Green Innovation and Policy: a Co-Evolutionary Approach

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Abstract

This paper seeks to analyse the role of institutions and entrepreneurship in the field of green innovation in Wales. Green innovation can be defined as innovations in environmentally responsible products and services that are both sustainable and contribute to reducing the impact of greenhouse gases (GHG) upon the environment. The paper adopts a standard co-evolutionary perspective that will take into account differences in the history of firms and institutions in the emerging renewable energy sector. However, the paper finds soime problems with the standard theoretical accounts in the literature.. Here, and based on case study analysis, the paper investigates the extent to which technologies and institutions can be seen as co-evolving systems and the degree to which co-evolutionary thinking and its elements are present in government policy for green innovation. The test is applied in the mainly rural regions of Wales where green innovation is pronounced.

Key words: system innovation, institutions, co-evolution, renewable energy

Introduction

As the most recent policy documents at international, national and regional levels stress, there is incontrovertible evidence that climate change – caused by greenhouse gas emissions producing or at least contributing in major ways to global warming- is an issue that must be tackled if planetary environmental conditions are not to be further jeopardised. Although the environmental performance of the energy sector has improved over the past 30 years (e.g. reduction of SO2, NOx and particle materials), policy makers as well as other actors in society increasingly acknowledge the limitations of end-of-pipe solutions and the need for more structural change. Such change is aimed at placing the energy sector, as many other sectors in contemporary societies, in confrontation with serious structural issues.

In the UK, for example, as stressed in the Stern Review of the *Economics of Climate Change* (2006), experts agree that the opportunities offered for the deployment of relatively affordable renewable energy solutions to tackle global warming exist. Moreover, the rise from a low base of renewable energy innovation, notably in biofuels, biomass power, wind, marine and solar energy, and, particularly, photovoltaics, is welcomed. Nevertheless, attention needs to be given to current driving forces, obstacles and policy challenges to the diffusion of green innovation and the shift to low carbon economies. The challenge is directly and indirectly to address such *tranformation* which involves changes in a variety of elements, including technology, regulation, user practices and markets, cultural meaning and infrastructure (Elzen et al., 2004). These types of meta-changes are referred to as 'transitions' or 'system innovations' (Kemp & Rotmans, 2005). Adopting a co-evolutionary perspective, the aim here is twofold. Firstly, the paper analyses the role of institutions and entrepreneurship in the field of green innovation, defined as innovations that aim, first, to mitigate environmental damage from waste and resource over-exploitation, second, to moderate human contributions to climate change and, third, to manage the transition from fossil fuel to renewable energy. Such change thus has product, process and organizational innovation dimensions. The paper draws attention to the rise of various agro-food influenced biofuels and bio-materials innovations and activities by entrepreneurs in rural Wales.

Secondly, the paper adopts a co-evolutionary analysis of environmental policy and transition management with a special focus on the example of renewable energy provision, drawing from research recently undertaken in Wales focusing specifically upon current case studies. The authors investigate the extent to which technologies and institutions can be seen as co-evolving sub-systems and the degree to which co-evolutionary thinking and its elements are present in government policy for green innovation in Wales.

The paper starts with an overview of the theoretical perspective adopted, moving to the empirical discussion of green innovation. It follows this with a review of the policy arena in the green innovation field and conclusions are drawn on the extent to which the governmental and governance set-ups show capability to strengthen the connectivity between different elements of the regional green innovation system and on whether more needs to be done governmentally to encourage long-term thinking to create and develop niches. Stimulating the possibility of key innovations is important if any government, but especially hydrocarbons-rich Wales seeks to overcome possible economic lock-ins to the present hydrocarbons regime and promote technological diversity towards green innovation.

Theoretical perspective: innovation research, environmental innovation and co-evolution

This paper seeks to bring together elements of innovation research, environmental economics and policy analysis. Traditional neoclassical economics concepts of rationality, efficiency and optimisation are considered unsuitable given the systemic nature of technological innovation (Kemp, 1997) and the themes of systems and adaptability are recurrently adopted to facilitate more pertinent innovation research. These concepts arise naturally in evolutionary approaches and evolutionary economic thinking is considered the most valuable theoretical framework which can offer a better understanding of the possibilities and limitations associated with the shaping, the evolution and the transformation of innovation systems. Innovation systems (Lundvall, 1992, Freeman, 1987, Nelson, 1993, Braczyk et al. 1997, Edquist, 1997 Breschi and Malerba, 1997) involve a combination of technological, organisational and institutional novelties and the involvement of a multitude of actors at different scales (national, regional, local and sectoral). Innovation systems are therefore seen as part of broader socio-economic processes and, as argued by Foxon (2006), evolutionary economics offers a bridge to the social shaping of the technology approach. The seminal work undertaken by Nelson and collaborating scholars (2002 and 2001) confirms this, as they highlighted how institutions can be seen as ‘social technologies’ that evolve in the context of a range of factors, including organisational and governance structures and the broad systems of norms, beliefs and rules of the game that constitute the institutional environment in innovation.

With respect to the relationship between innovation and environment, Green (2005) argued that researchers have concentrated on a few key issues such as ‘green(er)’innovations in either products or processes drawing attention to the importance of environmental regulation to nurture innovation. More recently, however, according to Green there has been a shift towards thinking about innovation for sustainability, rather than just for the more limited aims of reduction of ecological impacts of existing products and processes, having significant implications for policy. This still leaves the issue of green innovation against climate change an open one.

Thus the pressure posed by climate change emphasises a structural weakness of the more traditional sustainability discourse as it is possible to construct an argument for sustainable utilisation of, for example, fossil fuels so they are available for future generations to use, whereas this is not possible from a climate change perspective. This is clearly because their exploitation is seen as the cause of the potential destruction of the earth’s atmosphere. Cohen et al., (1998) explore the differential theoretical and practical implications of these two perspectives. They note the early contrast between the hard natural science discourse and research culture associated with Climate Change work and the more human-centred, normative, politically and geographically sensitive discourse of Sustainable Development. They conclude the relative absence of overlapping discourses arose from the latter’s analytical vagueness and the former’s reductionism, prioritisation of environmental over societal concerns and rational-technical instrumentalism. While this may be a reasonable representation of the position ten years ago, it is less representative of the contemporary position. This may be characterised as the predominance of the Climate Change discourse, now increasingly animating social scientific and political interests, while encompassing many Sustainable Development concerns.

This moves us forward by injecting rigour into the manner in which ‘development’ has to be re-invented (e.g. removal of hydrocarbons from production and consumption; see Tukker et al., 2008). Much of the newer social scientific discourse on environmental issues is governed by a Climate Change perspective, and one that moreover questions the adequacy of long-term technological change concepts and analytical instruments as never before (see Geels, 2006; Smith 2006). At issue here is the question of which social scientific theoretical perspective is best at capturing the long-term implications of a global response to Climate Change? Smith and Geels as well as Tukker and colleagues (see also Weber & Hemmelskamp, 2005) hint at the need for a broader conception of the implications of policy intended to mitigate increases in global warming. That is, an established discourse of technological regimes (Dosi, 1982; Freeman & Perez, 1988) that explains economic change in terms of disequilibria forced by the evolving replacement of one technological regime by another, in a Schumpeterian (1975) process of 'creative destruction,' seems to work well in relation to 'long waves' of development (Manning, 2004)[1]. Moreover, one of the fundamental relationships underpinning the transformation of innovation systems towards sustainability and climate change, according to Saviotti (2005), has to be found in the co-evolution of technologies and institutions and the extent to which there is scope for introducing innovation by means of suggesting 'appropriate' institutional and policy changes.

Co-evolutionary thinking offers a dynamic multi-level perspective on system innovation[2] and, although originated from the synthesis of ecology and evolutionary biology, it has found applications in a variety of disciplines; among these evolutionary economics and innovation studies (Geels 2006), offering an insight into the complexity of evolutionary systems: each sub-system poses its own variation, innovations, and selection pressure but also interaction takes place between these subsystems (Van der Berg et al., 2007). Norgaard (1984a; 1984b) was one of the first to suggest that the idea of co-evolution could be usefully applied to socio-economic systems due to the evident limits of the neoclassical market model in explaining environmental problems and implied that co-evolution explains the joint and interactive evolution of nature, economy, technology, norms, policy and other institutional structures.

Co-evolution, in innovation research, also implies that technological and sectoral complementarities (as well as a diversity of complementary technologies) play an underlying role (Van der Berg, et al. (2007) and highlights the role that policy can play in stimulating them. By combining elements of innovation research, environmental economics and policy analysis a new applied perspective has emerged in energy-related Climate Change consciousness and, subsequently new policy models like transition management and time strategies for policy actions have been developed that strongly influence current debates about policy for innovation and the environment (Weber and Hemmelskamp, 2005). The notion of transition originated in population dynamics and is used by Kemp and Rotmans (2005) to highlight the social transition to a gradual and ongoing process of social change, leading to structural changes in society; it is used to refer to system innovation that goes beyond technological change. It follows that the transition policy approach is thus much broader than traditional policy approaches in the fields of environment, energy and technology, encompassing elements of all these policy fields, involving technology policy, development of knowledge at individual and public levels, behavioural change and alterations in organisations (including networks) as well as institutions (including markets) (Rotmans et al, 2001). It follows that policies and governments can try to influence or even mould transitions in systems of innovation (van der Berg et al. 2007).

Co-evolutionary thinking of this kind identifies three conceptual levels: niches; regimes; and landscapes (Rip & Kemp, 1988). The research reported on here remains largely at 'niche' or even pre-niche level as new agro-food and energy products find markets. They contribute to a socio-technical regime change that may be envisaged as 'sustainable' and conceivably evolving ultimately and in the relatively long term into a new production-consumption 'landscape' we may call 'post-hydrocarbon.' Our focus on the niche level is also because this is where innovations, which may influence regimes and ultimately co-evolutionary 'landscapes', begin. Normally, this 'niche' approach is adopted by researchers seeking to understand the articulation of discourse and 'constituency building' by means of which innovations are adopted in markets, a process involving uncertainty, experimentation, market probing and learning. In this research, energy-related Climate Change concerns explain the 'niche' innovation and understanding of its early uptake in some settings. Secondly, the research is interested in the extent to which ground up and top-down processes influence the possible emergence of regional or national 'socio-technical regimes.' In the UK, for instance, there is evidence from the emergence of the UK Transition Towns initiative, first evolving mainly in south-west England, that supports the idea of imitative 'contagion effects' to make this line of research well worth investigating (Giangrande, 2008) although Smith (2007) implies top-down has been the key driver in the English part of the UK because of local and regional resource constraints imposed from Whitehall. The experience reported below in the region of Wales seeks to investigate whether co-evolutionary thinking and its elements are present in government policy for green innovation and to investigate to what extent the government as key actor is playing a major role in coordinating and influencing the transition process as the literature predicts (Van der Berg et al., 2007; Rotmans et al., 2001).

Wales and its green potential

Before exploring the role that the government and governance are playing in system innovation in Wales, it is useful to investigate the most interesting and innovative developments in the green innovation field that have occurred in recent years in Wales.

Descriptively speaking it involves patented knowledge derived by the Institute for Grassland & Environmental Research (IGER) based at Aberystwyth in rural, central Wales. This UK Biological Research Council-funded research institute has, for seventy years to 2007 been the UK's main, been a specialist grassland research institute. It was tasked from the outset with improving the quality of fodder for cattle and sheep feedstock, which is mainly grass. By the early 1980s research, this involved not simply breeding richer grasses but understanding the rumen of these ruminative animals, had revealed that a limit to quality on these mountain-bred animals occurred because the enzymes that broke down fodder into protein were actually consuming a significant portion of the nutritional value of the fodder consumed by the animal. Following many years of lengthy field trials and laboratory research, cross-breeding the basic rye-grass commonly utilised for cattle and sheep fodder with breeds possessing enhanced sugar content produced optimal results. The enzymes took some of the enhanced sugar content, transforming it directly into energy but left a substantial portion for the animal sufficient for the amount, nutritional value and flavour of the animal to be significantly enhanced.

This came to the market at a time when consumer demand for leaner meat of the type raised in mountainous areas rose significantly and continuous improvement to the original *AberDart* strain of rye-grass, marketed by Germinal Holdings, over the intervening years led to it reaching 50% of the UK market. It further secured the status of Welsh Black beef and Welsh lamb as premium products and enabled significant improvements to occur in comparable upland cattle breeds such as Aberdeen Angus.

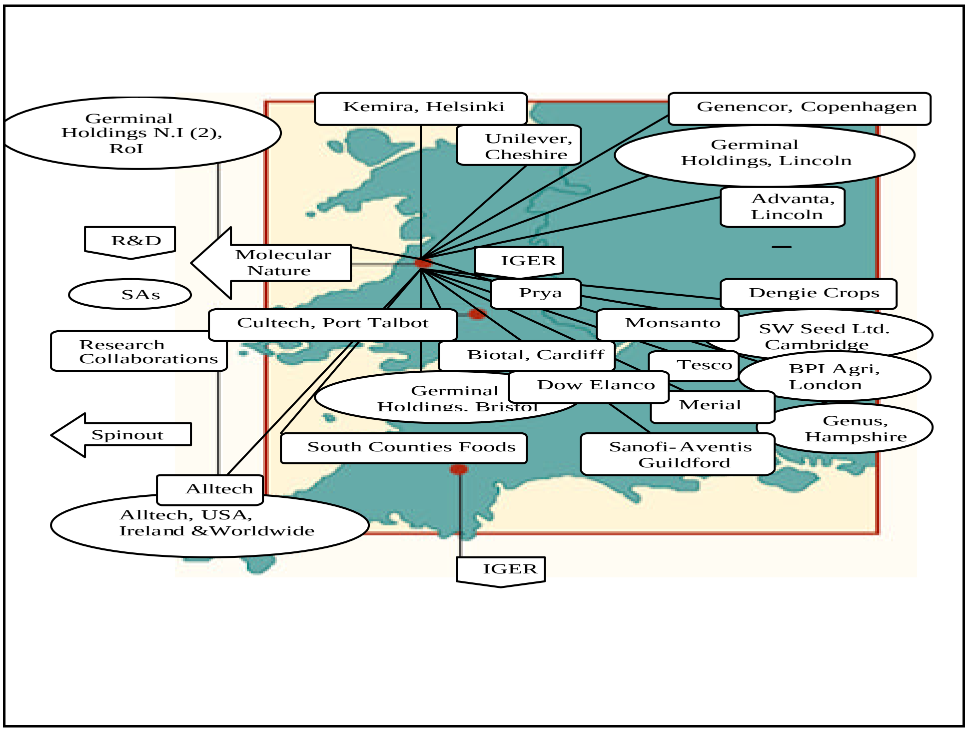
In 2003, it was realised that IGER had, in the form of these SugarGrasses, an indigenous product to add to its burgeoning portfolio of biofuels. Tests had shown that SugarGrass had twice the calorific value of sugar cane, the source of much of the world's biofuel. IGER thus evolved a second string to its grassland expertise by developing a renewables research division. One of the biofuel feedstocks in which it became supreme early on was the growing and processing of Miscanthus, more popularly known as Elephant Grass, an African tall grass that grows on marginal land. Accordingly it doesn't compete for land with food crops, one of the criticisms of the US and Europe's 'bolt for biofuels'. This has seen the ears and cobs of wheat and corn being turned into ethanol because of easy availability and major subsidy, causing up to 40% increases in the price of such cereals, and grief in developing country food markets.

IGER is widely perceived as in a global class of its own in these specific bioenergy sub-fields, with competitors such as University of California, Berkeley that has received a $500 million endowment for a Climate Change research institute from British Petroleum (BP) and the University of Illinois. However, IGER sustains that with the SugarGrass has a current lead on both of them as it is twice as calorific as Miscanthus and SugarGrass is favoured as the technology with the best long-term prospect to replace oil. IGER has the patent for SugarGrass, currently earning royalties of £100,000 per year from sales of seed varieties for fodder and nevertheless, as the world awakens to the relatively simple processes of biorefining the product, these are likely to grow substantially.

Discussions are also underway with Welsh Government officials about the promise of funds to help build an experimental biorefinery and it is believed that when the oil ceases to be refined at the huge Milford Haven refineries in neighbouring

Pembrokeshire, the pool of talent and infrastructural sunk costs would make them ideal candidates for becoming SugarGrass (and *Miscanthus*) biorefineries.

Fig 1. IGER- Novel Agricultural Products Research

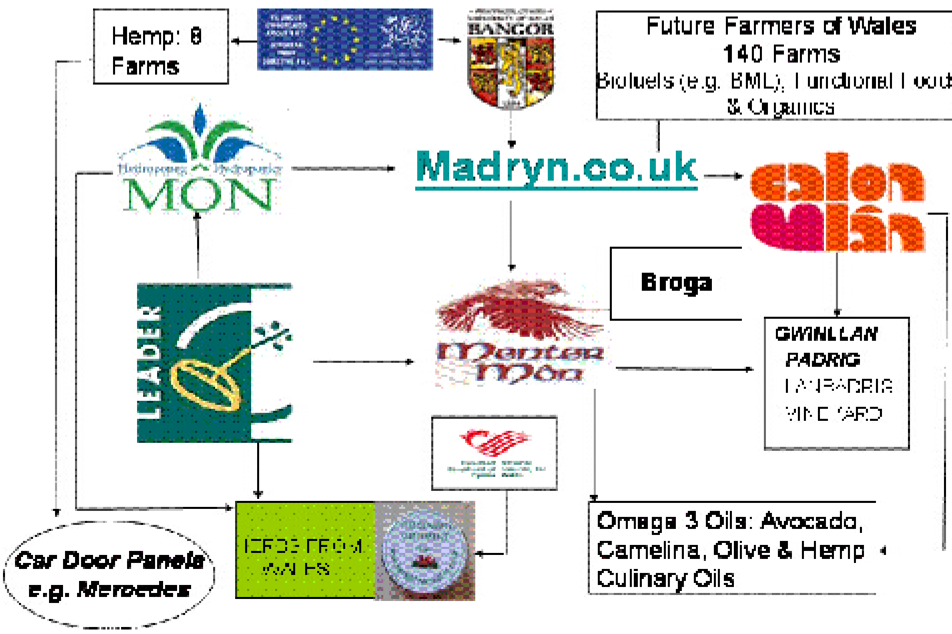


These would continue to meet a huge share of the UK's future energy. But it is not simply a spinout-venture capital model that is in mind. Possibly because a spin-out model doesn't yet work as well as a commercialisation outsourcing model in this nascent field. For example, *Molecular Nature*, the spin-out identified in Fig. 1, burnt–up its venture capital but because of the value of its patent for biofuels potential as well as its fodder market, it was acquired by spin-in company Summit. Moreover, true to the traditions of co-operation among Welsh mountain farmers, IGER promotes a new vision of mixed farming whereby groups of farmers grow Miscanthus on their poorest soil, devote some fields for SugarGrass fuel cropping and raise quality Welsh Lamb or Welsh Black Beef on their best SugarGrass land.

The prospects include that farmer co-operation would enable the undertaking of local, small-scale biorefining. SugarGrass is fermentable for extracting the juice that becomes ethanol to be used on farm or sold. But the dried remnants can also be used either as fodder or as feedstock for yet another bioenergy variant, biomass power station burning. A bio-revolution seems to be afoot in rural Wales, as not only biofuels but bio-composites are also being researched and experimentally produced among groups of entrepreneurial farmers linked to Bangor University in north Wales. Mercedes cars use hemp-based insulation material of the kind being produced by an eight-farm group in Snowdonia and 'Future Farmers of Wales,' a 140-strong association of younger farmers willing to diversify into biofuels, functional foods and cosmeceuticals is thriving.

Hence, Fig 2 attempts to delineate key interactions in the emergence of a biocomposites, biofuels and related agro-biotechnology platform of inter-connected and emergent clusters in north Wales. In this emergent and relatively sub-regional innovation system are found a number of key organizations.

Fig 2 Entrepreneurship and Alternative non-food crops production in North Wales

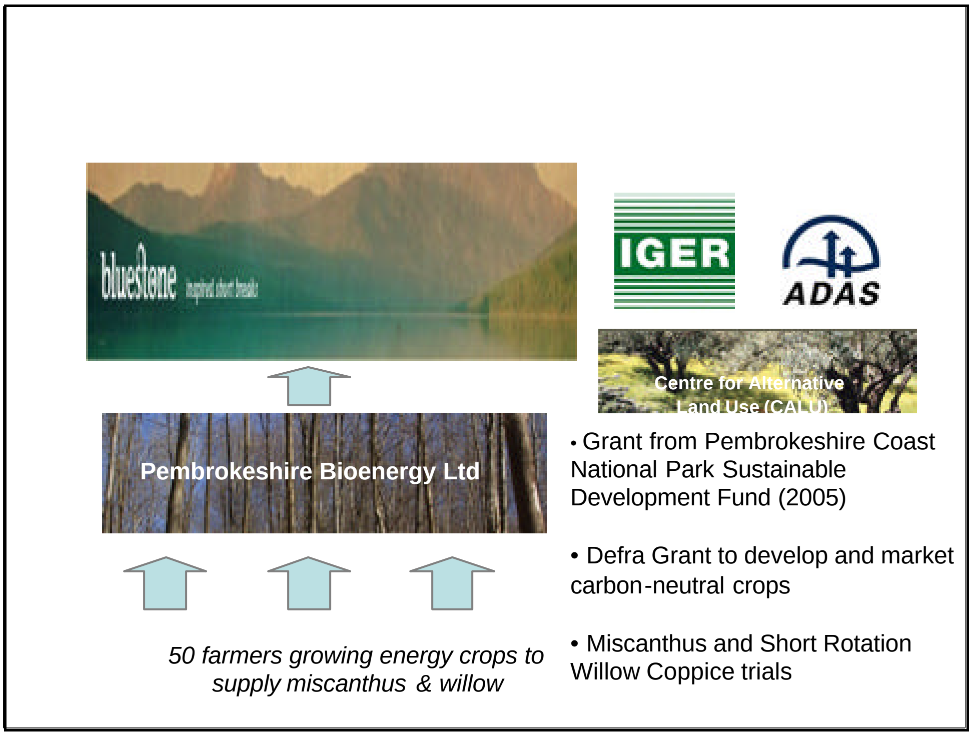


Thus EU Convergence Funding plays a role in a project whereby a number of farms experiment with hemp as a biocomposite of the kind utilised by automotive firms such as Mercedes as insulation in car body panels. Partnership with Bangor University's Biocomposites Centre is a means by which knowledge generated in the Centre is exploited commercially. However, also important to the network is *Madryn* an intermediary firm that takes on a combination of 'knowledge aggregator' and 'entrepreneurship accelerator'. It works closely with, on the one hand an association of farmers seeking to diversify into agro-bio and sustainable product development and marketing while, on the other, engaging in serial entrepreneurship itself and entrepreneurship acceleration among other businesses. These range from firms producing 'green cosmeceuticals' (herbal make-up) to functional foods and locally-grown culinary oils enriched with, for example Omega-3 oils. These include relatively recently introduced olive trees that survive the hitherto cold winters of north Wales as a consequence of climate change. *Madryn*'s support was also fundamental for the set up and running of BML Biofuels (a farm-based bio-diesel plant in North Wales), the first plant in Wales - and only the second in Britain - to extract oil by cold pressing oilseed rape[3], that will produce 1.3m litres of bio-diesel every year (3,600 litres-a-day) as well as 2,500 tonnes of high protein feed pellets for livestock.

Several other projects are also underway that show how Wales could lead further development in the bio-energy field. One problem that some farmers are facing in entering alternative non-food crop production is the lack of initiatives on the demand side that cover the extra costs that non-food crops farmers experience (e.g. lack of availability of EU subsides such as those under CAP scheme). The creation of the Bluestone Holiday Village is an example of how the opening up of a new market opportunities (De Laurentis & Cooke, 2008) has thrived the establishment of a cooperative of about 50 farmers and the constitution of a ESCO (energy supplier company), Pembrokeshire Bioenergy Ltd (see Fig. 4).

When it was completed and opened in July, 2008, the Bluestone holiday village situatedon the edge of Pembrokeshire Coast National Park, took a first step to fulfilling the vision of a new kind of 'green tourism' and is a showcase for renewable energy and sustainability.

Fig. 4 Opening up Market Opportunities: Pembrokshire Bioenergy and the Bluestone Holiday Village



The development will include some 340 timber chalets surrounding a 'Celtic Village' of 80 permanent buildings within the National Park. Outside the park, it will link to an existing leisure centre extending it with the inclusion of a Snow Dome, Waterworld and sports centre. The development is valued to around £60 million. Preseli is the unique home to the blue sarsen stones that comprise the celebrated neolithic monument and World heritage Site of Stonehenge in what is now south west England. The Bluestone philosophy “is care and enhancement of the environment”. Committed to sustainability the company attained the highest environmental accreditation in Europe, ISO 14001, and Level 5 of Wales’ Green Dragon Environmental Scheme. To this end a showcase Biomass Energy centre will form part of the development. The first of its type in the world, it will ensure that the country is at the forefront of sustainable technology in the UK. Strong support for energy crops has been shown by the developers through their commitment to biomass technology, ensuring the establishment of a market for energy crops such as *Miscanthus* and coppiced willow.

Wales is also home of Europe's first commercial scale biomass power station on a 6-acre site in Port Talbot, whose construction work started in July 2006. The £33 million pound station is scheduled to be fully operational by June 2008. The 13.8 MW station will generate 104 GWh per year, sufficient to meet the needs of around 31,000 homes. The Cardiff-based renewable energy company Eco2 is building the power station, for a project originally proposed by the Western Log group, which secured planning permission in 2004. The plant will be fuelled with 16,000 tonnes per year of clean wood which has come from sustainable, managed forests and saw mills. With trees drawing carbon dioxide from the atmosphere as they grow, the carbon dioxide produced in combustion results in no net increase of the gas. By generating electricity in this way, some 47,000 tonnes of equivalent fossil fuel carbon dioxide emissions are avoided. This will help reduce the negative effects of global warming. The serial entrepreneur and director of Eco2 is beyond several renewable energy projects in Wales, England and Spain. The company's most recent development is in tidal energy as the company is backing Tidal Energy Limited to develop DeltaStream - an innovative technology designed to generate electrical power from tidal stream resources[4].

Hence, the discussion shows that there are numerous indications of clustering among small firms, but also some large firms, along with an applied and basic research infrastructure focused upon the production of non-fossil fuel energy that contributes to the moderation of global warming (Cooke, 2007). From a co-evolutionary perspective, the cases discussed above represent examples of strategic niche management in action, where niche creation is done searching, selecting, learning and leading by actors involved in networking, in which niche solutions are created to provide a more sustainable regime alternative[5].

The role of government and governance

The literature sees government as key actor that plays a major role in coordinating and influencing the transition process and can sometimes take the initiative in setting up a form of initiating transition management (Van der Berg et al., 2007; Rotmans et al., 2001), which will take into account a combination of external environmental effects (social costs), external benefits of innovation (knowledge spillovers) and lock-in of a socially undesirable technology. Innovation issues and environmental sustainability issues have usually been addressed through separate policy regimes, based on distinct analysis of problems, types of policy instrument, implementation issues and rationales for policy intervention. Nevertheless, a co-evolutionary approach envisages that various policy domains are relevant for the stimulation of energy innovations: energy policy, technology and innovation, environmental policy, climate policy scientific and transition policy.

As may be imagined, the largely entrepreneurial innovations described above sit on a highly complex governmental and governance system in Wales that supports by articulation of discourse and some subsidies (mainly that take the form of innovation grants) many of these traditional industry innovations. Before turning to analyse the governance in Wales, it is important to review the UK context in which the Welsh renewable energy policy is set.

At UK government level, national and international climate change strategies as well as the Kyoto protocol have pressured governments to set up targets to reduce greenhouse gasses (currently 20% by 2010 compared to 1990 levels). The Energy White paper lunched in 2003 asked for a 60% reduction in greenhouse gases by 2050. This commitment was also given a new added impetus in the more recent Climate Change Bill (2007) and the Stern Review (2006)[6]. The form of support at industry level has taken the form of two main policy instruments: the climate change levy (a tax on energy used by industry and the Renewables Obligations (ROs). Since its introduction in 2002, ROs have become the key policy in the government's strategy for nurturing the renewable energy sector, replacing a problematic policy framework that had been in place for a decade the 'Non-Fossil Fuel Obligation'. The ROs[7] has successfully stimulated interest in renewable energy projects in the UK and has created a new market for what are commonly known as tradable green certificates (or Renewable Obligation Certificates)[8]. As a result, renewable energy generators earn revenue from both, the electricity market and the separate trading of the certificates.

However since their introduction, the ROs were confronted with several challenges in order to be successful to reach the UK Government renewable energy targets, (Smith and Watson, 2002; UKBCSE, 2007), in particular:

- the process of obtaining planning permission and delays in planning for new renewable projects, particularly wind;
- technical and infrastructural problems in connecting renewables to electricity networks
- long term development of 'next generation' renewables and near to market technologies, like offshore wind energy.

The lengthy and difficult process of obtaining planning permission has presented a major barrier to renewable expansion in the past decade. In response of the planning bottlenecks, the government has sough to engage with regional governments both in England and Wales to set strategic renewable targets for 2010, which are expected to cascade down to the structure plans and local plans of local authorities and become material of consideration in local planning decisions (Smith & Watson, 2002). A plan to streamline the planning process for renewable energy is also under consideration (such as the establishment of the Infrastructure Planning Commission that would act as a 'one stop shop' for large scale renewable energy projects); one problem this may cause, however, is that top-down imposition of renewables may lack the support of local communities and a more ground up approach needs to be explored as each region has its own geography, resource endowments and socio-economy that structures the renewable energy options available (Smith & Watson, 2002; Smith, 2007).

The infrastructure has also posed several problems to achieving renewables targets, resulting in an undersupply of ROCs in the market and an associated increase in price (UKBCSE, 2007). An out of date infrastructure that is designed primarily for the traditional transmission of power from large generators down to consumers means that small generators wishing to connects to the distribution systems will need to sustain the expensive costs of connection, including any upstream reinforcement to the transmission system (Smith & Watson, 2002). The National Grid is currently working with government and the renewable industry to reduce these barriers to grid connections, but further improvements in networks capacity and availability needs to be targeted.

Furthermore, since their introduction ROs have not distinguished between renewable technologies which meant that next generation technologies such wave power, tidal and photovoltaics had to compete against cheaper technologies such as on-shore wind power and energy-from-waste (Smith & Watson, 2002) which also represented the most controversial in planning applications hindering the achievement of set targets for renewable energy. In co-evolutionary thinking, this has meant that the ROs failed to provide a means of stimulating innovation, building up skills and capability and insuring against the risk of locking into sub-optimal technologies preventing investment in a diverse portfolio of new technologies. A co-evolutionary approach would require promoting systems of innovation which implies uncertainty, experimentation and a certain degree of economic waste.

Nevertheless, from April 2009, different technologies will receive different amount of ROCs for each MWh of renewable energy generated (e.g. tidal, wave and fuel cells created by anaerobic digestion, gasification and pyrolysis, as well as dedicated biomass burning energy crops with or without CHP, solar photovoltaics, geothermal and tidal impoundments will all be allocated 2 ROCs for each MWh of electricity generated).

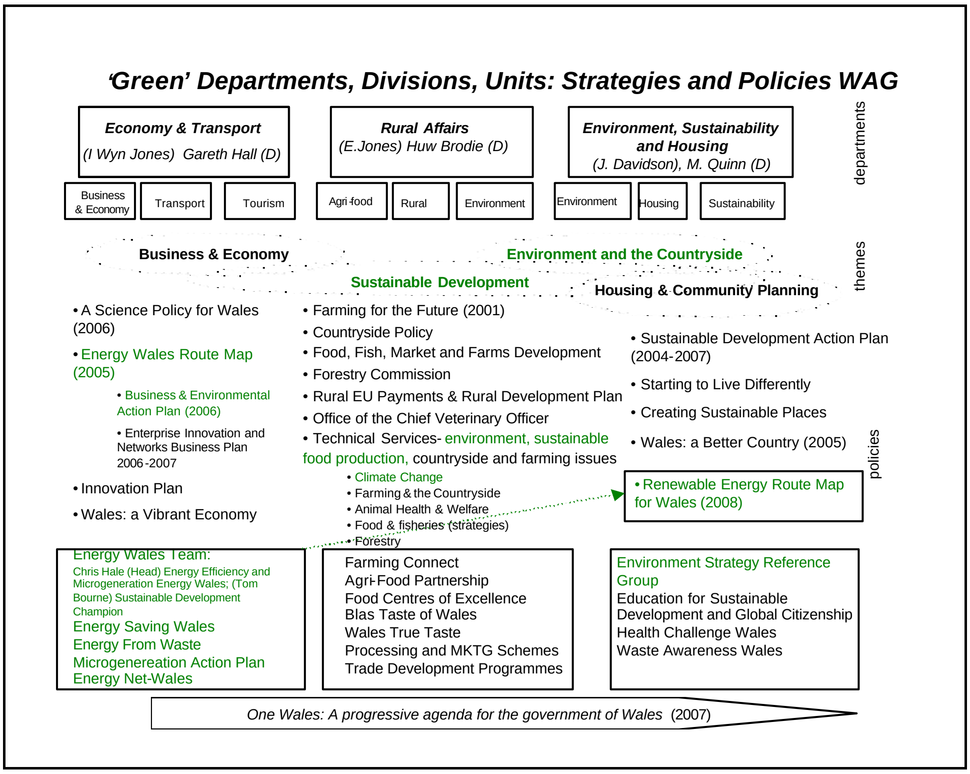
As argued, although energy is not a devolved matter, the Assembly Government in Wales and governments in the other 9 English regions, are experiencing the emergence of a new regional level governance for renewable energy (for the English regions see Smith, 2007), creating a web of institutions and policies to promote renewable energy and the transition to a low carbon economy.

Within the UK context, the Welsh Energy Strategy launched in March 2003 and the Sustainable Development action plan of October 2004 underpin the UK Government's 2003 Energy White paper. The Welsh response highlighted the environmental importance of energy efficiency and clean energy developments, while simultaneously seeking to provide competitive and secure energy supplies from a wide range of sources. Recent policy documents and their implementation are setting out specific actions on how Wales can meet the renewable energy self-sufficiency objective and highlight the importance of policy support to innovation and deployment of green innovations. A link between environmental and innovation policies was set up in the ‘Science Policy Strategy for Wales’, which highlighted that there are three areas upon which a science policy focussed on innovation should concentrate; these are: Health; Low Carbon Economy and Sustained social and economic renewal. In particular, different policy documents highlighted an overarching commitment to sustainable development which aims at contributing to the reduction of greenhouse gases and at developing a low carbon energy business and research sector based in Wales. The latter, in particular, will build from unique geo/environmental factors, a strong private sector energy, forestry and energy crops and internationally recognized University science base, with a number of smaller research groups at Glamorgan University (hydrogen, combustion, controls) Cardiff University (power engineering, renewables), Swansea University (materials, marine energy) IGER (bio-crops) and Bangor University (marine and PV).

In order to build on Wales’s existing relevant R&D base, the Assembly recently announced approval for a £5 million grant from HEFCW (university funding agency) to create a ‘Low Carbon Energy Research Institute’, that will be supported by the Assembly Government Technology Transfer and Knowledge Bank teams to ensure maximum private sector involvement and rapid exploitation. The most recent renewable energy related document, ‘The Renewable Energy Route Map for Wales’ (2008) set out specific actions on how Wales can meet the renewable electricity self-sufficiency objective, increasing renewable energy generations from different technologies, such as marine, wind, biomass, waste, hydropower (fig 5 shows the complex governmental system in Wales that supports renewable energy).

The Assembly Government is committed from 2011 onwards to a 3% annual reduction in Wales’s greenhouse gas emissions in areas in which the Assembly has devolved competencies; to reach specific sectoral targets and, by 2011 all new buildings in Wales to be built to zero carbon standards. Wales has signed up to the 2020 EU target of 20% of energy requirements (electricity, heat and vehicle fuels) coming from renewable sources, including those linked to the waste cycle. According to the Assembly, this commitment can be met by taking advantage of the considerable endowment of natural renewable sources of energy – wind, tide, wave, hydro and biomass – building from the success in the past in using coal reserves.

Fig. 5 The Governmental System in Wales in support of renewable energy



The long term vision of the government sees considerable scope for combining economic, skills and social benefits, with the environmental ones. In particular, the Assembly Government is set to:

- develop a strong 'green jobs' strategy, building on previous skills and economic development initiatives, such as the 'green energy cluster' work and the recommendations of various high level bodies including the Webb review and the economic and skills Ministerial Advisory Groups and
- work with colleges, the relevant sector skills councils and the private sector to ensure Wales has the necessary skills base to enable the rapid transition to a low carbon economy.

Finally, the Assembly has shown a long –term commitment to energy crops which is opening up in Wales upstream and downstream within the bioenergy supply value chain as discussed above. On this line, the One Wales Programme commits the Assembly Government to explore the desirability of introducing a grant scheme aimed at encouraging the establishment of energy crops – whether short rotation coppice (most likely willow) or energy grasses (such as *Miscanthus*). This work is being carried forward as part of the wider review of the future of land management schemes in Wales, covering support for agri-environment actions, forestry and high nature-value areas, as well as biomass-energy. These follow several criticisms raised by the farming industry that lacked the incentives to move into alternative non-food crops production. The problems originated from the lack of planting grants (available elsewhere in UK) could have been overcome by the availability of a premium price for energy generated from renewable sources and fed into the grid (e.g. a feed-in tariff system is behind the huge success of the renewable energy sector in Germany).

It could be argued that the Assembly Government is concerned with issues of dynamic change in ways that fit co-evolutionary thinking as they are trying to foster collaboration between industry and public research organisations. It is recognised, at a discourse level, that there is a need for coherence between energy policies, innovation policies and planning, yet, in many cases, innovative firms in the green innovation field feel that the Assembly is still too reactive to change and little has been done to tackle the barriers that the renewable energy sector is facing in contextual issues of planning consents, electricity grid infrastructure and development capability[9].

Conclusions

As discussed in the paper, in recent years, Wales – one of the UK's four countries, has displayed innovative developments in the green innovation field. Research in agro-food has helped co-evolve a pronounced green innovation production platform, with linking new and more established firms and the research arena. The paper argues how these are clear examples of the co-evolution of new sectors and highlight how the emergence of innovations in the renewable energy industry in Wales has required the restructuring of old institutions and the establishment of new institutions (Freeman & Perez, 1988 and Nelson, 1995) to adapt to the exigencies of exogenous (e.g. to reduce greenhouse gas emissions) and endogenous (e.g. the emergence of a new industry) forces, providing example of niche development.

The paper highlighted how recent policy documents and their implementation are setting out specific actions on how Wales can meet the renewable energy self-sufficiency objective and highlights the importance of policy support to innovation and deployment of green innovation. It argued that offering the appropriate support to indigenous firms to become more competitive through sustainable innovation is a rising issue on the regional policy agenda and poses challenges in terms of instruments, policy approaches and implications for governance. Nevertheless, the research showed that the systemic interaction between policy making processes in innovation, planning, energy and environmental policies is often lacking. There are evidences of networks of actors involved in green innovation that foster knowledge flows; but the role that is played by the government in nurturing these knowledge dynamics seems marginal. The institutional framework is often criticised for its unclear and conflicted vision, being often seen as reactive.

As argued, policy and institutions appear different from the viewpoint of co-evolutionary thinking that from that of traditional economics. The co-evolutionary approach suggests that diversity of options is regarded as essential for adapting to changing circumstances and preferences, through selection and new innovations. Policy setting is argued needs to be directed to improving the way in which variety selection and innovation processes operate, acting to stimulate and guide the exchange of information between players so that a collective learning process takes place. The paper showed how the rationale beyond the ROCs has failed to provide a means of stimulating innovation preventing investment in a diverse portfolio of new technologies. Little seems to be done on subsides and government tendering policy in order to stimulate the mergence of niche markets, which accelerate learning curves and increasing returns to scale of innovative technologies, products and processes.

In the discussion above, we have argued that Wales, after starting to awaken early to a co-evolutionary perspective that seeks more coherence between energy policies, innovation policies and planning, it is fraught with paradoxes and contradictions. Hence, in practice, it seems that complementary aspects of different policy fields receive relatively little attention and more needs to be done to tackle the barriers that are emerging in regime transformation. The paper concluded that policy at national and regional level is facing difficulties in triggering green innovation and there is need to strengthen the connectivity between key elements in system innovation. More needs to be done at national and regional level to encourage long-term thinking, to create and develop niches to stimulate key innovations in order to overcome possible lock-in, promote technological diversity and regime transformation.

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[1] These are for example the replacement of sail by hydrocarbon fuels or the emergence of air transport to challenge ground transport and the rise of Information and Communications Technology to rival traditional communications media. However, according to Cooke (2008) at a deeper level, nearly all the aforementioned technologies depended to a greater or lesser extent upon hydrocarbon energy. Even sailing ships contained at least some iron artefacts based on hydrocarbon (charcoal, coal) energy in production.

[2] Here 'system' involves the co-evolution of social, economic, political, scientific and technological sub-systems beyond that of the specific technological regime (Smith et al, 2005).

3 The oilseed rape needed for the plant will initially be supplied from Shropshire and Herefordshire in England.

[4] The technology has been validated in sea trials and simulations by Cardiff University and is undergoing detailed design work at Cranfield University supported by Carbon Connections UK Limited. The DeltaStream device is a nominal 1MW unit which sits on the seabed without the need for a positive anchoring system, generating electricity from three separate horizontal axis turbines mounted on a common frame.

[5] Although the literature on strategic niche management mainly refers to niches involving radical innovations, according to Smiths (2006) niches will be more influential when they show some compatibility with the incumbent regime.

[6] A key driver has also been energy security. Political instability in countries supplying fossil fuels and their finite nature contributed to further increases their prices, making renewable resources becoming more competitive.

7 The RO requires all licensed electricity suppliers to obtain an increasing proportion of electricity from 'eligible' renewable sources. When first introduced in 2002 the obligation was set to 3%; this raised to 7.9% in 2007-2008 and is expected to rise to 15.4 in 2015-2016; rising gradually in subsequent years up to April 2027. From April 2008 a new obligation started on transport fuel suppliers (RTFO), aimed at deliver carbon saving of approximately one milliones tonnes per annum from the transport sector by 2010-2011. From 2008-2009 the obligation is fixed on 2.75 % by volumne of fuel from renewable sources, set to increase to 5% by 2010/2011.

[8] The energy suppliers can meet their obligation in three ways: by producing ROCs to show that they have generated or bought electricity from renewable generators; by buying ROCs on the open market

from other suppliers with a surplus; by paying a buy-out price (equivalent to £34.30/MWh in 2007-2008 and rising each year with retail price index.

[9] An exemplar case is provided by a company that had a project approved from one pool of expert within the Assembly and then rejected a few month later by the Assembly planning committee.