Understanding Transitions to a Hydrogen Economy(-ies) with and through 'Regions'

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Introduction

The key question we seek to address in this paper is: how can we understand attempts to develop hydrogen economies in three different 'regions' of the UK? We do this by unpacking the sorts of issues we need to consider in moving beyond the techno-economic 'possibilities' of a potential future hydrogen economy(-ies) and to consider the ways in which hydrogen and fuel cell technologies shape the 'regional context' within which attempts are made to embed them but also are shaped, enabled and constrained by such 'contexts'. The power, but partiality and shortcomings, with which accounts of technical and economic possibilities articulate hydrogen futures have been outlined elsewhere (Hodson and Marvin, 2004). Macro level 'visions' of hydrogen futures (see Eames and McDowall, 2004) similarly offer partial and often 'placeless' accounts.

The aim here is to raise a number of ideas and understandings which allow us to think through a series of issues in addressing empirically attempts to develop, 'functionalise' or 'make work' a regional hydrogen economy(-ies). In doing this we address ideas from multi-level technological transitions (TT) literature (e.g. Geels, 2002a, 2002b). This multi-level approach although useful in understanding aspects of technological transitions and regional hydrogen economy(-ies) would benefit from an appreciation of interrelated issues of 'multi-level governance', space, place and also a sensitivity to processes and interactions. All of which relates to how we might understand the, conceptualisation(s), role and significance of the region in hydrogen economy developments.

This is particularly significant in times of increased 'globalisation' and neo-liberalism, where the changing role of the state and issues of 'multi-level govern*ance*' raise a whole series of issues not only about how we might think about the region but also the interrelationships between regions, the local, national and supranational. This inability to specify *apriori* what a region 'is' leads to the questions: when and where are the region? Which provide a basis – through a series of themes related to regional hydrogen economy development, including representations, relationships, interactions and resources - to inform empirical investigation of understanding the unfolding relationships between hydrogen economy(-ies) developments and different regions.

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A Multi-level Perspective on Technological Transitions

Thinking about prospective hydrogen economy(-ies) is about more than technical and economic 'characteristics' and 'possibilities' of individual hydrogen technologies or combinations of such technologies into 'systems' (Hodson and Marvin, 2004). We need to move beyond a hydrogen economy(-ies) at such levels of technical and economic abstraction and think about how the 'possibilities' and 'promises' of a hydrogen economy(-ies), and associated technological innovations, may be understood in relation to existing socio-technical systems and broader social, cultural and political pressures. An interesting way of encompassing some of these issues is through the work of numerous Dutch-based researchers (e.g. Geels, 2002a, 2002b; Kemp, 1994) who have focused on the study of technological transitions – which are defined as 'major technological transformations in the ways societal functions such as transportation, communication, housing, feeding, are fulfilled' (Geels, 2002a, p.1257) - and in particular have highlighted interrelated, 'nested', concepts of landscape, regime and niche.

The levels of landscape, niche and regime 'are not ontological descriptions of reality, but analytical and heuristic concepts to understand the complex dynamics of sociotechnical change' (Geels, 2002a, p.1259). This being the case the concept of landscape is important in seeking to understand the broader 'conditions', 'environment' and 'pressures' for technological change and transition to a hydrogen economy(-ies). The landscape includes 'the large-scale material context of society' such as 'the material and spatial arrangement of cities', political cultures, economic growth, macro economic trends, land use, utility infrastructures and so on (Geels, 2002b, p.369).

The concept of regime relates to incumbent technologies being intertwined within a configuration of institutions, practices, regulations and so on, where configurations impose a logic, regularity and varying degrees of path dependencies on technological change. Regime is defined as: 'the whole complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures' (Hoogma *et al*, 2002, p.19). This emphasis on 'rules' refers 'not just

[to] rules in the form of a set of commands and requirements, but also rules in the sense of roles and established practices that are not easily dissolved' (Hoogma *et al*, 2002, p.19).

The stability and interrelatedness of regimes helps to explain the reason why many 'promising' technologies remain 'unexploited':

> For instance, the new product may require different knowledge and capabilities, new production techniques and skills that may not be available. Their use and development may require complimentary inventions and changes in organisation (in production routines, in plant and factory lay out) plus changes in the institutional context (in regulation, fiscal policies and social norms and values). These are known to come about slowly (Geels, 2002b, p.366).

This focus on embeddedness of transitions to a hydrogen economy(-ies) necessitates taking account of history. Path dependencies and logics of regimes are historically underpinned by circumstances which may have favoured a particular technology over another within specific local contexts. A frequent example is the QWERTY keyboard which in 'no sense is demonstrably optimal', and the rationale for which has become obsolete in the age of electronic keyboards, yet 'the triumph of qwerty has in practice become irreversible' (Mackenzie and Wajcman, 1999, p.20).

The emphasis on regimes highlights the enablement and constraints on new technologies breaking through whereby incremental evolutionary change may be more likely than 'revolutionary' change:

> Such reconfiguration processes do not occur easily, because the elements in a sociotechnical configuration are linked and aligned to each other. Radically new technologies have a hard time to break through, because regulations, infrastructure, user practices, maintenance networks are aligned to the existing technology (Geels, 2002a, p.1258).

That is to say:

> New technological regimes are not created; they evolve through the actions and strategies of many different actors. In this sense, regime-shifts gradually exceed the capability of any single actor to maintain control of the overall process of systemic change (Hoogma *et al*, 2002, p.22).

Regime we may see not only as interrelated in the nested hierarchy but also through patchworks of related regimes (Geels, 2002a, 2002b), including, for example, science regimes, policy regimes, technological and product regimes, etc (Geels, 2004).

The idea of socio-technical niches is of '"protected" spaces in which actors learn in various ways about new technologies and their uses' (Geels, 2002b, p.365), where innovation and processes of learning by trying keep alive novel technological developments which otherwise may be 'unsustainable'. The concept of a niche provides a basis for addressing an appreciation of the circumstances within which we might understand the development of radical innovations where initially 'commercial viability might well be absent. [For example] The first applications of electricity at world fairs, theatres and public events had symbolic value; they brought excitement' (Hoogma *et al*, 2002, p.25). This requires 'special conditions created through subsidies and an alignment between various actors' (Geels, 2002b, p.367). These actors may include various users, producers and political actors, according to Geels.

This necessitates a premise on highlighting the promise and expectations of hitherto 'unproven' technologies where to 'get the new technology on the agenda, actors make promises and raise expectations about new technologies' (Geels, 2002b, p.367) where these promises 'are especially powerful if they are shared, credible (supported by facts and tests), specific (with respect to technological, economic and social aspects), and coupled to certain societal problems which the existing technology is generally not expected to be able to solve' (Geels, 2002b, p.367).

The constitution of networks and the expectations of a technology they present is important in creation of niches where a variety of possible radical innovations are generated. In seeking to go about generating activities in support of these developments niches may be seen as spaces for network development and learning (in some ways) 'protected' from the regime:

> In the niche model, lock-in and path dependency assumptions are relaxed. Various technological options can co-exist over a long period, precisely because of the existence of niches requiring other functionalities…Niches may also persist because actors such as firms and governments act strategically by

keeping certain options alive which might be important for future competition or other broader societal goals (Hoogma *et al*, 2002, p.26).

Frank Geels highlights seven issues to be addressed through niche processes. These include: adjustments to technical and design aspects of a technology; the role of government and in particular in terms of policy in stimulating applications of technology; addressing symbolic aspects and constructing 'meaning' around technology; constructing and shaping markets for technology in relation to consumers; addressing production issues related to who should produce and distribute technology; development and maintenance of associated infrastructures; and what effects does the new technology have on society and the environment? (Geels, 2002b, p.368).

The level of 'protection' of niche from regime is interesting in that 'the emergence of technological regimes does direct research, development, use and regulation in specific directions leading to dominance of specific artefacts' (Hoogma *et al*, 2002, p.26). The emphasis in Geels' work is on focusing on the regime in terms of transitions and incremental developments, more so than earlier work focusing on radical innovations by Kemp (1994). Technological transitions are premised not on radical regime shifts but through 'stepwise process of reconfiguration' (Geels, 2002a, p.1272).

Regime shifts may take place over a considerable period of time and be informed by tensions in the regime, similar to Thomas Hughes' (1987) notion of the reverse salient, or through landscape pressures. Geels (2002a, p.1262) points out that TT involves the linking of 'multiple technologies' and that the use and development of innovations in different domains and contexts see a cumulation of niches – an important mechanism in gradual regime shift. Early linkages between niche and regime may rely on 'link up with established technologies, often to solve particular bottlenecks' (Geels, 2002a, p.1271). There is an important focus on ideas of technological add-on and hybridisation where existing and new technologies 'form some sort of symbiosis' (Geels, 2002a, p.1271).

What can Technological Transitions Tell us about Regional Hydrogen Economy Development?

The TT approach highlights the importance of the nested interrelationships of wider landscape 'environments', the stability and interrelationships of regimes and the innovative possibilities of niches. It outlines a way of thinking about the relationships, resources and practices, including technologies, institutions, skills, etc, which sustain existing configurations and regimes but also addresses processes of adapting and evolving such a regime in respect of 'pressures' for, and contexts of, new technological possibilities and innovations through processes of branching, add-on and hybridisation.

Geels (2002a, p.1273) points out that regimes are 'a broad unit of analysis'. In terms of a potential hydrogen economy(-ies) development we can situate this in relation to an incumbent national carbon-based regime which we may see as constituted by a patchwork of, for example, industrial regimes, transportation regimes and so on. The relatively homogenous nation-state as 'imagined community', however, outlined by Benedict Anderson (1991), is being undermined by the 'imagined economies of globalisation' (Cameron and Palan, 2004). How do these landscape changes which link a 'trifurcated' state – of 'offshore' 'space of flows' (Castells, 2000); increasingly 'private' institutional arrangements and processes as adaptable to, and informing of, the offshore; and the 'anti-economy', 'a space of "exclusion" lying beyond the norms and practices of the emergent global order' (Cameron and Palan, 2004, p. 17) – frame and inform contexts, processes and practices of regional hydrogen economy development? The changing landscape of international political economy over the last three or so decades, and 're-emergence' of the region, requires that we address the complexity of political and policy involvement in technological transitions not just at the national level but through taking account of the interplay and 'relevance' of a variety of levels of scale. How are hydrogen economy(-ies) developments in various regions – for example, in the world-city region of London (Eade, 2000), the 'less favoured region' of Wales (see Morgan and Nauwelaers, 2003) and the post-industrial sub-region of Tees Valley (Tees Valley Partnership, 2004/5) - represented and how is meaning produced? What is distinctive? What is similar? This, potential for variability, suggests that Geels' approach requires further reference to notions of 'space' and 'place'.

Geels also points out a key role for government particularly in terms of utilising policy to stimulate technological applications. This understanding needs to be fleshed out through addressing the complex and unstable ways in which regional representations are informed by various aspirations and policies produced both with and through technologies but also through network governance relationships which move 'within' and 'beyond' the region. That is to say that the idea of hydrogen *economy* development, moving beyond narrowly technological and economistic definitions, needs to encompass entangled relations of governance – a broad and often vaguely defined term but where: 'governance of and in modern societies is a mix of all kinds of governing efforts by all manner of social-political actors, public as well as private; occurring between them at different levels, in different governance modes and orders' (Kooiman, 2003, p.3).

This, then, relates the production and construction of representation and meaning to particular spaces and places in which governance interactions occur and through which the interpretative flexibility (Bijker *et al*, 1987) of a future hydrogen economy frames and mediates such interactions in 'niches'. Meaning is, thus, not produced around the hydrogen technology as a narrowly conceived technological and economic focus but is entangled within and produced through a range of institutional and individual aspirations and negotiations at a variety of scales.

Interesting, here is to translate ideas of regimes as contexts of relative stability and niches as contexts of potential innovation in relation to networks of place and space – 'local' and 'regional' networks of co-presence and networks 'at a distance'. To what extent and in what ways are 'regional' aspirations and policies (including 'sub-regional' and 'local' involving politicians, industrialists, etc) informed by but also informing of 'national' and 'international' aspirations and policies? This relates to the development of particular novel regional hydrogen economy niches which have as a backdrop not only 'global' landscape pressures for 'competitive', 'entrepreneurial' and 'technological innovation' but also ambiguity about which regime, within the patchwork of carbon regimes, may be experiencing a bottleneck in the context of regional aspirations – policy, industrial, energy, regeneration?

This ambiguity raises serious issues about the regime context (e.g. policy, industrial, consumption, energy) from which niche network members bring their aspirations and expectations of the regional hydrogen economy and how it informs such developments. That is, networks constituting niches, through the frame and interpretative flexibility of the hydrogen economy(-ies), may draw institutions and individuals from various regimes with the possibilities and potential (though not necessarily) for entrepreneurial and innovative niche construction. These messy and unstable processes through which various vested interests differentially influence niche development is an acknowledgement that 'because socio-technical regimes are a broad unit of analysis it is difficult to draw precise boundaries. Such boundary work deserves more attention in the future' (Geels, 2002a, p.1273), as does another issue about which little is said, this being 'about (the interactions between) actors' (Geels, 2002a, p.1273).

This is particularly pertinent in terms of producing 'meaning' around hydrogen technologies in 'competitive' times in which 'image' is crucial to the 'success' of places (Allen *et al*, 1998). Following the TT perspective: what promises and expectations are made about regional hydrogen economy developments? How do these manifest themselves in particular representations? How can we understand the network processes and negotiations that produce these representations?

It is useful here to move beyond the 'evolutionary' focus of TT to view the cultivation of networks producing 'images' and representations in niches not solely as an actor-network (that is as a theory of agency) but in terms of the differential and structured 'relevant' resources which institutions and individuals may bring to the network often from different regime settings. The symbolic meaning of hydrogen technological transitions may be 'socially constructed' but on the basis of differentially positioned institutions' and individuals' potential to inform such processes. Technological transitions are not necessarily about 'problem solving' and 'evolution' but are related to the different roles of actors and institutions and their (in-)capability to shape differentially, reflexively and in relation to resources, regional technological innovation.

This analysis may be extended to the 'consequences' of attempts to develop regional hydrogen infrastructures, particularly where one examines the relationships between attempts to re-embed hydrogen and fuel cell technologies in 'unfamiliar' contexts and the lessons which may be learned. The representation of regional hydrogen economy(-ies) development presents a narrative framing the building of a regional hydrogen economy(-ies). These representations mediate interactions locally and 'at a distance' in the process of producing a regional hydrogen economy(-ies). The interesting issue is to understand the relationship and the 'gap' between representation and performance and if this differs and is similar in various regional contexts.

The remainder of this paper fleshes out these issues – the importance of the 're-emergence' of regions and the relationship to issues of technology and governance; regional representations and issues of context; and the performance of regional hydrogen economies, through infrastructure development – in relation to regional hydrogen economy(-ies) development through drawing on literatures which provide a basis for subsequent empirical interrogation.

'Globalisation', Governance and Technology: the 'Re-emergence' of the Region
Informing these issues is the notion of landscape and how it helps us thing about why the region is a fruitful focus for the study of developing hydrogen economy(-ies). A focus on landscape issues leads us to suggest that processes of hydrogen economy(-ies) development are informed by reference to wider social, political and economic changes to which we adapt. To paraphrase Karl Marx (1963 [1852]), human beings make history but not in circumstances of their own choosing. In terms of an emerging hydrogen economy(-ies) this leads us to address how we might flesh out the notion of landscape.

In many areas of literature related to the 'pressures' for developing a hydrogen economy(-ies) aspects of geopolitics, with differing geographical emphases, have been highlighted, including the idea that movement towards a hydrogen economy(-ies) may address issues related to reducing carbon dioxide emissions and security of energy supply particularly in relation to future scarcity, volatile prices and international 'terrorism' (e.g. Rifkin, 2002).

Changes in the international economy, through the reconfiguration of national and international financial and political institutions and architectures (a change in the relationships between regimes of accumulation and modes of regulation, see Aglietta, 1979) over the last three or so decades highlight neo-liberal pressures for increased 'competitiveness', 'entrepreneurialism' and 'innovation', particularly technological innovation in an increasingly, if unevenly, 'globalised' world.

Whilst 'there is scant evidence in the existing literature to specify what is "global" about globalization' (Held *et al*, 1999, p.15) we are seeing the 'stretching' of social relations across regions of the world, which become more 'regularised', 'intensified', 'speeded-up', 'extensive', 'intensive' and exhibit a greater 'velocity' in terms of interactions and flows of goods, services, ideas, capital and people (Held *et al*, 1999, p.15). These flows in relation to their velocity and issues of 'competition', 'innovation' and 'entrepreneurialism' inform a tension between flows and the territories within which they are embedded. Of importance here are not just the 'concrete' practices and processes of 'globalisation' but the stories and narratives which are told about 'it'. Globalisation is 'a *mediated* concept – what we know about globalisation comes to us through the filter of theories and images that prescribe both its form and consequences and our responses to them' (Cameron and Palan, 2004, p.3, original emphasis). This is particularly important in relation to regional responses as the 'imagined community' of the nation-state (Anderson, 1991):

> is very rapidly giving way to a series of imagined *economies* which maintain the fiction of the state – and indeed perpetuate it as a legal entity – but situate within a radically different set of boundaries and notions of social space. So the state continues to play an important role: but it is a very different state. The transformation of the state takes place through the deterritorialization and denationalisation of myths of identity and belonging particular to the nation-state of the nineteenth and twentieth centuries, which in turn necessarily imply a radical recasting of the spaces of the political (Cameron and Palan, 2004, p.8).

This raises issues related to governance and technology in developing a hydrogen economy(-ies). In particular, the changing role of the nation-state is important, where we are seeing a shift from the Keynesian Welfare National State (KWNS) to a Schumpeterian Competition State (SCS) (Jessop, 2002; 1994). The SCS, importantly, has a 'concern with technological change, innovation and enterprise and its attempt to

develop new techniques of government and governance to these ends' (Jessop, 2002, p.96, emphasis added).

A key facet of the SCS, amongst others, is in promoting 'national or regional capitalisms and appropriate conditions for their global spread' (Jessop, 2002, p.138). Jessop does not talk of the 'end of the nation-state' (Ohmae, 1996) but of its 'hollowing out'; by which he means a re-orientation in the functions of the state and the shifting of some tasks to both the supranational level and to the local. In particular, the shifting of functions down to the local may see new local partnerships formed – Jessop calls this a shift from local government to local governance. Regeneration of local economies may become the task of partnerships of local chambers of commerce, local venture capital, local education bodies, local research centres and local states (Jessop, 1994, p.272).

Thus configurations of institutions of governance create and respond to increasing international economic competitiveness through encouraging (particularly technological) innovation. Importantly technological change is both a product of, and produces political pressures for, institutional change. Although the nation-state is still important so also, increasingly, are various other levels and scales of governance which are related often in complex and different ways in various contexts. This brings the suggestion that: 'contemporary urban regions must be conceived as pre-eminently "glocal" spaces in which multiple geographical scales intersect in potentially highly conflictual ways' (Brenner, 1999, p.438). In particular: 'In major urban regions throughout the EU, regionally scaled regulatory institutions are being planned promoted and constructed as a means to secure place-specific locational advantages against' (Brenner, 1999, p.440). The key point here being: 'that new geographies of urban governance are currently crystallising at the multi-scalar interface between processes of urban restructuring and state territorial restructuring' (Brenner, 1999, p.443).

Understanding responses to such pressures requires asking how we might think about regions and urban regional restructuring, here through the idea of a hydrogen economy, with and through relations of networks of governance and their manifestation in representations of regions.

Imagining the Region: Regional Representation and Issues of Context

The development of a nascent hydrogen economy(-ies) in niches offers a means of framing the reconfiguration of regional identities through unfolding and re-shaping governance networks. That is not to say the region should be seen as homogenised in this identity construction as the 'discontinuous region…is comprised of places of internal variability, unboundedness and porosity' (Allen *et al*, 1998, p.89). The point here is that in contemporary neo-liberal circumstances:

> …"image" becomes of salient significance. A setting of "success" can be a vital part of a company's location decision…It can mean paying attention to local setting and architectural design. And it can mean – and this is the important point here avoiding the like the plague anything which might give off an image of decline. What we begin to see here, then, are some of the differentiations – local and quite precise, but very effective – in the social conditions necessary for recent forms of economic governance (Allen *et al*, 1998, p.72).

Pressures for economic and technological changes and activity inform the re-articulation of places through a series of relationships of institutions and individuals but which are predicated on history, and prior trajectories and which rely on processes of adaptability and reflexive individuals and institutions. In this respect territorial regions' economic 'competitiveness' is linked to their capability to adapt and transform identities through reconfiguring and adjusting regional institutions of governance to economic change. In relation to this: 'We need to understand how regions have become active players in the process of transformation' (Herrschel and Newman, 2002, p.13). The interesting issue is how this happens in specific regions in relation to the dynamic and complex rescaling of institutions of governance. In addition to this regional identities are relational not only 'within' the region but also in respect of relationships to other territories within a 'global' space of flows (Castells, 2000).

This, then, is to highlight a 'contrast between the notion of regions as territorial containers of policies with a traditional emphasis on fixed and clear territorial

boundaries, and more dynamic, social spaces' (Herrschel and Newman, 2002, p.22). To do this is to address 'a "region" in terms of social relations stretched out reveals, not an "area", but a complex and unbounded lattice of articulations with internal relations of power and inequality and punctured by structural exclusions' (Allen *et al*, 1998, p.65).

This fluidity highlights that:

> It is a characteristic of the region to have neither a definition nor an outline. The empirical criteria which allow the socio-economic entity to be recognised as sufficiently homogenized and distinct, are vague and mixed (Smouts, 1998, p.30).

In such processes of recognition, an issue is how we understand 'multilevel governance' in regional development of a hydrogen economy(-ies). Without *apriori* definitions, '"regions" or more generally "places" or localities can only be defined for specific purposes, as a result of the posing of specific questions' (Allen *et al*, 1998, p.34). This means we must ask not what is a region but when and where is it? (see Allen *et al*, 1998). In doing this in relation to the development of a hydrogen economy(-ies) in specific territories we need to outline specific representations of regions and interrogate the ways in which unfolding institutional arrangements shape the development of a hydrogen economy(-ies) and vice versa.

A key idea here is 'embeddedness' – which to an extent 'remains a vague and undeveloped notion' (Oinas, 1997 quoted in Hayter, 2004, p.99) – but which permits us to move beyond economistic analyses of regional renewal and development and to acknowledge that 'economic processes are socialized (and politicised)' (Hayter, 2004, p.107). There is a 'necessary embeddedness of a market logic within a whole set of values, legal frameworks, and nonmarket institutions' (Boyer and Hollingsworth, 1997, p.434). This embeddedness is in institutions that are both economic and importantly non-economic - for example institutions of government and governance. The key point being that economic activity is not left to the market but is the product of a complex co-ordination of institutional mechanisms (Hollingsworth and Boyer, 1997).

Much recent attention to the development of partnerships, networks and integration of regional interests and institutions has been as a basis for the possibilities for mutual learning, 'reflexivity' and innovation as a means of addressing regional economic renewal. This has been grouped together under the rubric of 'new regionalism' (Lovering, 1999). Such a focus allows us to link networks to place, through thinking about regional institutional development in relation to political mobilisation and exclusion (Paasi, 2003) and also via the notion of path dependencies and institutional lock-in which situates institutional inter-relations historically in relation to place. Although these issues of network development are crucial, as we have already highlighted, they should not be seen as a distinct endogenous regional focus divorced from the 'global'. This highlights that: 'much new regionalist thinking has paid insufficient analytical observance to the intricate social relations and interconnecting properties that may exist between the recent regional renaissance and the restructuring of the state' (MacLeod, 2000, p.4 [online version]). It also suggests that:

> Within regions, populations in their various circumstances make choices and create institutions to absorb, adapt, fight and reject globally instituted processes. Simultaneously, these local choices contribute to global processes that have impacts elsewhere (Hayter, 2004, p.108).

With this in mind:

> "Regional identity" is, in a way, an interpretation of the process through which a region becomes institutionalised, a process consisting of the production of territorial boundaries, symbolism and institutions. This process concomitantly gives rise to, and is conditioned by, the discourses/practices/rituals that draw on boundaries, symbols and institutional practices (Paasi, 2003, p.478).

This raises an interesting distinction between regional identity and identity of a region (Paasi, 2003). The importance here being that regional identity, or regional consciousness 'points to the multiscalar identification of people with those institutional practices, discourses and symbolisms that are expressive of the "structures of expectations" that become institutionalised as parts of the process we call a "region"' (Paasi, 2003, p.478); whilst identity of a region 'points to those features of nature, culture and people that are *used* in the discourses and classifications of science, politics, cultural activism, regional marketing, governance

and political or religious regionalization to distinguish one region from others' (Paasi, 2003, p.478, original emphasis).

This focus on producing regional distinction has led to an emphasis on sectoral specialisations and the development of 'clusters' which attempt to situate regional renewal in relation to the production of tacit know-how in adapting sectors of historical regional importance. There is a vast literature on clusters, both prescriptive and analytical, employing a range of methodologies (see Wolfe and Gertler, 2004).

This necessitates acknowledging the role of path dependency and existing institutions in shaping economic development trajectories, or stability, and new partnerships and networks as potentially circumventing them. This relates to the notion that the 'current phase of global economic development seems to demand reflexive actors in both public and private sectors who can ensure supportive institutional environments' (Herrschel and Newman, 2002, p.19). We should be careful not to overplay co-operation and mutual benefits as: 'Some networks and some network members are more powerful than others, and underlying power relationships need to be exposed in addition to just mapping interconnecting networks' (Herrschel and Newman, 2002, p.29).

This necessitates addressing the role of institutions, individuals and networks of governance in adapting to and/or shaping a regional hydrogen economy(-ies). If, as the niche literature suggests, network-building is important in technological transitions how do we understand this 'within' and 'without' the territorial region? To what extent are 'traditional' institutions of local and regional decision-making adapted or circumvented as 'entrepreneurial' responses to the perceived possibilities of hydrogen technologies?

Understanding these relationships may be pertinent if we think in terms of the path dependencies, historically, of industrial and governance 'regimes' – for example embedded in Teesside and south Wales – or the 'world city' status of London. This links the formation of 'regional' networks, central to niche hydrogen economy(-ies) developments, to historical aspects of the territorial region within which material

developments are taking place. This view situates technological innovation within (contested) historical negotiations of territorial regional identities.

That these negotiations are contested suggests that more 'collective' understandings of regional identity are not necessarily the consequence of consensus but the outcome of unfolding manoeuvrings and positionings within networks which inform the particular development not only of a regional hydrogen economy(-ies) but also the ways in which this is represented to 'others' in the search for 'regional success'.

The Performance of Regional Hydrogen Economies – Understanding Infrastructure Development

It is important to outline not only how we think about regional representations but also the ways in which these stories and representations inform the performance and practice of regional hydrogen economies, including the ways in which these representations mediate a series of network relationships of proximity 'within' the territorial region but are also an important means of 'connecting' and mediating relationships beyond the territorial region to national and supranational level bodies and departments.

Understanding the development of a regional hydrogen economy should be seen not only as a technical issue, in terms of design and technical adjustments, but as a space for engaging in learning not only about aspects of a future hydrogen economy(-ies) but reflecting on the possibilities of hydrogen technologies, the historical identities of the region and the resources and relationships which may be cultivated in reshaping and mediating aspects of regional identities through transition to a hydrogen economy.

Interesting here is the relationship between hydrogen technologies and the 'context' of use, in particular through the development of demonstration projects. It is useful to make the distinction between 'generic' and 'configurational' technologies. The design and development of a 'generic' technology occurs where 'all possible user requirements and information about the circumstances of use, are largely anticipated in the design of the system prior to first adoption' (McLoughlin, 1999, p.132). The implicit suggestion is that there is little interpretative flexibility (Bijker *et al*, 1987).

By contrast, configurational technologies 'are largely shaped in each application by user requirements and the specifics of the circumstances in which they are to be used' (McLoughlin, 1999, p.133). Where hydrogen technologies are developed in regional contexts there may be some degree of interpretative flexibility in use. Important here is the notion of enrolling various individuals and institutions, drawing on numerous forms of resources, and artefacts into networks on the basis of negotiated aspirations, expectations and understandings revolving around interpretations of the regional representation. Our focus needs to be on providing a basis for understanding processes of innovation, drawing on hydrogen technologies as configurational technologies open to interpretative flexibility, within different regional contexts.

At this point James Fleck's (1999) notion of 'innofusion' offers an interesting means of understanding re-shaping and re-innovation of hydrogen technologies in territorial contexts. Given the mutuality of the regional context and hydrogen technologies for subsequent transformation, but also variable degrees of uncertainty in 'how to go about' such a process, focus is on the relationships, roles, resources and knowledges drawn upon in such an unfolding process. 'Where [in this instance partial 'regional'] requirements are uncertain, their clarification and identification may well lead to an important advance in terms of what the technology can be used to do' (Fleck, 1999, p.246). This is the negotiation between the 'possibilities' of hydrogen technologies, the various forms of 'local' knowledge in getting these technologies 'to work' in territorial context and the more general (codifiable) lessons that are learned.

Of importance for Fleck is the meeting of generic technology knowledge and local knowledge which may be deep rooted and developed in organisational and institutional practices over time. Fleck suggests that the key relationship is between those in the local context and generic technology suppliers (or their proxies). The more implicated in the 'implementation' process that generic technology suppliers become the more likely that the generic technology knowledge wins out over local knowledge, as through the unfolding process generic knowledge and innovations are fed back into subsequent technological developments. This way of thinking, and the negotiation and interaction of different forms of knowledge, allows us to view

infrastructure development in terms not only of novelty but also in relation to potential hybridisation and technological add-on.

Processes of regional hydrogen economy(-ies) innovation are, therefore, culturally negotiated and open to interpretative flexibility. The issue is how certain configurations win out in the vast array of innovative possibilities. The key is how heterogeneous socio-technical networks come to be 'assembled' (Law, 1992). How are otherwise diverse sets of interest and actors 'aligned' within such networks? This, in many ways, is linked to processes of 'translation' (Callon, 1986) where various actors' interests are brought into line or accordance with those of key actors. The process of ensuring enrolment to address network problems may require further enrolment which may be either human or non-human. This use of 'translation' does not imply a fullscale acceptance of all the tenets of this particular variant of actor-network theory. In particular we would reject the view that does not take account of the sometimes direct ways in which macro-level structures shape and impinge on micro 'contexts' and the differential positionings, manoeuvrings and possibilities of individuals and institutions. The use of this is in allowing the utilisation of the ideas of enrolment and alignment in assembly. This addition of, for example a new politician, a consultant or a technological artefact, whilst designed to address an existing problem may create unforeseen consequences and hence shifting alliances. The development of innovative networks in this sense is a negotiation, an achievement, and is ongoing.

In its movement between the local context and a more general context of technological suppliers and knowledge of hydrogen technologies, there remain issues of how we might understand how different forms of knowledge and expertise *interact* and the key users and roles within such processes. It relates to the ways in which regional institutions and individuals respond and adapt to not only pressures to develop a hydrogen economy capability but in terms of how they 'get it to work' in context and in unfolding processes of uncertainty.

Given such uncertainty and the consequent contestation as to how to go about regional hydrogen economy development, in pursuit of different interpretations of the regional representation and who should be involved in such a process, it serves us

well to remember that 'the construction of expertise and relations between experts and non-experts is profoundly political' (Faulkner *et al*, 1998, p.7). This addresses issues about why 'some occupational groups are more effective than others in claiming expert status for their knowledge and skills. This raises questions about who gets to be seen as skilled or expert' (Faulkner *et al*, 1998, p.7).

Innovation underpinned by uncertainty is reliant on knowledge from sources 'internal' and 'external' to territorial regions (Faulkner, 1998, p.173). The pursuit of innovation, or more appropriately innofusion, relies on numerous different forms of knowledge. It is important not only to understand the forms of such knowledges, but also processes of knowledge creation/acquisition, communication/circulation, and also the implications of such in interplay. In this respect James Fleck (1997, pp.153) highlights six 'components' of knowledge. *Formal knowledge* is knowledge embodied in codified theories and which is often available in written or diagrammatic form through formal education. *Instrumentalities* refers to knowledge embodied in tool use and links with other forms of knowledge for 'effective mobilisation'. This form of knowledge is learnt through processes of demonstration and practice. *Informal knowledge*, which Fleck characterises as 'rules of thumb' or 'tricks of the trade' are embodied in verbal interactions with regard to a specific environment within which such knowledge may be learnt. *Contingent knowledge* is knowledge embodied in a specific context, often 'apparently trivial information' which can be acquired through 'on the spot learning'. *Tacit knowledge* is embodied in people and is related to 'practice and experience' and is 'transmitted by apprenticeship and training'. Finally, *meta-knowledge* is embodied in an organisation. Such knowledge relates to 'general cultural and philosophical assumptions' including values and goals. Fleck suggests some of these are specific to individual organisations whilst others to wider society.

Summary

This paper has addressed the issue of technological transitions in relation to regional hydrogen economy(-ies) developments. It took an important way of understanding such transitions, the multi-level TT transitions approach, and through highlighting the heuristic importance of this approach but also some shortcomings in relation to

regional hydrogen economy development cultivated a series of themes to interrogate regional hydrogen economy(-ies) development.

This was done through first situating the 're-emergence' of regions in the context of changing relations of international political economy, an emphasis on technologies and technological development in contemporary economic life and the importance of a politics of scale where negotiations of levels of governance inform and are informed by regional development. This in turn was related to the importance in contemporary neo-liberalism of images of 'success' and the ways in which regions are represented, imagined and 're-branded'. The power of this is in legitimising a particular but partial view of regional futures with and through technologies. This, then, frames and informs, but does not determine, the performance of regional hydrogen economies and attempts to develop infrastructures. The interesting issues relate to the power of representations, how these inform performance and practice, and the 'gap' between representations and performance of regional hydrogen economies. It is key to look at this individually in terms of regional development but also by looking across different attempts to develop regional hydrogen economies. The ideas presented in this paper offer a basis for doing so.

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