terms of creating acceptance for solar thermal technology and a more active stance toward energy in general. Regarding the third question, the Finnish courses seem quite effective in promoting acceptance and local embedding of solar heat. The threshold to get involved in solar heat through self-building courses seems low: participants enrol with only very preliminary interest and knowledge about solar heat, and are also driven by DIY motives. Based on our field observation, they begin to talk about energy issues and rehearse their skills during the course while being materially engaged and conducting rather simple tasks of assembly. Empowerment seems to result out of successful accomplishment of material tasks in renewable energy and from the ability to address these technologies in a way that is meaningful in the peer group. Renewable energy is not only doable, it might even be enjoyable. Meanwhile, participants' capacity to formalize and distribute knowledge also increases: the survey results indicate that a significant share of participants also continue to collect and disseminate information about renewable energy technologies. Thus, even if the courses and participants lack social organization and collective momentum in promoting solar heat technology, many course participants seem to act as carriers of this technology on their own.

User involvement and self-building activities have been related to social movements for alternative energy technology (Jamison, 2001; Ornetzeder, 2001). While the course participants' motives to enrol in the course were not explicitly political, the courses appear to lead participants into taking a more active and political role (cf. Marres, 2009). We reported active opposition of centralized energy systems and state involvement in distributed energy systems during field observation. In the survey, this is reflected in the large share of respondents reporting to have started to consider far-reaching energy self-sufficiency. The survey also reports broader political interest as a result of course participation.

In response to the fourth question, we argue that participants gain significantly more than the single piece of equipment as a result of the course. Many have started to follow their energy consumption and report to have invented new ways to save energy at their home. Participants' interests in energy self-sufficiency suggest that the course is part of a trajectory towards adopting other renewable energy technologies. Overall, the fact that many collectors are installed with delay and some remain uninstalled is only part of the story. Gains in tacit knowledge and an active orientation towards using renewable energy sources do not require that collectors are installed. As we reported, participants have started to advise and plan installations for others even if they have not installed their own equipment. However, much to our surprise, it is not those who had the least background who report the most significant impacts in this respect. Rather, those with some professional overlap with solar heat are the ones who seem to pick up the most momentum to continue to discuss and work on solar heat and other energy related issues.

Conclusions

Climate change mitigation and a transition towards low carbon energy systems are increasingly visible and important policy objectives. However, in this agenda, ordinary citizens have mainly been assumed to take up a role of passive receiver of novel technologies. Yet, studies of user involvement in technology development and adoption make it obvious that users can have a far more active role in technology dissemination. Equally obviously, outside the deep-green marginal groups, the motives to get involved align with a mix of more or less private concerns.

Our interest in the self-building courses for solar heat collectors initially arose from the thought that these courses might reveal something interesting about the mixed motives for getting involved in domestic low carbon technologies. Recognizing the Austrian experiences we also thought that these courses might be a feasible avenue for public promotion of low carbon technologies. To put the issue another way, we were interested in what kinds of motives, and more generally paths and backgrounds, drove people to participate in these courses, and whether such motives could be made use of more widely to support the diffusion of renewable energy technologies and energy saving. Previously, solar heat collector self-building courses have been assessed from the point view of the nation-wide diffusion of solar water heat collectors (Ornetzeder, 2001) and that of user-led innovation (Ornetzeder & Rohracher, 2006). However, the role that courses play in disseminating general energy awareness and particularly in engaging citizens in practical work for energy efficiency and climate change mitigation goes beyond their role in technology development and deployment.

The courses proved effective in drawing people into solar heat technology even with little background knowledge and specific ideas about how to put the built collectors to use. The same phenomenon is also reflected in the fact that we found frequent delays in installing the collectors and unanticipated budget limitations. This is, we argue, however not much of a failure. Rather, a plausible interpretation is that self-building courses represent a low-threshold first step toward more demanding changes towards renewable and more self-sufficient energy systems. The pathways through which individuals become involved in self-building activities are nevertheless complex: our results indicate that background knowledge in building technology prompts higher levels of active engagement after the course. However, here we run into the limits of quantitative analysis in trying to understand engagement processes.

The Finnish courses proved a more extensive phenomenon than what we had expected. We came across over 700 course participants during a period that starts from the early 2000s. This number is far from insignificant when compared with the low number of solar collectors in Finland in general. However, we also came to the conclusion that self-building activity in Finland has depended on a few key teachers and the folk high schools and lacks institutional support. This limits the potential replication of the course concept. The difference compared to the Austrian example is clear. Ornetzeder (2001) reports the success of Austrian self-building groups that made use of collective resources and knowledge whereas we have found in Finland self-building courses that depend on initiatives from outside the group of course participants. Notwithstanding this difference, the Finnish courses seem to offer alternative ways to get people involved with low carbon technology and promote local acceptance and embedding of this technology. They also seem to set trajectories for processing and adopting more formal knowledge about energy. We hence suggest that they are a promising route for further experimentation in public policies promoting distributed energy generation.

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References

Bijker, W. E., Hughes, T.P. & T.J. Pinch (1987) The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology (Cambridge, MA: MIT Press).

Darby, S. (2006) 'Social learning, household energy practice and public policy: lessons from an energy-conscious village', Energy Policy 34(17): 2929-2940.

ESTIF (2012) Solar Thermal Markets in Europe - Trends and Market Statistics 2011. European Solar Thermal Industry Federation. Online: http://www.estif.org/statistics/st_markets_in_europe_2011/.

Faninger-Lund, F. & P. Lund (2000) Aurinkolämmön itserakentamisopas [Guide for self-building of solar heat, in Finnish] (Helsinki: Motiva).

Freeman, S. (2007) 'The Material and Social Dynamics of Motivation: Contributions to Open Source Language Technology Development', Science Studies 20(2): 55-77.

Heiskanen, E. (2005) 'Taming the Golem – An Experiment in Participatory and Constructive Technology Assessment', Science Studies 18(1): 52-74.

Hoffman, S.M. & A. High-Pippert (2005) 'Community Energy: A Social Architecture for an Alternative Energy Future', Bulletin of Science, Technology & Society 25(5): 387-401.

Holthgrewe, U. & R. Werle (2005) 'De-Commodifying Software? Open Source Software Between Business Strategy and Social Movement', Science Studies 14(2): 43-65.

Hyysalo, S., J.K. Juntunen & S. Freeman (2013) 'Internet Forums and the Rise of the Inventive Energy User', Science & Technology Studies 26(1): 25-51.

Jamison, A. (2001) The Making of Green Knowledge. Environmental Politics and Cultural Transformation (Cambridge: Cambridge University Press).

Lindström, D. (2006) Aurinkolämmön rakentamisen opaskirja [Guidebook for building solar heat, in Finnish] (Vaasa: Svenska Yrkehögskolan).

Marres, N. (2009) 'Testing powers of engagement: green living experiments, the ontological turn and the undoability of involvement', European Journal of Social Theory 12(1): 117-133.

Marres, N. & J. Lezaun (2011) 'Material and devices of the public: an introduction', Economic and Society 40(4): 489-509.

Ornetzeder, M. (2001) 'Old technology and social innovations. Inside the Austrian success story on solar water heaters', Technology Analysis & Strategic Management 13(1): 105-115.

Ornetzeder M. & H. Rohracher (2006) 'User-led Innovations and Participation Processes: Lessons from Sustainable Energy Technologies', Energy Policy 34(2): 138-150.

Palm, J. & M. Tengvard (2011) 'Motives for and barriers to household adoption of small-scale production of electricity: examples from Sweden', Sustainability: Science, Practice and Policy 7(1): 6-15.

Parnell, R. & O. Popovics-Larsen (2005) 'Informing the Development of Domestic Energy Efficiency Initiatives. An Everyday Householder-Centred Perspective', Environment and Behaviour 37(6): 787-807.

Raven, R.P.J.M., E. Heiskanen, R. Lovio, M. Hodson & B. Brohmann (2008) 'The contribution of local experiments and negotiation processes to field-level learning in emerging (niche) technologies: meta-analysis of 27 new energy projects in Europe', Bulletin of Science Technology Society 28(6): 464-477.

Rip, A., T.J. Misa & J. Schot (1995) Managing Technology in Society. The Approach of Constructive Technology Assessment (London & New York: Pinter Publishers).

Schot, J.W. (2001) 'Towards New Forms of Participatory Technology Development' Technology Analysis and Strategic Management 13(1): 39-52.

Van Vliet, B., Chappells, H. & E. Shove (2005) Infrastructures of Consumption. Environmental Innovation in the Utility Industries (London: Earthscan).

von Hippel, E. (2005) Democratizing innovation (Cambridge, MA: MIT Press).

Watson, M. & E. Shove (2008) 'Product, Competence, Project and Practice DIY and the Dynamics of Craft Consumption', Journal of Consumer Culture 8(1): 69-89.

Wolf, M., & S. McQuitty (2011) 'Understanding the do-it-yourself consumer: DIY motivations and outcomes', AMS Review 1 (3-4): 154-170.

Notes

1 see e.g. http://www.24volt.eu/eng_home.php and http://www.scoraigwind.com/

2 All data presented here pertain to the time of responding to the survey. Since the participants may have attended the course as early as the 1990s (and one participant indicated he took part in 1974), the characteristics do not necessarily reflect the situation when taking the course.

3 Not all courses were strictly self-building courses in the sense that each participant made a solar heat collector for themselves. Of our respondents, 90% had participated in a self-building course.

4 The share is 80% for the building professionals and 71% for those without any background in building (Pearsons Chi square Sigma 0,318 (2-sided)).

5 This set of questions pertained to whether they had collected information on solar thermal products in the market, had familiarized themselves with actual installed solar thermal systems, or had knowledge of the general principles of solar heat, or had planned to install a heat collector in their own property.

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Discussion Paper

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

Yael Parag

Traditional literature and policy approach to energy security focus on the security of energy supply. It is argued here that a supply-centric approach to energy security is too narrow to account for the complex nature of energy systems and tends to overlook energy users, their expectations from, interaction with and roles in future low carbon energy systems. From users' point of view, be they households, businesses or governments, the supply of kWh or oil barrels is often meaningless. What matters is not the source of energy, but rather the services provided by it. Therefore, securing energy services seems to be the public and the government's concern, and the security of supply is only one mean to achieving it. Stemming from science, technology and society studies, this discussion paper suggests that applying a multi-level socio-technical and user-oriented perspectives which focus on the energy services and considers also psychological, social and cultural aspects of energy consumption, could reveal new and overlooked actors, roles, means and strategies that may provide and contribute to energy services security.

Keywords: energy security, energy services, socio-technical systems

Background

Keeping the 'lights on', the 'cars moving' and the 'economy growing', which are seen by many as vital indicators for a thriving and healthy modern society, depends on functioning energy systems[1]. Interruption to the energy systems through technical failure, political reasons, higher energy prices or volatile energy markets are known to foster political and social unrest and disrupt economic growth (Olander et al., 2007). Securing a stable supply of energy, thus, becomes one of the highest priorities for many governments around the world (see for example, Hedenus et al., 2010; Kazantsev, 2012; Vivoda, 2012). International comparative public survey found that future energy sources and supply, in other words energy security, was rated by the public in different countries (including Australia, the UK, Belgium, Germany, Italy, China, Japan, South Africa, Sweden, the USA and others) as one of the key environmental concerns, higher even than climate change (Ipsos, 2011).

Today, energy systems need to comply with an increasing number of constraints posed by the economic, technical, social, political and environmental arenas. Energy systems need to respond to economic efficiency constrains and to be competitive and affordable. They also need to comply with environmental health and safety regulations (e.g. air pollution standards). Moreover, energy systems have to cope with the rapid increase in demand for primary energy sources, notably coal, oil and gas, in Asia and other developing regions (e.g. China and India's rapid growth); the depletion of conventional reserves of gas and oil (e.g. North Sea) along with the rise of unconventional energy resources (e.g. shale gas in the United States); the geopolitical instability in many oil and gas-rich regions which may have widespread implications on fuel supply (e.g. Nigeria, Sudan, North Africa, and the Persian Gulf); the reshaping of global energy markets (e.g. Chinese national oil companies play a more prominent role in global oil exploration and production); and the growing public awareness to risks and vulnerabilities of power supply technologies (e.g. Fukushima nuclear power failure). All of these compromise the ability to supply reliable affordable energy, and hence should be seen as a threat to energy security (Sovacool, 2011b).

The commitment taken by many states in the EU and elsewhere to decarbonise their energy systems in the next couple of decades (e.g. European Commission, 2011; Pielke, 2010: chapter 4), as a climate change mitigation measure, adds significant economic, technical and feasibility constraints to energy systems, which in turn, threat to widen the gap between energy supply and 'business as usual' demand scenarios (e.g. Skea et al., 2011). Future, low carbon energy systems could take various forms. For example, they may feature a centralized mode of power production (e.g. nuclear) or a decentralized one (e.g. renewable); they may include a greater interface with energy consumers (e.g. via demand management, smart metering, smart displayers); they are likely to involve different types of interactions with households and communities (e.g. utilities not only selling but also buying electricity from household/community owned generators); likewise, private and public transport may be bio-fuelled or electrified.

Those changes to the existing energy systems challenge the adequacy of the current supply-oriented governing structures to deliver low carbon energy, and introduce new types of threats and opportunities to the security of the systems (Skea et al., 2011). To illustrate, successful energy demand management schemes, which aim to improve energy security by modifying consumers' demand for electricity during 'peak time' through economic incentives or public education, rely on consumers' responsiveness. Lack of responsiveness to incentives (e.g. to price signals or information), therefore, poses a threat to energy security.

Science, technology and society (STS) scholars have acknowledged the complex socio-technical nature of energy systems and investigated the interactions between energy infrastructures, energy users, energy behaviour, society and cultures. They highlighted the importance of acknowledging those interactions for better understanding the ways through which energy systems have been shaped, and more recently in the context of the transition to a low carbon society (see for examples, Nye, 1998; Nye et al., 2010; Verbong & Geels 2010; Wilhite, 2008). However, the issue and concept of energy security did not receive enough attention from STS scholars. While a few did examine related issues (e.g. Bennett, 2005), they focused mostly on various aspects of failures in energy supply systems. In this discussion paper I argue that energy security scholars and policymakers alike perceive energy security as a supply issue and therefore fail to incorporate the STS insights regarding energy demand and energy practices into the discourse and policy. I suggest that approaching energy security from energy services point of view allows accounting for those insights and opens up a room for overlooked energy security strategies.

The paper begins with a brief review of the traditional academic and policy approaches to energy security. It then points at the weaknesses of such approaches and suggests the security of energy services as a complementary approach. The paper concludes with highlighting some insights for energy services security strategies.

Energy Security: Academic and Policy Perspectives

Definitions of energy security vary (for a review of 45 definitions for energy security see Sovacool, 2011a:3-6). One typical definition, taken from the Australian government (2011: 2, emphasis added), frames *energy security* as "the adequate, reliable and competitive *supply* of energy", where *adequacy* is "the provision of sufficient energy to support economic and social activity"; *reliability* is "the provision of energy with minimal disruptions to *supply*"; and *competiveness* is "the provision of energy at an affordable price that does not adversely affect the competiveness of the economy and that supports continued investment in the energy sector". Others add parameters and aspects of *equity*, *environmental concern* (International Energy Agency, 2011) and *public acceptability* (e.g. Jansen, 2009; Sovacool, 2011a). Public acceptability refers to social, psychological and cultural barriers, such as negative perceptions of generation technology that may hamper supply.

The rapidly growing literature on energy security elaborates on the different threats to the security of energy supply. The principal concerns are economic, political and environmental. This literature concentrates on resources (e.g. gas, oil, coal, renewable) their costs and markets; on international relations between exporters and importers of fuels and resources; and on technical, infrastructural and technological aspects of energy systems (e.g. Yergin, 2006; Chaudry et al., 2009; Hughes, 2009; Kruyt, et al., 2009; Claes, 2010; Pascual & Elkind, 2010). A similar approach is taken by leading supranational organizations and agencies (e.g. World Economic Forum, 2006; International Energy Agency, 2011), and by national governments around the world (e.g. Department of Trade and Industry, 2007; Australian Government, 2011).

Inevitably, a supply-side orientation to energy security leads to indicators, policies and measures that aim to diversify the fuel mix in order to avoid the dependency on a single fuel; diversify foreign suppliers and fuel transport routes, in order to reduce the exposure to various events (natural, social or political) at supplier's state or region; as well as to promote investments in technical elements of the system in order to improve efficiency of supply and prevent technical failures along the supply chain. Accordingly, the main actors that take part in the policy forums and that compose the governing structures of supply-oriented energy security are nations, international institutions/agencies, big energy/fuel companies and technology providers (e.g. Chester, 2010). Energy users are nearly absent from the energy security literature, practices and governance and have been so for many years.

One exemption to this practice could be found, to some extent, in the literature discussing events of severe failure in different components of the supply system, which lead to significant reductions in energy supply and/or blackouts, and which in turn result in broader societal and economic impacts (e.g. Bryan PaSquier, 2011; Trentmann, 2009). However, while in such events energy consumers are recognised as crucial for successfully implementing a package of demand-side energy-saving measures, their role ends when the system is restored and consumers are expected to resume immediately to previous demand patterns.

Another exemptions to this practice are policies and efforts to improve end-users' energy efficiency. Some estimate that more than 70% of global energy use could be saved by achievable demand-side changes to passive energy systems and efficiency (Cullen et al., 2011). Evidently, energy efficiency has been recognized by policy makers and energy providers for many years now as a cost-effective mean to improve energy security (e.g. Department of Energy and Climate Change, 2012), and more recently, as a mechanism to enhance other societal, economic and environmental benefits (Ryan & Campbell, 2012). However, despite being cost-effective many barriers and obstacles impede a wider installation of energy efficient measures, processes and appliances by small, medium and large end-users (Thollander et al., 2010). Different policies and programmes were issued in order to overcome these barriers with varying levels of success (World Energy Council, 2008). Energy efficiency policies often fail to alter the socio-cultural contexts which interact to effect energy use practices (Nye, 1998; Wilhite, 2008), and the heavy emphasis they put on techno-economic aspects of efficiency does not result in the expected savings. Indeed, despite the tremendous improvements in energy efficiency, a rebound effect[2] often offsets much of the claimed efficiency-related savings of both energy and emissions (Sorrell, 2009; Sorrell et al., 2009; Gonzalez, 2010; Druckman et al., 2011).

From 'Energy Security' to the 'Security of Energy Services'

Barrett et al. (2010: 4) point at the need to widen the scope of energy security analysis: "The level of security is not determined by supplies alone, but by the immediate balance between supply and demand and the longer term trade-off between more energy security and environmental considerations (e.g. more wind farms vs. open spaces or more nuclear power vs. global security and nuclear proliferation)". They suggest that a comprehensive understanding of energy security requires a socio-technical and interdisciplinary approaches. Approaches that take into account the interrelations between society, drivers for energy demand and a wider scope of energy security variables.

Along those lines, this paper suggests that a comprehensive understanding of energy security in a low carbon society requires the employment of a socio-technical and user-oriented approaches that concentrate on *energy services*, and the *security of energy services*.

The socio-technical approach refers to the relations and interactions between social and human aspects of a system and the system's institutional and technological aspects. This approach acknowledges that changes in a system are not determined by a single component (technical, behavioural or social), but rather are co-evolved and co-shaped by all of them (Hughes, 1987). Such an approach calls for the examination of energy security from new angles, which complement – rather than replace – traditional approaches that tend to concentrate on physical, political, economic and technical aspects of the energy system. In particular, the paper highlights STS contribution to our understanding of energy users and energy consumption.

To this end, energy services are the benefits – or functions – that energy carriers produce for human wellbeing. From the users' point of view, be they households, businesses or governments, kWh or oil barrels are non-tangible and often invisible, meaningless units. What matters is not the source of energy but, rather, the services provided by it. In effect, securing energy services seems to be the public and the government's goal, and ensuring th*e security of supply is only one mean to achieving it*.

Examples of energy services include heat for cooking, cooling for refrigeration, illumination for houses, power for water pumping and power to allow mobility, accessibility and communication. Energy services can be derived from a variety of energy carriers. For example, mechanical power can be produced from kinetic or potential energy of water, from kinetic energy of wind, from a liquid fuel, or from electricity. Energy carriers can be derived from a variety of primary sources; electricity for example can be generated from hydropower, petroleum, solar, or wind (Modi et al., 2005: 9).

A broader and more inclusive definition for energy services suggests the inclusion of *any useful output of energy input* (Kendal, 2008: 153). To illustrate, while illumination, cooling and heating services could be supplied by fuels or electricity (the narrow definition of energy services), they could also be provided via the design of passive buildings and spaces, which harness directly solar and wind energies (e.g. Kaan & de Boer, 2006; Schnieders & Hermelink, 2006). Likewise, significant contributors for thermal comfort are fabrics and clothes, which by means of insulation and ventilation better utilise energy embedded in the food that we eat. Unlike energy efficiency (i.e. using less energy from the grid to provide the same level of service), it is suggested here that low carbon energy services, such as thermal comfort, mobility, accessibility as well as others, could also be provided via means such as new consumption modes, cultural and social norms, behavioural change, and via various social and professional practices.

Energy services security (ESS) are "the extent to which the population in a defined area (country or region) can have access to affordably and competitively priced, environmentally-acceptable energy services of adequate quality" (Jansen, 2009: 7). This definition implies an end-use orientation that goes beyond the provision of energy to count also the ways in which energy is consumed. Because many of the energy services are demand driven, but are defined also by the supply system, exploring ESS requires the inclusion of psychological, social, cultural and political contexts in which energy is produced and consumed (e.g. Wilhite et al., 2003; Gram-Hanssen, 2008; Wilhite, 2008; Späth & Rohracher, 2010). Additionally, since provision and consumption of energy happen at different levels, ESS examination requires multi-level perspectives: from the top-down, i.e., suppliers and regulators' point of view; from the bottom-up, i.e., end-users' point of view; and from the middle-out, i.e., the point of view of actors who are neither energy suppliers nor consumers, but rather those who shape or construct various aspects of the ways in which energy is provided to end-users or used by them (examples include architects, building professional, town planners, social leaders) (see also Janda & Parag, 2013). This, in turn, calls for the deployment of a different set of enquiry tools than those traditionally employed in the study of the security of supply. A set of tools that also examines psychological, cultural and normative aspects of energy services, and ask questions such as who sets work-places dressing codes, what are the implications of these codes on energy demand for heating and cooling services, and what are the cultural functions of those codes in the work place; what factors impact mobility modes and preferences and what are the implications of these on the use of transport means and on the users themselves. Tools that analyse roles that state and non-state actors fulfil in shaping the demand and provision of energy services (e.g. private sector, NGOs, social networks, religious congregations, communities, opinion leaders, professional organizations, local authorities, etc.). Initial answers could be found in the STS and practice theory literature, which provides some inquiry tools and insights as to how energy-related technological, social and cultural aspects interact in the construction and shaping of everyday energy practices (e.g. Shove, 2003; Gram-Hanssen, 2008; Devine-Wright et al. 2010; Hargreaves, 2011; Devine-Wright, 2012) and essentially, everyday energy services. However, those insights were not framed, thus far, in an energy security context or framework and were not incorporated into the energy security research, discourse or narratives.

Significant challenges remain to identify the various energy services; understand how, what and who shape behaviours, norms and practices related to those services; and envisage what would make low carbon (and often off-the-energy-supply system) energy services becoming acceptable, desirable, widely available and used by the public.

Energy Services and Resilience

Resilience ought to be a pivotal concept in this discussion, as it is a key concept in energy security literature (e.g. McPherson et al., 2005; Pascual & Elkind, 2010; Skea et al., 2011; Sovacool, 2011b). According to one definition, *resilience of energy systems* refers to their ability to "tolerate disturbances and to continue to deliver affordable energy services to consumers" (Chaudry et al, 2009: iv). Resilience is most commonly viewed as a *system's attribute*: "a resilient energy system can speedily recover from shocks" (e.g. short-term interruption in electricity supply) and can "provide alternative means of satisfying energy service needs in the event of changed external circumstances" (Chaudry et al., 2009: iv). A supply-centric energy security approach leads to narrow resilience strategies that are implemented by a relatively small set of actors, and in which consumers have – if at all – a small and short term role.

When applying the broader definition of energy services security, resilience is understood as a *societal* attribute and therefore includes not only the suppliers of energy but also the consumers and intermediates of energy services. Hence, securing energy services requires identifying actors and roles which could response to interruptions in those services. It also calls for the examination of new resilience strategies, which incorporate a wider set of stakeholders and consider new roles for various, overlooked actors.

Insights for Energy Services Security Strategies

Energy security is a major concern for governments and societies, in particular given the increasing pressures on current supply systems, the required transition to a low carbon economy, and the uncertainty surrounding these processes. Securing energy systems is costly: trillions of dollars are invested around the world by states and the private sector in different elements of energy systems. Most of these investments are in technical elements of the system (e.g. 'smart grids', infrastructures, nuclear, renewables) and while some of these technical elements contain components of user-interface to some extent (e.g. smart metering and energy information displayers) their relevance is primarily to energy suppliers (e.g. for more efficient demand management). Significantly less attention and resources are allocated to other than techno-economic demand reduction means or to the funding and promotion of low carbon energy services that could be provided by technology, social innovation, practices and cultures (to illustrate, providing mobility services via car sharing modes or other modes of collaborative consumption of energy services). Likewise, agents of change outside the realm of the energy technology experts, such as those who influence our daily energy services norms of consumption, lifestyle and culture (e.g. Parag & Janda, 2010), are largely being overlooked. To illustrate, agents of change might be found within the fabrics and fashion industries, which via fabric technology, fashion and dressing culture and norms could contribute new approaches for achieving low carbon thermal comfort.

Events, such as the Fukushima nuclear power disaster in Japan, which resulted in a dramatic reduction of electricity generation capacity, expose the numerous everyday life routines and practices which are electricity dependent (see also Trentmann, 2009). At the same time they highlight the huge role that large and small energy consumers could play in building a society resilient to energy services security threats. While the energy supplied by the electricity grid was limited, new and innovative ways have emerged in Japan for providing energy services, and many daily practices had changed, including dressing codes in offices, mobility modes, lightning standards and consumption patterns (e.g. Stanford, 2012). Many of the resiliency strategies emerged from the bottom-up and from the middle-out, and involved state and non-state actors, which were not supplier, energy experts or the regulator. Those actors and practices were neither the 'usual suspect' to be included in energy security governance structures nor tools to be considered in energy security policy strategy.

The traditional approach to energy security seems to perceive such demand side 'saving energy in a hurry' strategies (Bryan PaSquier, 2011) as valid and justified only for a short period of time or as emergency practice. A challenge for policy makers would therefore be to closely examine such bottom-up and middle-out emerging sustainable low-energy and off-grid energy services, and to recognise and support those that could be maintained. And this, as highlighted by STS scholars, might also require changes in energy related cultures, norms and practices at both policy and users levels.

Given the threat of dangerous climate change, broadening the policy scope from focusing nearly solely on securing the supply of *more* energy to considering also securing the provision of adequate *energy services* might point at new and overlooked directions for promoting resilient, low carbon, societies: societies which are less dependent on the energy grid but at the same time enjoy high level of energy services. For achieving such thriving low carbon society there is a need for actors who can 'build' more 'Negawatts' (power stations avoided) instead of Megawatts (power stations built to meet escalating demand) (Lovins, 1989)[3]; actors who can help constructing sustainable, secure and resilient energy services.

Table 1 highlights the additional components and elements that STS and user-oriented perspectives contribute for the study and perception of energy security.

References

Australian Government (2011) National Energy Security Assessment (NESA) (Department of Resources, Energy and Tourism).

Barrett, M., M. Bradshaw, A. Froggatt, C. Mitchell, Y. Parag, A. Stirling, J. Watson & C. Winzer (2010) Energy Security in a Multi-polar World: Discussion Draft ESMW research cluster. Available on http://www.exeter.ac.uk/energysecurity/documents/Energy_Security_in_a_

Table 1. The contribution of user-oriented and socio-technical perspectives to the study of energy security.

Perspective	Traditional	Socio-technical and user-oriented
Main concern	Security of supply	Security of services
Relevant actors	Energy suppliers Regulators Governments International institutions Technology providers	End-users State and non-state actors Off-grid services providers Actors that shape norms and practices
Means	Regulation International relations Incentives Technological innovations Improved energy efficiency	Energy related behaviour, norms and cultural changes Provision of low carbon energy services via social innovation New modes of energy consumption
Main strategy for energy security provision	Top down	Bottom up Middle out Both supported by top actors
Resilience	An attribute of the energy system	An attribute of the society
Disciplines	Economics Political science International relations Engineering Geology	Psychology Sociology Planning Design

Multipolar_World_Working_Paper_DRAFT.pdf.
Bennett, J. (2005) 'The Agency of Assemblages and the North American Blackout', Public Culture, 17(3): 445–65.
Bryan PaSquier, S. (2011) Saving electricity in a hurry, information paper by the International Energy Agency (IEA), original 2005, update 2011 (Paris: International Energy Agency). Available on http://www.iea.org/publications/freepublications/publication/Saving_Electricity.pdf .
Chaudry, M., P. Ekins, K. Ramachandran, A. Shakoor, J. Skea, G. Strbac, X. Wang & J. Whitaker (2009) Building a Resilient UK Energy System working Paper UKERC/WP/ES/2009/023 (UK Energy Research Centre).
Chester, L. (2010) 'Conceptualising energy security and making explicit its polysemic nature', Energy Policy 38(2): 887-895.
Claes, D.H. (2010) 'Global energy security: resources availability, economic conditions and political constraints', paper presented at at the panel: Contextualizing energy security and transition: concepts, framing and empirical evidence,the SGIR 7th Pan-European International Relations Conference.
Cullen, J.M., J.M. Allwood et al. (2011) 'Reducing Energy Demand: What Are the Practical Limits?', Environmental Science & Technology 45(4): 1711-1718.
Department of Energy and Climate Change (2012) The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK (London: DECC). Available on https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65602/6927-energy-efficiency-strategy--the-energy-efficiency.pdf
Department of Trade and Industry (2007) Meeting the Energy Challenge. A White Paper on Energy (HM Government). Available on http://www.berr.gov.uk/files/file39387.pdf.
Devine-Wright, P. (2012) Renewable Energy and the Public: from NIMBY to Participation (London: Routledge).
Devine-Wright, P., H. Devine-Wright & F. Sherry-Brennan (2010) 'Visible technologies, invisible organisations: An empirical study of public beliefs about electricity supply networks', Energy Policy 38(8): 4127-4134.
Druckman, A., M. Chitnis, S. Sorrell & T. Jackson (2011) 'Missing carbon reductions? Exploring rebound and backfire effects in UK households', Energy Policy 39(6): 3572-3581.
European Commission (2011) Energy Roadmap 2050 (Brussels: European Commission). Available on http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf.
Gonzalez, J.F. (2010) 'Empirical evidence of direct rebound effect in Catalonia', Energy Policy 38(5): 2309-2314.
Gram-Hanssen, K. (2008) 'Consuming technologies–developing routines', Journal of Cleaner Production 16(11): 1181-1189.
Hargreaves, T. (2011) 'Practice-ing behaviour change: Applying social practice theory to pro-environmental behaviour change', Journal of Consumer Culture 11(1): 79-99.
Hedenus, F., C. Azar & D.J.A. Johansson (2010) 'Energy security policies in EU-25 - The expected cost of oil supply disruptions', Energy Policy 38(3): 1241-1250.
Hughes, L. (2009) 'The four R's of energy security', Energy Policy 37(6): 2459-2461.
Hughes, T.P. (1987) 'The evolution of large technological systems' in W. Bijker, T.P. Hughes & T. Pinch (eds), The social construction of technological systems: New directions in the sociology and history of technology (MIT press): 51-82.

International Energy Agency (2011) Energy Security. Available on http://www.iea.org/topics/energysecurity/.

Ipsos (2011) Key environmental concerns by nations. Available on http://www.slideshare.net/IpsosMORI/key-environmental-concerns-by-nation-ipsos.

Janda, B.K. & Y. Parag (2013) 'A middle-out approach for improving energy performance in buildings', Building Research & Information 41(1): 39-50.

Jansen, J.C. (2009) 'Energy Services security: concepts and metrics', expert paper submitted as input to the ongoing IAEA project: Selecting and Defining Integrated Indicators for Nuclear Energy, Energy Research Centre of the Netherlands. Avilable on http://www.ecn.nl/docs/library/report/2009/e09080.pdf.

Kaan, H.F. & B.J. de Boer (2006) 'Passive houses: achievable concepts for low CO2 housing', paper presented at the ISES conference 2005, Orlando, USA, September 2005. Available on http://www.ecn.nl/docs/library/report/2006/rx06019.pdf .

Kazantsev, A. (2012) 'Policy networks in European–Russian gas relations: Function and dysfunction from a perspective of EU energy security', Communist and Post-Communist Studies, 45(3-4): 305-313.

Kendal, G. (2008) Plugged In – The End of the Oil Age (Brussels: WWF–World Wide Fund for Nature).

Kruyt, B., D. van Vuuren, H. de Vries & H. Groenenberg (2009) 'Indicators for energy security', Energy Policy 37(6): 2166-2181.

Lovins, A. (1989) 'The Negawatt Revolution – Solving the CO2 Problem', keynote lecture given at the: Green Energy Conference in Montreal. Available on http://www.ccnr.org/amory.html.

McPherson, H., D.W. Wood & D.M. Robinson (2005) Emerging threats to energy security and stability. Nato Security Through Science Series (New York: Springer-Verlag).

Modi, V., S. McDade, D. Lallement & J. Saghir (2006) Energy and the Millennium Development Goals (New York: Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project, and World Bank).

Nye, D.E. (1998) Consuming Power: A Social History of American Energies (Cambridge: MIT Press).

Nye, M., L. Whitmarsh & T. Foxon (2010) 'Sociopsychological perspectives on the active roles of domestic actors in transition to a lower carbon electricity economy', Environment and Planning A 42(3): 697-714.

Olander, L., E. Weinthal & B. Binder (2007) 'For Security's Sake: Can the United States Help Petroleum Rich Nations Avoid the Resource Curse?', Report and consensus recommendations from a round table hosted by the Nicholas Institute for Environmental Policy Solutions, held Sept. 22, 2006, in Washington, D.C. Available on http://nicholasinstitute.duke.edu/sites/default/files/publications/for-securitys-sake-can-the-united-states-help-petroleum-rich-nations-avoid-the-resource-curse-paper.pdf.

Parag, Y. & K.B. Janda (2010) 'A Middle-out Approach to Agency, Capacity, and Societal Change'. Paper presented at the 8th British Institute of Energy Economics Academic Conference (BIEE), 22–23 September Oxford, UK.

Pascual, C. & J. Elkind (eds) (2010) Energy Security: Economics, Politics, Strategies, and Implications (Washington DC: The Brooking Institute).

Pielke, R.J. (2010) The Climate Fix: What Scientists and Politicians Won't Tell You About Global Warming (Colorado: Basic Books).

Ryan, L. & N. Campbell (2012) Spreading The Net: The Multiple Benefits Of Energy Efficiency Improvements. (OECD / IEA). Available on http://www.iea.org/publications/insights/Spreading_the_Net_FINAL.pdf.

Schnieders, J. & A. Hermelink (2006) 'CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building', Energy Policy 34(2): 151-171.

Shove, E. (2003) 'Users, technologies and expectations of comfort, cleanliness and convenience', Innovation: The European Journal of Social Science Research 16(2): 193-206.

Skea, J., P. Ekins & M. Winskel (2011) Energy 2050, Making the transition to a secure low carbon energy system (London: Earthscan).

Sorrell, S. (2009) 'Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency', Energy Policy 37(4): 1456-1469.

Sorrell, S., J. Dimitropoulos & M. Sommerville (2009) 'Empirical estimates of the direct rebound effect: A review', Energy Policy 37(4): 1356-1371.

Sovacool, B. K. (2011a) 'Introduction: Defining, measuring and exploring energy security', in B. K. Sovacool (ed), The Routledge Handbook of Energy Security (NY: Taylor & Francis): 1-42.

Sovacool, B.K. (ed) (2011b) The Routledge Handbook of Energy Security (New York: Taylor & Francis)..

Späth, P. & H. Rohracher (2010) 'Energy regions: The transformative power of regional discourses on socio-technical futures', Research Policy 39(4): 449-458.

Stanford, K. B. (2012) The Impacts of the Fukushima Daiichi Nuclear Disaster on Electricity Consumption: An Examination of TEPCO's Daily Load Curve. Scripps Senior Theses, Paper 73. Available on http://scholarship.claremont.edu/scripps_theses/73.

Thollander, P., J. Palm & P. Rohdin (2010) 'Categorizing Barriers to Energy Efficiency - an Interdisciplinary Perspective', in J. Palm (ed), Energy Efficiency. Available from: http://www.intechopen.com/books/energy-efficiency/categorizing-barriers-to-energy-efficiency-an-interdisciplinary-perspective. .

Trentmann, F. (2009) 'Disruption is normal: blackouts, breakdowns and the elasticity of everyday life', in E. Shove, E., F. Trentmann& R. Wilk (eds), Time, Consumption and Everyday Life: Practice, Materiality and Culture (Oxford: Berg): 67-84.

Verbong, G. P. & F.W. Geels (2010) 'Exploring sustainability transitions in the electricity sector with socio-technical pathways', Technological Forecasting and Social Change 77(8): 1214-1221.

Vivoda, V. (2012) 'Japan's energy security predicament post-Fukushima', Energy Policy 46(0): 135-143.

Wilhite, H. (2008) 'New thinking on the agentive relationship between end-use technologies and energy-using practices', Energy Efficiency 1(2): 121-130.

Wilhite, H., E. Shove, L. Lutzenhiser & W. Kempton (2003) 'The legacy of twenty years of energy demand management: We know more about individual behaviour but next to nothing about demand', in E. Jochem, J. Sathaye & D. Bouille (eds), Society, behaviour, and climate change mitigation (New York: Springer-Verlag): 109-126.

World Economic Forum (2006) The New Energy Security Paradigm (World Economic Forum). Available on http://www.weforum.org/pdf/Energy.pdf.

World Energy Council (2008) Energy Efficiency Policies around the World: Review and Evaluation (London: World Energy Council). Available on http://89.206.150.89/documents/energy_efficiency_es_final_online.pdf.

Yergin, D. (2006) 'Ensuring energy security', Foreign Affairs 85(2): 69-82.

Notes

1 Energy systems, to slightly rephrase one working definition produced in the UK, can be characterized as "set of technologies, physical infrastructure, institutions, policies and practices", located in and associated with a state, "which enable energy services to be delivered to … consumers" (Chaudry et. al., 2009: iv).

2 Rebound effect describes a situation in which (some) money that was saved as a result of a new energy-saving technology, is used to increase the consumption of the same (direct effect) or other (indirect effect) energy consuming goods. This, in turn, partially offsets the initial energy-saving potential (Sorrell, 2009)

3 Negawatt power is a measuring unit theorized by Amory B. Lovins (1989). It indicates how much electric power has been directly conserved by means of higher energy efficiency, energy saving, or both.

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Bruno Latour. An Inquiry into Modes of Existence: An Anthropology of the Moderns. Translated by Catherine Porter. Cambridge, MA: Harvard University Press. 2013. 513 pages. ISBN 978-0674724990.

Bruno Latour is the *enfant terrible* of contemporary thought. He resolutely refuses to be a philosopher, an historian, a sociologist or an anthropologist. His way of thinking is reminiscent of Michel Serres' "troubadour of knowledge" or Mario Biagoli's "bricoleur" for its eclecticism, syncretism and disregard for disciplinary presuppositions. Latour's most recent and difficult book *An Inquiry into Modes of Existence: An Anthropology of the Moderns* is his most abstract and philosophical work since *Irreductions* (Latour, 1984). This new *Inquiry* is a guide (or, better, a template for a guide) to everything and anything: science, technology, law, politics, organization, literature, philosophy and religion. In short, this is a work of systematic philosophy in a grand key. Wilfrid Sellars might have been proud, for Latour is trying "to understand how things in the broadest possible sense of the term hang together in the broadest possible sense of the term" (Sellars, 1963). Latour's *Inquiry* is even more ambitious than Sellars' attempt to square causality with rationality, if that is possible. For Latour, there is no *one* way everything hangs together. Rather there are *ways* that things hang together, and even these may change over time. Given this stance, Latour's *Inquiry* is necessarily a Borgesian encyclopaedia or map that may be extended and modified over time.

In STS circles, Latour is usually identified with actor-network theory and the noisy disputes between ANT and the Bath and Edinburgh schools of the sociology of scientific knowledge in the 1980s. Since *We Have Never Been Modern* (1993), Latour has been increasingly focused on trying to characterize modernity and to use that characterization to diagnose the roots of the current ecological crisis. This shift was very clear a decade after *We Have Never Been Modern* in *The Politics of Nature* (2004). The present *Inquiry* takes these two decades of concerns as its departure point. *We Have Never Been Modern* began in an ANTish fashion by observing that the Antarctic ozone-layer hole "mixes together chemical reactions and political reactions" (Latour, 1993). The present *Inquiry* begins with Latour observing a scientist debating anthropogenic climate change with industrialists and attempting to close the debate with an appeal to "trust in the institution of science." For Latour, this appeal to trust stands in stark contrast with more typical appeals to "the indisputable certainty" of scientific evidence. Unlike appeals to proof, appeals to trust in science engenders "a concern for a fragile and delicate institution" and invites inquiry into exactly what ensures that there are matters of concern that could be "valid, robust and shared" (p.3-4). In other words, what makes our common world and what does this common world hold for our common future?

Latour's position is that our common world is heterogeneous. A distinctive feature of modernity as it is usually portrayed is that it attempts to belie this heterogeneity by processes of reduction. Physicists say that everything reduces to space-time and energy. Sociologists of science claim everything reduces to social relations. Economists say that everything reduces to market calculations, and so on. Latour acknowledges that such reductions are entirely possible and plausible but not without the effort of mobilizing an array of resources. Recall that his "principle of irreducibility" only required that, "Nothing is, *by itself*, either reducible or irreducible to anything else" (see Latour, 1988: 158). An upshot of modernity's propensity towards reductionism is what Latour calls "iconoclash" which is simply the conflict that arises when different candidate reductions compete for supremacy (see Latour et al., 2002; Latour, 2010). There is, however, the possibility of a more peaceable existence but it requires abandoning the possibility of modernization for its opposite, ecologization (p.8). That's an unpardonably ugly label for Latour's brand of metaphysics.

The ecological metaphysics advocated by Latour draws upon William James's pragmatism and Alfred North Whitehead's process philosophy. From the former, it takes an emphasis on what is actually *done* rather than what is typically said. From the latter, it borrows the idea that existence or reality is a dynamic process, not merely a reflection of the properties of some ontologically primitive substrate. The upshot of combining these philosophical positions is an outlook in which our common world is composed by the operation of a number of diverse "modes of existence." This ecological outlook contrasts with the modern view that there is a critical stance which alone properly represents the primitive substrate. In other words, modernity's iconoclastic drive for the ultimate critique is rejected in favour of an ecology of modes of existence, each on-goingly making contributions to the composition of the common world.

The new *Inquiry* marks a notable departure from actor-network theory. Latour acknowledges that ANT "played a critical role in dissolving overly narrow notions of institutions, in making it possible to follow the liaisons between humans and nonhumans, and especially in transforming the notion of 'the social' and SOCIETY into a general principle of free association." But, while ANT provided indispensable insights, Latour notes that ANT "retained some of the limitations of critical thought" by tending towards the "unification of all associations." In the *Inquiry*, ANT is replaced by the more modest network mode of existence which "no longer offers the same metalanguage for all situations" and it is "just one of the forms through which we can grasp any course of action whatsoever" (p.64). However, the network mode retains ANT's "principle of free association" through which inquirers are encouraged to make connections among actants whether they be chairs, heat, microbes, doormats or cats. Of course, licensing free associations across a blancmange of actants threatens unifying the world to such an extent that every specific situation collapses into James' blooming, buzzing confusion. Latour's reply to this charge is that the "multiplicity of associations" that networks promulgate may be differentiated by other modes of existence (p.62). The prepositional mode of existence, for instance, is a descriptive genre that allows specific kinds of associations and discontinuities to be noticed and traced. The prepositional mode is, as Latour attempts to explain, "a *position-taking* that comes before a proposition is stated, determining how the proposition is to be grasped and thus constituting its interpretive key" (p.57).

Thus, the network mode of existence provides a metaphysical principle of integration which draws individuals together when they threaten to become too isolated and too compartmentalized, while the prepositional mode of existence provides a metaphysical principle of differentiation which resists the agglomeration of everything into an undifferentiated whole. It is, of course, tempting to ask which metaphysical principle is fundamental. Latour asks that you not ask that question but recognize that the question itself rests on a category mistake. As Latour explains, from the standpoint of descriptions that invoke the network mode of existence "all the networks resemble one another" and the differences of the prepositional mode of existence "remain totally invisible." Similarly, from the standpoint of descriptions that invoke the prepositional mode of existence, "networks are now only one type of trajectory among others" (p.63). Just as a tourist makes a category mistake when they ask to see the University after visiting several of the buildings that comprise the University, the metaphysician makes a category mistake when they examine several modes of existence and then ask which mode of existence is fundamental.

So far, Latour's *Inquiry* purports to have identified fifteen distinct modes of existence that compose the common world. There are likely more modes to come. Each mode is tagged by a three-letter code in square brackets. In addition to the [NET]work and [PRE]position modes, there are [REP]roduction, [MET]amorphosis, [REF]erence, [HAB]it, [LAW], [FIC]tion and [REL]igion. The list goes on. Modes of existence co-exist "side-by-side" (p.142). Each mode institutes – brings to being – relations among individual actants along with "conditions of veridiction" that sanction some relations among actants as (borrowing from J.L. Austin) "felicitous" or "infelicitous," "happy" or "unhappy" (p.18). What is felicitous or happy by the criteria of one mode may be infelicitous or unhappy by the standards of another. Because each mode has different and often incompatible veridiction conditions, there is always the potential for difficulty, confusion and even conflict when modes "cross."

Crossings generate difficulty and confusion when important practices are composed of multiple modes of being. Such is the case in matters of "the economy" which integrates three different modes of existence: [ATT]achment, [ORG]anization and [MOR]ality. Crossings are also risky places. They are where accidents happen, pedestrians get run over, ships are lost, and swords meet. Crossings require careful navigation and sometimes diplomacy to mediate among modes and diffuse iconoclastic disputes about the right or best mode of existence. Simply acknowledging a plurality of modes of existence, Latour argues, makes for a "more universalizable world" shared with humans and nonhumans and collected together in more than one way. Given that there are many modes of existence, Latour cannot claim that his metaphysics is true, right or fundamental, but instead, he asks: "Is this not a more engaging way to take the inventory of our own inheritance? And, above all, a less provincial way to prepare us to inhabit a world that has become common at last?" (p.292).

For Latour, the *Inquiry* is not a book but a "provisional report on a collective inquiry that can now begin" (p.474). The modes of existence need further documentation and elaboration, crossings between modes of existence need to be thoroughly explored and new modes of inquiry are out there awaiting discovery. As Latour notes, all this work will require "volumes of erudition" (p.478). AIME is the name given to the collective project, and the project's clearing-house is www.modesofexistence.org, available in French and English versions. Indeed, the text version of the *Inquiry* is merely an advertisement for the AIME project's website. And, since the book itself has no index, readers are compelled to go to the web where a searchable version of the text is available along with extra commentary and exposition. (Sadly, the website is often painfully slow.) Once registered, users are encouraged to begin contributing to the AIME project. Less cynical reviewers might simply observe that the AIME project turns Latour's *Inquiry* into a participatory anthropology of modernity through which moderns may reflect on their condition. More cynical reviewers might grudgingly admire the charming efficiency with which Latour has crowd-sourced content generation. AIME is a nervous tentative project of overwhelming ambition and uncertain consequence. Latour worries that he has brought together "a hodgepodge of curiosities that says a lot about the odd tastes of the autodidact who collected them, but very little about the world he claims to be describing" (p.476). This is very certainly the case but it is of no consequence. Arguably, a philosopher is a person who transforms their idiosyncrasies into analytical tools.

References

Latour, B. (1993) We Have Never Been Modern (Cambridge, Mass.: Harvard University Press).

Latour, B. (1988) The Pasteurization of France: (Cambridge, Mass.: Harvard University Press).

Latour, B. (2002) Iconoclash: Beyond the Image Wars in Science, Religion and Art (Cambridge, Mass.: MIT Press).

Latour, B. (2004) Politics of Nature: How to Bring the Sciences Into Democracy (Cambridge, Mass.: Harvard University Press).

Latour, B. (2010) On the Modern Cult of the Factish Gods (Durham: Duke University Press).

Latour, B., C. Bigg & P. Weibel (2010) Iconoclash: Beyond the Image Wars in Science, Religion and Art (ZKM, Center for Art and Media).

Sellars, W. (1963) 'Philosophy and the Scientific Image of Man,' Science, Perception and Reality 2: 35-78.

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Jens Lachmund. Greening Berlin: The Co-Production of Science, Politics, and Urban Nature. Cambridge, MA and London: The MIT Press. 2013. 320 pages. ISBN 978-0-262-01859-3.

Greening Berlin: The Co-Production of Science, Politics and Urban Nature, written by historian and German science-technology scholar Jens Lachmund is a well-researched book that traces how ecologists in post-war Berlin translate ecological field work into a political tool for urban planning. As such the Berlin school of urban ecology, lead by Herbert Sukopp, one of the book's two main characters – the other being Berlin itself – came to influence the organization of urban ecological science. From c. 1960-1990, we get to follow how a small research group tries to put into action their grand vision of "urban renewal under the guidance of ecology" (p.231) by including new type of field sites (wastelands and "bombed lots"), develop the "biotope category", and create maps to mobilize planners, political parties, and activists. Lachmund stays away from simplifying the story, but sensitizes readers to the continuous negotiations and internal tensions of what he refers to as an emergent "biotope protection regime". Based on sound archival records and complementary interviews, this book is of great interest to human geographers, political ecologists, science-technology students, environmental historians, and ecologists – but also, albeit more cursory perhaps, to historians of Europe and Berlin and its reunification.

The main aim of the book is "to shed light on the changing place of nature in the modern city" and "to understand the political use of science [in] environmental conflict" (p.3). This links to debates on science and value statements (Latour, 2005; Ernstson & Sörlin 2013), but also how the modern city has figured as a scene to rework and understand urban nature (Gandy, 2005; 2014; Kaika 2005; Heynen et al., 2006; Karvonen, 2011). Another aim revolves around the role of place in ecology (here Berlin), or in field sciences more generally (Evans, 2011; Vetter, 2011). He delivers on all three through effectively demonstrating how a historical narrative can be interspersed with theoretical analysis, following in the tradition of science and technology studies.

The book contains six empirical chapters, plus an introduction and conclusion. The first empirical chapter describes four previous "regimes" of urban nature protection since the 1900s, while the second chapter introduces Herbert Sukopp through his 1973 article that recognizes the city as an object of ecological research (Sukopp, 1973). While breaking with ecologies wilderness tradition, this was also part of a wider effort among ecologists in industrialized countries to "link their expertise to the environmental problematique" (p.47). However, as Lachmund demonstrates, Sukopp's argument was deeply rooted in a local research tradition of flora and fauna in Berlin, including "hikers, naturalists, field biologists, and other Naturfreunde" (p.47). With the establishment of the Institute of Ecology in 1973 at Technische Universität Berlin, this web of relations and practices provided the means through which the "biotope-protection regime" and the Species Protection Programme could be articulated (p.47). The third and fourth chapters narrate how the influence of Sukopp's group on spatial planning grew through their field work, theoretical developments and mobilization of other interests and actors. He chooses a couple of intense land use struggles to make credible the alliances forged between ecologists and the growing civic environmentalism of the 1970s and 1980s, but also how disputes occurred. The clearing of an oak forest next to an airport, which local citizens' groups opposed, was deemed as beneficial to Sukopp as it would restore a heath with higher biodiversity (p.154). The final two chapters narrate how the ambitious biotope protection regime were watered down in the late 1980s as they met the realities of the capital city's growing demand for housing and transport infrastructure (especially after re-unification). Rather than the all-encompassing protection and care of land, it was through "more specific site-focused projects [...] that the goals of the program actually became implemented." (p.161; in particular in turning wastelands into "nature parks"). The final chapter demonstrates tensions between, and ultimately a shift, from protecting land because of biodiversity and wildlife, to recreation.

The major theoretical contribution of this book lies in the textured understanding we receive on how the practice of field science is necessarily caught between a (hard) place and universalism, a theme discussed by others (Evans, 2011) but not at this length. For instance, Lachmund effectively demonstrates how Sukopp created a shift in the "circuits of observation" of urban nature, from "species spotting", often carried out by naturalists and amateurs, to "surveys [of] exemplary sites" by professional researchers (p.59). The surveys introduced, Lachmund argues, three crucial "spatializing strategies" that would influence the subsequent steps: demarcation (of sites), inventory (that attaches various data to the same site), and differentiation (constructing the identity or quality of the exemplary site). This recording of data aimed in the 1970s towards a "comprehensive structuring of the Berlin territory" that would use statistical indicators and maps to represent Berlin as "complex flora, fauna, and living spaces" (p.59). It crucially also established "the city (or the urban ecosystem) as a generic object of ecological knowledge" (p.72), mingling place based field work with universal claims. Lachmund pays due diligence on how the ambition to 'map' the whole of Berlin based on science (an explicit goal by Sukopp and his group) was fractured as the deadline for their Species Protection Programme approached in 1984. To avoid time-consuming fieldwork, "quick mapping" and a "reduced methodology" (p.105) was eventually used where "biotope types" came to basically equate with "land-use categories", which did not explicitly or empirically take biological conditions into consideration, but nonetheless "assumed to each represent ecologically homogenous conditions" (p.105) with equal "ecological significance and conservation needs" (p.107). Lachmund argues that this followed modern politics in creating standardized forms (citing Portes, 1995), which on one hand made them accessible to relevant publics in the policy process, but also concealed the type of nature in question.

Indeed, this had two effects, which brings home another theoretical point of the book of how science, value and politics are intermingled. Instead of discussing trees, bogs, fish and wetlands – the categories by which nature is usually described – values were assigned to abstract "biotopes". This shifted what kind of demands that could be articulated, and by whom, and therefore also the nature of politics. It also foreclosed radical changes, since existing "dominant" land-use was given priority. In effect, the

Species Protection Program pragmatically aimed to operate with the 'green spaces' that existed, although a real novelty of the programme was to include wastelands as ecologically important.

This timely book helps us understand some of the roots of the quickly emerging field of urban ecology, but also ecologists' promises to follow the sanitarians (Duffy, 1990) in fixing the (modern) city (see statements in Pickett et al., 2014; Niemelä et al., 2011). Until now we have lacked a longer historical exposition of how urban ecology is caught up in all sorts of politics, value judgments and internal tensions in wanting to be both objective science and a guide towards (urban) sustainability (for articles see e.g. Evans, 2011, Ernstson & Sörlin, 2013). If there is anything I would have wished for, it would have been for Lachmund to more explicitly engage in theoretical debates in his conclusion. For instance, Evans (2011) has written on how "circuits of ecological observations" (in Baltimore) place the whole notion of truth in a different light when ecologists are part of the system they study. Lachmund also has material to discuss more extensively prospects for sensitizing decision-making processes to non-humans (Gandy, 2013; Hinchliffe & Whatmore, 2006), and could head-on take on Latour's claim that nature is not a useful analytical object, a task Lachmund recognizes only in a footnote (p.237).

Greening Berlin contributes to debates on the relation between science, value, politics and place. As a final point, it was at the end, when the species protection regime was losing its grip on policy that it created changes on the ground through place-specific projects and struggles. Here ecological knowledge was of significance, though it was blended with recreational and cultural-historical arguments to articulate value, place meaning, and urban memory, in one word – uniqueness. What thus seems to have bought real political purchase was not the scientifically based mapping of Berlin's biotopes, but its mixing with recreational and cultural-historical arguments and an active citizenry. It is on this point that Lachmund ends, stating that the politics of sustainability will depend on the "subtlety" of environmental expertise and "the imagination and experimental attitude of a lively civil society" (p.236).

References

Duffy, J. (1990) The Sanitarians: A History of American Public Health (Chicago: University of Illinois).

Ernstson, H. & S. Sörlin (2013) 'Ecosystem services as technology of globalization: On articulating values in urban nature', Ecological Economics 86: 274-284.

Evans, J.P. (2011) 'Resilience, ecology and adaptation in the experimental city', Transactions of the Institute of British Geographers 36(2): 223-237.

Gandy, M. (2013) 'Marginalia: aesthetics, ecology, and urban wastelands', Annals of the Association of American Geographers 103(6): 1301-1316.

Heynen, N.C., M. Kaika & E. Swyngedouw (eds) (2006) In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism (London and New York: Routledge).

Hinchliffe, S. & S. Whatmore (2006) 'Living cities: Towards a politics of conviviality', Science as Culture 15(2): 123-138.

Karvonen, A. (2011) Politics of Urban Runoff: Nature, Technology, and the Sustainable City (Massachusetts: MIT Press).

Kaika, M. (2005) City of Flows: Modernity, Nature and the City (London and New York: Routledge).

Latour, B. (2005) Reassembling the Social: An Introduction to Actor-Network Theory (Oxford: Oxford University Press).

Niemelä, J., J.H. Breuste, G. Guntenspergen, N.E. McIntyre, T. Elmqvist & P. James (eds) (2011) Urban Ecology: Patterns, Processes, and Applications (Oxford: Oxford University Press).

Pickett, S.T.A., M.L.Cadenasso & B. McGrath (2013) Resilience in Ecology and Urban Design: Linking Theory and Practice for Sustainable Cities (London: Springer).

Sukopp, H. (1973) 'Die Großstadt als Gegenstand ökologischer Forschung', Schriften zur Verbreitung naturwissenschaftlicher Kenntnisse 113: 90-140.

Vetter, J. (2011) Knowing Global Environments: New Historical Perspectives on the Field Sciences (New Jersey: Rutgers University Press).

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Jeannette Pols: Care at a Distance: On the Closeness of Technology. Amsterdam: Amsterdam University Press. 2012. 204 pages. ISBN 978-9-0896-4397-1.

Engaging with Transformations of Care

A patient + body weight + webcam + home + computer + health professional + standard + policy: most social science scholars involved in analysis of technology will recognize that this adds up to a socio-technical assemblage of some kind. Those interested in technomedicine might guess that this is the breakdown of the elements of some kind of telemedical arrangement. Telemedicine or telecare – devices and arrangements increasingly used in healthcare for managing patients 'at a distance' through information technology – has been a focus of interest for many STS researchers for a number of years. Such STS interest might relate to the way in which these particular assemblages insert the 'plus signs' between otherwise distinct phenomena thus introducing a number of interesting hybrids: computers as caring-devices; patients as medical experts; homes as clinics. Hybridity, transgression of physical and epistemic boundaries, and mutability of roles and identities seem to be at the heart of these emerging technological arrangements – something recognized and even promoted by the technologists and biomedical actors engaged in these practices.

The two excellent books on telecare that we review here are written by STS-scholars with longstanding engagements with questions raised in relation to technological and epistemological transformations in healthcare. Nelly Oudshoorn has published extensively on issues around medical technologies and their users, and Jeannette Pols has explored interrelations between practices, ethics, and technologies in care practices. In their present works both have the Netherlands as the primary setting of their ethnographic inquiries into transformations brought about by the introduction of telecare arrangements of various kinds. This shared geographical affiliation may not be coincidental as medical practices in the Netherlands have long striven to incorporate ICTs in medical practice and are a rich source of well-regarded STS-scholarship on medicine, technology, and innovation more broadly.

In this review we first evaluate these books on their own terms, that is, according to the criteria provided by the authors' ambitions of creating situated, relevant, robust accounts of telecare that intervene by providing "food for thought". We then take the opportunity to, tentatively, discuss how STS researchers might tackle more deeply embedded roles in innovation processes while they attend to analyzing the broader, societal changes that telecare is a symptom, product, and vehicle of.

Situated Accounts of Telecare

From the position of engaged spectators, Oudshoorn and Pols both set their minds to sorting things out in a field characterized by on one hand hype and a persistent knowledge deficit on the other. Telecare is central to many contemporary healthcare policies and promises. Projects and prototypes are conceived (and laid to rest) in large numbers, and in the midst of it all, engaged researchers (themselves divided by disparate epistemic commitments) try to find a way to produce knowledge about these emerging technologies and practices and their effects; knowledge that will work as a substantiated, alternative narrative to the hype. Providing an alternative narrative is for both Oudshoorn and Pols a matter of bringing STS into dialogue with deterministic and instrumentalist myths and tales circulating in innovation and healthcare policy circles; to produce "useful" knowledge about a phenomenon that has proven hard to make stable, and with effects that seem to escape the grip of the evaluative methods most commonly applied.

Although sharing this common ambition, Oudshoorn and Pols also have diverging motivations and orientations. Pols frames her engagement as a quest to counter the dichotomous tales of promises and nightmares related to telecare. She does so by questioning the distinction between cold and warm care so often dominating public as well as scholarly discourses on telecare technologies. Care – in variable forms – is accomplished with telecare. By showing how various arrangements achieve different versions of care, Pols seeks to help solve the "knowledge paradox" in telecare by replacing evaluation studies with an ethnographically based "fitting research". Where the core object of study for Pols is the slippery concept of 'care', Oudshoorn places the technologies, and the transformations in healthcare practices that these afford, at the core of her analysis. Hers is in a sense both a modest and a comprehensive quest to *understand* these transformations, but also more ambitiously, through the unfolding of telecare technologies' transformative nature, to counter a predominant reductionist view of healthcare and instrumentalist stories of telecare technologies.

So How Do the Two Authors Carry Out Their Projects?

Nelly Oudshoorn tells the story of how telecare technologies transform healthcare through three cases of telecare for heart failure patients. The story moves in a very straightforward manner from an initial text analysis of the expectations – and resistances – attached to the specific technologies articulated on websites and in press releases, brochures, and interviews to an ethnographically based analysis of the practices and viewpoints of the users. Through her firm theoretical grip based on material-semiotics, human geography and a feminist approach to work, we learn how a new profession of telecare workers is established, enacted, and negotiated – shaped by and shaping the physical context and boundaries of care for heart failure patients. With the addition of a phenomenological orientation towards the embodied experience of coping with illness, the readers are further invited into the homes and lives of the patients who have to learn how to be patients and users in a landscape where technology facilitates new tasks, responsibilities and ways of relating to one's own body. Oudshoorn terms her approach a "technogeography of care" as it actively seeks to take into account the spatial dimensions of the realities and indeed changes of care practices. This we find to be an important contribution, as much STS research has made extensively use of spatial metaphors, but nevertheless given limited empirical and conceptual attention to what role places and spaces play and how they might change (for exceptions see Schillmeier & Domènech, 2010).

Jeannette Pols takes the reader through a both more nitty-gritty empirical examination and tentative philosophical conceptualization of the (micro-) interactions between users and various telecare technologies. With a focus on the values and epistemologies shaped and enacted through the practices of using monitoring and communication technologies in chronic care, Pols plays her way through situations and "close-ups" in which notions of good care are both transformed and showcased by the entrance of technology. We learn about how terminally ill cancer patients are cared for - and care for themselves and their care workers – through a little white box, and how COPD patients care for each other and learn how to care for themselves through webcams which facilitates the production of collective, practical knowledge on how to live with their disease ("know-now" as Pols terms it). And we (try to) follow Pols on a zig-zag tour through sites and practices where nurses in the face of new means of delivering care for their patients tinker with technologies and values. Along the way Pols explores the relationship between values, facts, and practices – convincingly questioning the dichotomy between cold and warm care and proposing the concept of "fitting care" as a tool to overcome such distinctions and emphasize the situated, relational, and contingent nature of "good care".

Fitting Research for Innovation?

Where Oudshoorn and Pols set out with resonating motivations and move through stylistically different analyses with mutually echoing insights, they arrive at their conclusions and leave their readers with very different parting shots. And this is where we (as reviewers) find, in a backwards manner, our point of departure for a comparative critique centered on the questions "what kind of knowledge is this?" and "what can it do?".

Pols ends by promoting her "uncontrolled field studies" as "fitting research" – research "that actually delivers useful knowledge on novel telecare practices, that engages the parties concerned and their practical knowledge" and thus may work as "a policy developing method for innovation in care" (Pols, s.136). Demonstrating the shortcomings of conventional evaluative research, she argues for an engaged, yet unobstructive, approach in which researchers recognize the normativity of their own work and seeks to deploy this to provide "food for thought". We find this an honest, daring ambition, yet also somewhat unclear, if not paradoxical, in its insistence on both intervention and "minimum disruption". The tension between closeness and distance leaves us with the feeling that something still does not quit fit.

The conclusions of Oudshoorn *fit* to her ambition – precisely summing up the points made in the analysis, she convinces us that she has delivered a blow to reductionist and deterministic accounts of healthcare and telecare technologies. Let the message travel on. But how? While Oudshoorn argues that her technogeographical approach is relevant to designers and policy makers "because it makes us sensitive to some crucial issues concerning the future development of telecare technologies" (p. 204-205), it remains unclear how exactly 'technogeography' can be used "not only as heuristic tool but also to intervene critically" if the researcher remain somewhat detached.

Can we trust that ethnographic knowledge, however rich, provoking, and relevant, will find its own way into the repertoires of designers and decision makers? Neither Pols nor Oudshoorn tackle these questions head on. To finish up our review of these two otherwise exemplary, inspiring and highly important contributions we wish to briefly discuss this challenge of fitting or not fitting STS research for the ubiquitous innovation agenda. The discussion of how STS researchers can or should engage in the practices of science and technology that they study has been around for a while (Zuiderent-Jerak & Jensen, 2007) but it seems that we are still struggling with finding an adequate vocabulary for modes of engaging and for our contributions. In the "get real" discussions on the normative responsibility of STS research, positions have ranged from one saying that we always already are engaged and intervene in the practices and technologies we study merely by 'doing STS,' to one arguing that we should engage very actively in co-design experiments in which STS is practiced as a hands-on innovation business with 'solutions' as deliverables. Both authors discussed here stay distanced in the sense that they do not seem to have engaged directly in questions of how the devices of telecare should or could be (re)designed, or how the work with or around them should be organized. Encouraging users to tinker with care technology is proposed by Pols as a task for the ethnographer, but no concrete examples of such engagement between ethnographer and informant is shown in the stories told, and to the extent that interactions between informants, ethnographers and designers or policy makers might have taken place, accounts of these are likewise largely absent in the texts. Though this may not be the intention, both Oudshoorn and Pols seem in line with the position that textual contributions, accounts of "thinking differently about telecare" intervenes plenty.

Those STS-researchers who study telecare "by invitation" and as part of the increasing number of research collaborations funded under innovation headings are expected to fill in a more directly intervening and facilitating role will find little advice on how to manage such a role. For that they will have to look to other parts of STS – primarily identified with fields such as Participatory Design, Design Anthropology and Action Research – where partnering in design or implementation is done and debated. Maybe Pols' notion of 'unleashing' should also go for the STS researchers themselves – not just for users and devices. Finding the enmeshing in the politics and practices of telecare innovation challenging and inspiring ourselves, we would welcome more contributions that could stand on the firm basis of the work of these two insightful scholars and from here continue the development of a vocabulary fitted for engaging assertively, critically and for the betterment of society and healthcare.

References

Schillmeier, M.W. & M. Domenech (eds) (2010) New Technologies and Emerging Spaces of Care (Ashgate Publishing).

Zuiderent-Jerak, T. & C. Bruun Jensen (2007) 'Editorial introduction: Unpacking 'intervention' in science and technology studies,' Science as Culture 16(3): 227-235.

Note

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