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

[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).

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

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 economic 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 think 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 le

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

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

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 economic 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.

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' (see 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

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' (Herschel 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' (Herschel 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.

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

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

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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