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Sustainable Transitions and Complex Socio-technical Systems: Renewable Energy and the Electricity Grid in the USA, UK and Germany

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Abstract

Transitions management identifies broad national efforts that attempt to govern socio-technical change along more environmentally sustainable pathways. Although the complexity of such endeavours is generally acknowledged, it is not yet clear how governance practices work at an international level. This paper utilises the transitions management concept to compare three countries in their attempts to increase the adoption and use of renewable energy technologies. It notes that analysis at a micro-level needs to focus on the actions and requirements of particular user groups for a deeper elucidation of transition management processes. Furthermore, the complexity of socio-technical change processes implies that transitions management is a more useful concept when focused at the micro-level of change rather than at the macro level of strategy formulation over the longer term.

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Introduction

Academic investigation of sustainability transitions is a developing field of study, which focuses on elucidation of the profound changes necessary to embed new socio-technical practices (Markard, 2012; Falcone, 2014).Within this area, the specific approach of transitions management (TM), can be identified. TM explicitly focuses on the challenges involved in *ex ante* attempts to anticipate and direct current transitions over the longer term (Loorbach, 2007; Genus and Coles, 2008). This approach is concerned with identifying processes of socio-technical change which will ensure that there is a high chance of developing future conditions for environmental sustainability. The concept requires social systems to display qualities such as openness, flexibility and reflexivity for successful governance of sustainability transitions. In TM, therefore, the objective is to enact radical transformations towards a sustainable society under conditions of socio-technical complexity (Grin, 2010). Thus socio-technical changes will be steered towards the needs of sustainable development. Technology governance regimes can intervene in change processes by directing innovation towards goal-oriented outcomes that explicitly confront current sustainability issues. However, it should also be acknowledged that, as the concept of sustainable development is an ambiguous term, decisions to invest in new technologies are not always clear cut (Peters and Coles, 2003). Such ambiguity enables the very concept of sustainable development to be utilised to justify a myriad of different endeavours, but does not necessarily promote social consensus and cohesion (Steward et al, 2005). This article attempts to explore the implications of the TM approach in relation to sustainable energy transitions through the comparative analysis of electricity grid transformation in three countries. The USA, Germany and the UK have all attempted to incorporate power generation from renewable energy technologies into existing national grids. However, uncertainties involved in radical socio-technical change have given rise to context specific challenges in each country, which raises issues relating to the variability of TM in different socio-technical contexts.

Attempts to manage or steer a particular transition path must necessarily be flexible and responsive to the emergence of new socio-technical configurations. Thus, proponents of transitions management claim that it is not a command and control activity along a pre-defined and functionally prescriptive path but a process of heterogeneous socio-technical path co-creation (Garud et. al., 2010).TM is necessarily explorative and participatory, iterative and reflective with emphasis on reflexive social learning. In effect, the concept of management here is quite general and distributed. A transition cannot be steered by a single actor, although some actors are better placed to gain access to necessary resources, policy framing activities and influential discourse. In the model suggested by Loorbach

(2010), socio-economic arrangements that require sustainable change should be considered as a complex system. Groups or individuals who contribute to change process within the system, each work with a partial understanding of the system as a whole. In this approach, drawing on complexity theory, agency can be given to all actors, however weak or marginalised, as even extremely small effects can engender a radical impact (Byrne, 2005).

Loorbach and Rotmans (2006) note a sustainable transition is a structured concept, which requires fundamental socio-technical change over the longer term. Thus sustainability transitions are situations that present complex technology governance challenges that cannot be described by smooth descriptions of historical processes. In a complex system many changes can happen simultaneously so it is more difficult to tease out the contributory effect of activities of different magnitudes or to predict how disruptive change will occur. This approach to system governance also resonates with the argument made by Stirling (2008) in respect of empowering social agency in socio-technical choice. He points out how different socio-political configurations give rise to alternative discourses that may lead to different outcomes or, in the TM approach, to describing different transition paths. In an emerging system there is a real possibility of disruption due to system turbulence that could impact on a potential transition (Hughes, 1984, Genus and Coles, 2008). Also the contingent nature of socio-technical controversy cannot be ignored as a factor contributing to the direction of socio-technical path creation. Attempts to widen participation could lead to different outcomes. Stirling's argument reinforces the idea that transitions management is a process of distributed governance that continually readjusts in relation to novel socio-technical configurations as they arise (see also Genus and Coles, 2005; Chilvers, 2008). However, setting goals for future outcomes is not an untried or untested path. Social steering through development of new policy instruments has, in the past, arisen in response to radical new technologies. Regulations attempt to anticipate and control emergence of potential public risks (Coles, 1990, 2017). However, transition to sustainability requires more than policy change, it also needs broad based co-operation between significant social and business actors, prepare to enact 'future experiments', often on an international basis (Coles and Peters, 2006). In addition, in innovation terms, it requires participation of organisations which have a large R&D budget (Peters and Coles, 2010; for a discussion on the national difficulties inherent in creating new innovative industries see Peters, 2006).

Achieving transition to environmental sustainability is a complex process, and TM attempts to influence the direction and speed of transition through various attempts at co-ordination and social learning. In the TM approach the objective is not to impose a command and control managerial system where change is controlled by a powerful social group following a pre-defined blueprint of a transition path. The aim is to steer the transition through distributed governance activities to promote wide participation of individuals, social groups and stakeholders. For Loorbach (2010) managing a sustainable transition necessitates key requirements, such as:

> The system works towards both short term and long term sustainability goals
> There is a wide public debate and discourse over changes towards sustainability
> Continual processes of socio-political reflexivity, adaptation and repositioning in the light of experience

This paper discusses the impact of socio-technical practices in changing energy systems in three countries. It focuses on elucidation of the influence of national context as it impacts contingently on the specifics in particular situations. In the TM approach, transition paths are co-created from interactions between complex heterogeneous factors. It can be expected that the impact of technical change will vary by place, as uncertainties and non-linearity influence the emergence of new socio-technical relations. For example Kemp and Loorbach (2003) identify problems of change in complex social systems as a knowledge problem as well as a governance problem. In particular, they consider the possibility of lock-in to a new system too quickly, which could pre-empt embedding of sustainable objectives more broadly in policy deliberations over the long term. In addition, lock-in could disrupt the process of encouraging a synthesis between top-down and bottom up activities. The question remains whether a complex system is a useful metaphor to understand profound shifts in socio-technical configurations necessary for sustainable change, given the difficulties of analysis (Loorbach, 2010; see also Tsoi, et al 2008). The reality that is being modelled here is not systemic but may be comprised of many overlapping systems and subsystems which interact with other configurations that are not organised systemically. However, whatever the more general considerations, the TM approach used in this paper is primarily concerned with change processes in electricity generation dominated by national grids, which are mature national infrastructures. These can reasonably be considered technical systems in the way outlined by Hughes (1984).The complex system metaphor does have some advantages for analysis in that it circumvents a temporally linear progressive viewpoint focusing on outcomes and passage points. In a complex system even small changes enacted by individual actors have the potential to affect overall transition processes. In addition, a complexity view encourages focus on agency and interactivity where both social cohesion and contestation play a role in overall governance processes. The direction of change will be constrained by historical activity but there are also irreducible uncertainties and emergent properties associated with any particular outcome, so that unexpected effects could emerge and destabilise any particular transition path. Conceptualising socio-technical interrelations as complex also resonates with themes within the broader analysis of complex social systems (Urry, 2005).

This requirement for long term, adjustable goals contravenes the possibility that a particular transition path can be selected as a blueprint for sustainable change (Loorbach, 2010). In the TM approach, then it is not inconceivable that a socio-technical system might jump from one path to another during the process of long-term transition. In effect, paths can potentially be disrupted in response to unfolding unexpected events, or may fragment at an early stage (Coles et. al., 2015). This paper looks at the potential for different socio-technical pathways to be created in adoption of renewable energy technologies at specific sites of interaction which are mediated by the wider social context. The paper has a comparative focus on the relationship between emerging renewable energy technologies and the existing electricity grid in three countries, the UK, USA and Germany. In these countries the dominant method of electricity generation is structured around a deeply embedded, mature, large technical system, an electricity transmission grid, interwoven with many socio-technical sub-systems. In each of these countries early introduction of renewable energy technologies has taken different forms. In the USA and Germany renewables have provided an opportunity for domestic and industrial users to leave the grid altogether, while in the UK, domestic users are more likely to be linked into the dominant system. This paper first reports on the literature on renewable energy use, and identifies some of the key issues which affect user adoption and interaction within the electricity generation systems. Specific issues which affect these three cases are outlined and potential directions enacted through transition management processes identified.

Renewable energy: Factors affecting transition management

Any particular site of interaction between novel and established technologies is shaped by the local context in which certain aspects of the dominant system will be involved. Local conditions that have an impact at sites of interaction can include a range of social and technical factors that affect the final outcome. Issues such as reliability and affordability of novel technologies and their state of diffusion are examples of factors that affect the final socio-technical configuration. Other influencing factors can include the availability of skilled installers and operational knowledge of the technology (Coles and Piterou, 2015). In addition, general consultation exercises and surveys across Europe tend to reveal that the public has a limited understanding of energy options confined mainly to an appreciation of the potential applications of wind turbines and solar power. Findings indicate that people express generally broad but cautious support for wider use of renewable energy. However, individuals appear to be reluctant to actively participate in perceived ‘costly’ or ‘unproven’ innovation in either community or commercial projects (Brohmanna et. al. 2000). One of the fundamental issues for potential users in making decisions over whether or not to use renewable energy relates to the characteristics of the local building stock, including aspects such as density, size, and building function. In particular it has been suggested that variations in building function such as domestic single and multi-occupancy or manufacturing, business and commercial and the desirability of renewable technologies might affect technological choices (Coles and Piterou, 2015). Space restrictions can affect both individual homes and locality limiting the use of district and on-site technologies. In effect, there are a number of issues that can affect the outcome of technology steering efforts, arising from interactions at specific sites. These are both related to the success of the existing system to adequately fulfil energy requirements and expected benefits that could potentially accrue from adoption of new renewable technologies (ibid.). Improved understanding of such interactions can therefore be gained from identifying specific groups of end users and their expectations in relation to decision making over the uptake and use of renewable energy technologies.

Identifying end user group and variation in energy requirements

Countries which have an embedded infrastructural system linking energy generation and consumption tend to subsume the notion of the end user under a general notion of energy customers without need to differentiate to a large extent between different types of user in terms of their individual requirements. However, the variety of possibilities provided by different renewable technologies has led to the identification of users with differing energy needs. In the literature on adoption of renewable technologies different groups have been identified, including: existing consumers, householders, community groups and other organisations such as large and small firms; service organisations, institutions, local authorities, social and voluntary groups. In brief, the academic literature characterises these groups in particular ways:

Consumers

Current energy consumers are usually considered a homogenous group who define the potential market sector for energy companies. Although consumers are often seen as being motivated mainly by energy costs, they have the potential to influence investment decisions by large energy providers in renewable and energy efficient technologies. Actions and interests of consumers are also seen as a key part of growing societal acceptance of new methods of energy generation. Consumers, for example in Denmark, Germany and Austria, have been more enthusiastic users of renewable generation, leading to wider commercial use and a more integrated position in the energy infrastructure (Brohmanna et. al.

2007). Consumers require new types of energy generation to be competitive in cost of delivery and use and also expect that new technologies provide the same level of security and resilience of supply and end-use reliability.

Householders

Heiskanen, et al (n.d.) identify different kinds of building owners, including householder and rental properties to have an impact on energy use. Kellert (2007) identifies a role for householders in adopting and using modern energy efficiency measures. However, householders can also be resistant to adopting new energy technologies and implementing on-site micro-generation schemes. This may constitute a barrier in moving technologies from a niche to mainstream (Faiers and Neame, 2006). For owner-occupiers the small scale, low cost and short time scale involved in renovations could work against some decisions to adopt new energy technologies. However, the authors note that this segment is heterogeneous and includes both the richest urban and often the poorest rural households. In addition, living habits vary between European countries, for example, in both Spain and Romania, over 90% of families live in multi-occupancy buildings that increase the difficulty of making decisions about funding and implementing new technological solutions to a building.

Community groups

Innovations at the local level can be supported by a wide range of organisational types, including cooperatives, voluntary associations, informal community groups, or social enterprises. They can have access to a variety of resources including grant funding, voluntary input and mutual exchange. Although this category of users has been identified as being heterogeneous, it is also a group that has been identified as important in the renewable energy adoption process (Walker and Devine-Wright, 2008; NESTA, 2009). However, Kellert (2007) suggests that a community centred approach to implementing distributed generation should be based on analysis of local socio-economic circumstances (see also Peters and Jackson, 2008). Seyfang et al (2013) provide a review of the factors which lead to successful community-based energy projects in the UK. They identify these projects as encompassing a wide range of activities from local ownership of resources to community funded refurbishment projects, energy efficiency installation and other actions aimed at behaviour change. The authors note that collective activities have been supported by government funding as they are expected to 'bring additional public engagement benefits to top-down policy initiatives', and may become a policy tool for energy system renewal (Seyfang et. al. 2013: 977). There has been some success of local experiences in Austria with roof top solar collectors, but this locally generated experience has been difficult to translate into mainstream practice (Ornetzeder et al, 2013).   In

Denmark, as a result of a particular legislative and policy framework, over half of the electricity distribution companies are in some type of community ownership. However, the participatory dimension of urban energy projects may be undermined by action taken by the state and local government, incentives which may be captured by entrenched political interests and ‘closed’ policy-making practices and processes (Bomberg and McEwen (2012).

Organisations

This is a heterogeneous category comprising various organisations that have been identified as potential partners in managing local or distributed energy governance schemes. These include voluntary and not-for-profit organisations as well as dedicated entities such as Energy service Companies (ESCOS), socially orientated businesses that seek to improve energy efficiency for customers. Most of the experience with ESCOs to date has tended to relate to the commercial and industrial sectors (Vine, 2007, Boardman et al.2005). Both Local Authorities and private companies are also part of this category when they are acting as energy consumers. Commercial firms have a complicated role in changing arrangements for energy provision, as they are both providers and users of energy. Incumbent electricity suppliers, and are in a position where they could block novel innovations. However, these firms do invest in innovation including community-based demonstrations of smart grids and local energy generation schemes. In fact, Hess (2013) points out that over time local and community initiatives are vulnerable to being taken over by firms, due to their ability to invest and develop existing arrangements. In an analysis of the emerging fuel cell industry, Brown et al (2007) identify technology push by large incumbent firms to be the main impetus for innovation supported by government policies. Interactions between energy infrastructures, energy users, energy behaviour, society and cultures all comprise part of change processes (Parag, 2014: 98). Pellegrini-Masini and Leishman (2011) point out that firms’ themselves are customers and users of energy and that the costs of this could encourage them to invest in energy saving measures. The Carbon Trust (2005) identified factors influencing firms’ uptake of energy efficiency measures, including reduced costs, perceived benefits, market alignment which is an outcome of whether or not the firm owns or rents its premises and knowledge about the technical options. However, small companies may not play a role in change through use, as Rothenberg and Becker (2004) note the slow adoption of environmental technologies by SMEs.

Closer identification and analysis of sites of interaction between renewable energy technologies and the established energy generation systems can help to elucidate the factors which shape and form local technology pathways. Here, three cases are briefly introduced which feature end user groups who have different needs and expectations vis-à-vis their national energy infrastructures. These range from industrial users in Germany concerned about the effects of integrating more renewable energy to the national grid, to domestic users in the USA who desire a reliable alternative to grid distribution and domestic users in the UK who have been happy to interconnect to the grid even after installation of home micro-generation systems.

Case 1: Leaving the grid, industrial users, Germany

Germany has a long-standing policy to increase the supply of electricity from renewable sources through grid connection. This aim is particularly influenced by the fact that 70% of energy needs are imported, at a cost of €87 billion in 2012. Germany is the largest importer of Russian gas and that has proved to be an unreliable source. In addition there is a commitment at policy level to foster the 'green economy', which requires expanding exports of green technologies and committing a large investment for these changes. Figures estimated to be approx. €1 trillion over a 20 year period (World Nuclear News, 2013). Part of the current (and unanticipated) problems include the high cost of the subsidies for solar power, which are currently €16 billion per annum encouraging large commercial consumers to find acceptable means to leave the grid to avoid the high cost and fears that industry is subsidising the household consumer. The existing German power infrastructure and transmission grid requires upgrading and modernisation to cope with these increasing flows of electricity generated from renewable source and this has proved much more difficult and complex than was initially assumed. However, the intention to interconnect large sources of electricity generation from intermittent yet renewable sources, particularly from large solar farms is creating instability for the grid.

Industrial users have suggested that even a very low level of interrupted supply will be too unstable for some advanced manufacturing and other industrial needs. Such interruption, however, has a high chance of becoming a standard characteristic of a grid running with a large input from renewable sources Unwittingly, then the government has created an incentive for firms to leave the grid. By developing their own power generation infrastructure firms became eligible for subsidies designed to encourage energy efficiency and also avoid a 22% government levy to fund renewable energy sources. Some firms have already taken a major step and built their own independent on-site source of electricity supply. An article in the Wall Street Journal reported that the high electricity prices, in 2014 resulted in one in every six firms in the country generating its own electricity, a 50% increase on the figure for 2013 (Hromadko, 2014). Different firms have been active in developing their own power generation infrastructure. At one end of the spectrum there is the huge Dow Chemical plant that consumes 1% of the country's electricity and at the other end, small family-owned firms, like Warwick GmbH, an electric bass-guitar manufacturer located near the Czech border. Although some additional energy reforms were passed in 2014 to scale back subsidies and protect domestic customers from increases in their electricity bills, the great bulk of firms will continue to benefit significantly from the exemptions already in place. The growing trend for firms to opt to leave the grid has forced into the open two additional issues that have so far received little attention. The first is that consideration must be made beyond the mere promotion of renewable energy to ensure that it is fit for purpose for the end user. Industrial customers irrespective of size need a cost-effective, secure and reliable source of electricity. New methods need to be found to store large volumes of renewable energy efficiently and to 'level out' the intermittent flows of electricity generated from renewable sources. The second relates to the speed of change that the existing power infrastructure is experiencing. The disruption to the structure is already severe enough to the extent that the country's major utilities firms are struggling to keep up. These issues present the German infrastructure with specific challenges arising from the fact that the country has a leading position in the adoption and integration of renewable into the national grid (ibid.). In 2016 the scale of these problems were acknowledged by the German government who reached an agreement with the 16 federal states to *slow down* the expansion of electricity generated from renewable sources to contain the burgeoning costs and reduce the strain on the electricity grid (Anon, 2016; Zeller, 2016).

Case 2: Leaving the grid, domestic users, USA

Many parts of the USA are reliant on an electricity transmission grid that is over 100 years old, serving 144 million end-use consumers. It has proved to be very vulnerable to increasingly extreme weather, a major cause of power cuts. Over the past 30 years the US has experienced 144 weather-related disasters-total cost in excess of $1 trillion, while throughout the nine years 2003-2012 there were approximately 679 power cuts which affected more than 50000 people caused by extreme weather. These problems have been recognised and it is nationally acknowledged that a multidimensional strategy is necessary to address the problems. This includes improving electricity grid security and investing in grid modernisation, a major task considering the grid connects consumers with 5800 major power plants and includes over 450,000 miles of high-voltage transmission lines. An example of the type of problem faced in the USA is the effect of 'Superstorm Sandy' that hit New Jersey in October 2012. The storm surge of about 4 metres hit NYC causing flooding of between 4-11 feet in Lower Manhattan and led to 72 deaths. The storm caused an estimated $65 billion in damage. Hurricane Irene hit North Carolina in August 2011, affecting Vermont, New Jersey & Massachusetts, where 2.3 million people were mandatorily evacuated with 41 deaths. The cost of this storm was $15.8 billion, and 6.5 million lost access to power (US Department of Energy, 2013).

The response has been a level of grid defection identified in an analysis by Crey and Guccione (2014). At least five forces were identified as driving the increased adoption of off-grid hybrid distributed generation and storage systems:

•Interest in reliability and resilience
•Demand for cleaner energy
•Pursuit of better economics
•Utility and grid frustration
•Regulatory changes

There has been an increase in domestic users responding to these developments through the adoption of a domestic ‘system’ comprising solar panels and battery for energy storage. As the so-called ‘utility in a box’ technology improves this will increase the ability of domestic consumers to become independent from the grid altogether. Hawaii offers some very interesting insights as a state that currently illustrates the scale and scope of the potential disruption for the incumbent utilities. In the past five years the number of domestic solar installations has increased with the amount of net-metered solar capacity, especially on the island of Oahu. The other islands of Maui and Hawaii have experienced similar (but lower) levels of growth than the former. The state faces some of the highest electricity rates anywhere in the country. In Oahu, the amount of rooftop solar now accounts for 12% of the electric utility’s users, the highest penetration level anywhere in the country. On the same island, the average domestic bill for 600 kilowatt hours of electricity only declined by 18% from $217.24 to $177.45 (July 2014-March 2015). For the same amount of energy on the mainland the bill is approximately $72 per month. With so many homeowners going solar, there is a large surplus of solar power being sold back to the local grid. The local utility claimed the problem had become so acute that on the grounds of safety and the stability and reliability of the grid, the approval of new systems came to a crawl. As Cardwell (2015) states:

> ‘In Hawaii, the current battle began in 2013, when Hawaiian Electric started barring installations of residential solar systems in certain areas. It was an abrupt move — a panicked one, critics say — made after the utility became alarmed by the technical and financial challenges of all those homes suddenly making their own electricity.
> The utility wants to cut roughly in half the amount it pays customers for solar electricity they send back to the grid. But after a study showed that with some upgrades the system could handle much more solar than the company had assumed, the state’s public utilities commission

ordered the utility to begin installations or prove why it could not. It was but one sign of the agency's growing impatience with what it considers the utility's failure to adapt its business model to the changing market'.

In Nevada, the threat of disruption posed by solar roof top installations to the grid led to a highly controversial decision by the state's Public Utilities Commission to back the local utility, NV Energy, and protect the status quo by major increases in customers' tariffs. The new tariffs will gradually increase until they triple monthly fees that solar users pay to use the electric grid and cut by three-quarters users' reimbursements for feeding electricity into it**.** In the immediate aftermath the state's solar roof top installation industry has collapsed but what the long-term ramifications will be at both the state and national level is very uncertain (Leslie, 2016). Although this is an example of early use it demonstrates that consumers are ready to become pro-active in accessing new technologies that offer advantages over local infrastructures.

Case 3: Remaining connected to the grid (so far), domestic users, UK

In the UK conditions are different as retaining a connection to the national grid remains the clear choice of most user groups. This can be explained by a number of factors including the wide national coverage afforded by the grid and the competitive system of pricing introduced through privatisation of electricity supply. Also, UK consumers have been relatively slow in adoption of micro-generation technologies, which on a domestic scale are dominated by solar panels. Balcombe et al (2014) estimate that by 2013 there were 20,000 micro-generation installations in the UK, providing around 0.2% of energy used by households. However, those domestic systems that are in place have been encouraged by a positive policy of payment for 'feed-in' to the grid of all surplus electricity they generate. Connection of these small domestic facilities to the grid has been facilitated by supplementary innovations such as interconnectors that can be installed at household level. The immediate 'here and now', impression of the situation in the UK is that the pace of change is much slower than either in Germany or Hawaii. This though may actually be misleading. One analysis highlights the fact that the grid does face major upheaval and the pace of change may be much faster than is generally appreciated as the country gets to grips tackling the challenges of climate change (Carbon Brief, 2015).

One of the trends driving the pace of change is the growth of embedded solar energy systems. Between February 2014-February 2015 capacity almost doubled from 2.4 gigawatts to 4.4 gigawatts. This was in part caused by the decline in prices for modules and also by a rush to install solar farms prior to changes in the subsidy scheme that came into force in April. Although this type of system is not connected to the grid and the National Grid cannot directly monitor the amount of electricity they generate, it shows up indirectly as reduced demand (ibid.). That aside, a much more immediate issue for the National Grid (and policymakers) that has appeared is the looming ‘capacity crunch’, that is, the dwindling generating capacity required to meet demand. As the UK starts to deal with the impact of climate change, the rate at which old fossil-fuel burning power stations are being closed down exceeds the rate at which new capacity is being built and installed based on cleaner and renewable energy. In 2015 the rate of spare capacity in the system had declined to only 1.2%, the lowest level for a decade. Under the circumstances the National Grid was tasked with securing additional capacity and even after it had done this the level of spare capacity had only increased to approximately 5% (Moylan, 2015). Without adequate measure there are major doubts about whether the UK can avoid future blackouts (Critchlow, 2015).

Energy security is not just a national issue; it has been identified as a local one too. There is no better illustration of this than the case of London. Faced with a rising population and one that is projected to continue to grow by a quarter over the next 25 years, the need for a huge rise in house building, and the amount of new office space under construction at a seven-year high, the current electricity grid is already under a very heavy load (Sullivan, 2015). In conjunction with the Mayor of London’s office, the Greater London Authority (GLA) have developed plans to devise ways of not only how to meet electricity demand for the short and long term, but how the grid’s load can be reduced and how electricity can be generated and supplied at the local level. An indication of the challenge ahead for London and the investment required in the energy infrastructure is contained in one analysis with an outlook to 2050. In it an estimated figure of £148 billion is stated based on an assumption that over 50% of London’s energy would be produced locally by the middle of the millennium (Energy for London 2014). However, if the local generation and supply of electricity is going to become widespread then new innovative business models will need to be developed and this is another complex field in itself (Hall and Roelich, 2015). Finally, on top of these developments the grid faces additional changes with the development of the European Supergrid that will link the UK ever closer to Europe through a new series of interconnectors. The current level of disruption the grid is experiencing may prove to be a harbinger for things yet to come.

Discussion

Transition Management comprises a specific approach to understanding ongoing socio-technical change towards sustainability. It focuses on attempts to reform current socio-technical practices through innovation, governance and social engagement. Although sustainable development is a long-term project, TM offers a means of interrogating of current changes that may have an impact on future conditions of environmental sustainability. One issue is related to the reflexive ability of academic analysis to evaluate the management processes as they currently emerge. This sets a challenge in the sense that it is not only difficult to identify if a particular transition path is being described but also to identify which changes will be significant in facilitating future conditions of sustainability. Also, the complexities of concurrent socio-technical interrelations make predicting final outcomes difficult. The question remains whether the key actors can be identified and their potential contributions evaluated? The existing literature on renewable energy does reveal the ways in which different types of actors can interact with the technology. Potential for customers to exert pressure on energy providers as well as active community groups and innovative firms all have the potential to affect the direction of change in transition to a renewable energy regime. However, the three cases considered here, illustrate some of the challenges inherent in this kind of far reaching change. In particular it is clear that attempts at identifying TM processes are constrained by specific contingent conditions at the site of implementation of the new technologies.

What is emerging from this preliminary analysis is the significance of the shaping role that socio-political context can exert on the direction of technological adoption and change. The three countries discussed here all exhibit particular and contingent issues in terms of the way in which renewable energy technologies have become incorporated into grid operations. Variations in useful business models and adoption process respond to particular, national socio-material configurations. This configures distinct national contexts which construct the conditions for technological change. The examples in this article demonstrate how change factors directed towards sustainable development can interact to produce unexpected outcomes. Germany has a longer tradition of renewable energy consumers resulting in its position as a leading technology adopter. However, this analysis highlights how conflicting requirements between user groups has resulted in changes to grid usage. In Germany, the main issues appear to be technical systems issues such as interruption, instability and reliability of supply, financial considerations such as costs and incentives to the consumer; energy and environmental policies; energy security and exports. In the USA there are longstanding concerns related to security and reliability of energy supply, as well as an emphasis on cost effectiveness and modernisation of the existing infrastructure. The age, scope and size of the existing system, its stability and the cost of whole scale modernisation are factors influencing the situation with respect to renewable usage. The energy needs of specific consumer groups and availability of viable alternatives are also contributory issues, as are financial incentives and relevant policies. These are all issues that have resulted in domestic consumers searching elsewhere for their energy supply. In contrast in the UK the relative monopoly of the National Grid still engenders trust through all users groups, as well as political and business support. In the UK at the moment the operation of the grid is not as challenged by the incorporation of renewables into its operation particularly by on site use of technologies such as photovoltaics. However, users have been positively affected both by the availability of grid/domestic interconnecting technologies and financial incentives. However, as the use of domestic renewables is at a much earlier stage that the other two countries, it is probable that more complex issues, particularly concerning the rate and direction of financial investment strategies, will arise in the future. The complementarity between users groups in the three countries and their relation to the specific situations indicates that there are certain limits to the transitions management concept. In the literature it is presented as a means to build socio-technical change pathways by setting the political intention over the longer term. However, in practice the concept could be usefully applied to small-scale analysis, investigating the impact of change at a micro-level bounded both by time and the contingency of wider social context. Issues of technology and market maturity, innovation and engineering practices will have a continual effect on the rate and direction of change.

Conclusion

It is clear that the use and incorporation of renewable energy technologies into national distribution systems is at an early stage in the countries presented in this article. Also, change is as dependent on the types, requirements and strategic behaviour of different types of end user. Different types of end user can have proportionally different influences depending on the local situation. In addition, technical issues and building requirements form some of the multiple requirements that challenge changes to the systems of electricity generation. This analysis demonstrates the difficulties in attempts to identify particular transition paths for sustainable transitions 'in the making' and that decisions made in the light of many conflicting and intersecting factors need clear criteria and strategic positions. In addition, neither unexpected nor unpredictable events that influence the direction of change can be excluded. All three countries are expecting to keep existing infrastructures so more effort will be expected to be put into making these robust enough to accommodate greater use of renewable energy technologies over time. This situation provides some challenges to the transitions management concept in terms of measuring how a country is progressing towards a sustainability transition given the complexity of the processes involved.

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