ARTICLE IN PRESS

Energy Policy ■ (■■■■) ■■■–■■■

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Using network analysis to understand public policy for wave energy

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HIGHLIGHTS

- Network analysis of the UK wave energy sector.
- Introduction of network analysis metrics as an analytical tool within innovation systems.
- Identification of government fund *gating* for technologies within UK wave energy sector.
- Identification of *Mathew effect* among device developers within the UK wave energy sector.

ARTICLE INFO

Article history:
Received 8 October 2012
Accepted 17 July 2013

Keywords:
Network analysis
Innovation systems
Wave energy

ABSTRACT

The UK's wave energy sector is at a pre-commercial stage transitioning from prototype/demonstration towards a revenue supported industry. A host of advantages that could be realised through successful commercialisation include; the potential to generate 40–50 TWh/yr, £3.7bn of export, and 10,000+ jobs by 2020 (with tidal). Despite this, criticisms have been made about the lack of; coordination between funding bodies, communication between stakeholders and overly centralised actors. Although the value of strong problem solving networks has been noted, problems arise in validating the presence, nature and value of relationships as well as identification of tacit and informal linkages. Here network analysis is used to validate these criticisms and provide insight into sector activities. It is shown that although high levels of interaction are occurring overall, there are wide disparities. Prime movers are clearly present and less mature developers are isolated from the system as it develops norms and practices. This, combined with government fund gating has led to a Matthew effect whereby some have access to finance and are shaping institutional norms while others struggle. Although convergence is expected, a lack of public sector coordination, transparency of decision making and comparability between devices has reduced both investor and stakeholder legitimacy.

1. Introduction

There have been a wide range of public, academic and industry led studies over the last decade into the potential benefits and opportunities of commercialising marine renewable energy within the UK. These benefits fall roughly into two categories; technical, and economic. Technically, the waters around the UK are considered to be among the best in the world as a source of wave energy and could be used to provide 40–50 TWh/yr of electricity, helping to meet our wider CO_2 reduction targets (House of Commons and Energy, and Climate Change Committee, 2012; Committee on Climate Change, 2011; Renewables Advisory Board, 2008). Although more erratic in its predictability then tidal energy, wave energy availability within the UK should produce on average an estimated five times more energy during peak demand than periods of low demands, has lower levels of hour-to-hour variability than tidal energy and generation can be accurately forecast up to several days in advance. (POST, 2009; Carbon Trust and Environmental Change Institute, 2005; The Science and Technology Committee, 2001). From a deployment perspective, low levels of availability variation between different device types means that devices are substitutable on larger arrays and therefore the opportunity exists for policy makers to avoid technology 'lock-in' should the selection environment support a wider technology portfolio, allowing more devices to move to the higher TRLs and then to allow market instruments to apply and free market development to stimulate competitive enhancement (Carbon Trust and Environmental Change Institute, 2005). Additionally, since wave technologies are incrementally deployed, (unlike nuclear or other centralised generation technologies) environmental monitoring and cost assessments can be done concurrently

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http://dx.doi.org/10.1016/j.enpol.2013.07.066

Please cite this article as: Vantoch-Wood, A., Connor, P.M., Using network analysis to understand public policy for wave energy. Energy Policy (2013), http://dx.doi.org/10.1016/j.enpol.2013.07.066

with deployment as capacity ramps up, producing a lower risk profile.

Along with these factors, there are several other strong economic considerations for supporting wave energy technology: the long term value to the UK (for wave and tidal technology combined) is estimated to be in the region of £6.1bn per annum, while export potential alone could be as high as £3.7bn annually by 2020 (House of Commons and Energy, and Climate Change Committee, 2012, RenewableUK, 2010). It is also estimated that as many as 16,000 UK jobs could be created within the wave energy sector by the 2040s (Carbon Trust, 2009a).

Within the broader energy mix, diversifying renewable energy technologies reduces the risks faced if any one technology encounters large problems in performance, reliability or supply chain requirements. This diversification therefore not only helps to ensure energy security but could also lead to a reduction in extra capacity costs equating to an estimated £900M per year (DECC, 2010a). Finally, the UK has a significant historical advantage over many nations, with experience not only within marine engineering, but a long history of marine renewable energy research. This has resulted in a high number of device developers and some of the world′s current leading research institutes in the sector (Entec UK Ltd, 2009, Douglas-Westwood, 2008, Winskel et al., 2006).

The sector has nonetheless received criticism for failing to deliver any significant deployment in the 40 years since research began. It has been argued that this is primarily due to the technical difficulties of creating reliable, survivable technologies within the marine environment (and integrate them with existing infrastructure) which is simply more challenging than was originally expected (Mueller, 2009; Renewables Advisory Board, 2008; Jeffrey, 2007). Others have contended that due to the absence of actual materialisation (i.e. technology deployment and diffusion) the high value placed by developers upon intellectual property (IP) within the industry has created a lack of trust and ‘social capital′ among stakeholders. This in turn has led to low levels of cooperation, communication and information sharing among and between industry and academia (EPSRC, 2009; POST, 2009; Renewables Advisory Board, 2008). Additionally, it has been claimed that the UK marine energy sector has been driven by only a handful of key stakeholders (Winskel et al., 2006; ICCEPT and E4tech Consulting, 2003). Much of current innovation theory supports the argument that high levels of knowledge flow within a sector is vital for promoting technological dynamism and innovation as well as pushing forward increases in the legitimacy of high technology sectors (DIUS, 2008; Rogers, 2003; Carlsson et al., 2002; OECD, 1997; Coleman, 1988).

Those relationships that require no interpersonal contact and are based on one-way information flows, (such as reading publications or searching patent databases) can however only provide codified information (OECD, 2005). This is clearly problematic from a policy research perspective since many informal mechanisms of communication, knowledge sharing and learning not only help to strengthen and create confidence in the sector but also produce non-codifiable outputs such as; non-patented innovations, tacit knowledge, collaborative interactions, the establishment of social norms or practices and the creation of social capital (Dosi et al., 2002; Low and Abrahamson, 1997; Coleman, 1988). The presence of knowledge diffusion is difficult to map, though Håkansson suggests that more than two thirds of collaborative relationships are non-formal and thus not picked up by current formal methods of analysis (Hekkert and Negro, 2009; Håkansson, 1990).

This paper explores the activity occurring within the UK′s wave energy sector through the framework of an entirely novel application of network analysis to gain insight into informal linkages and communications occurring throughout the sector. Through this application of network analysis, measures of linkage are established which are used to create a ‘map′ of *all* interactions that respondents purport to have undertaken including informal connectivity. Metrics of Individual and group centrality are used to quantify key factors within the system such as identifying what Jacobsson and Johnson (2000) refer to as *prime movers* influencing the sector′s overall generation of knowledge. Through this technique, researchers and public policy makers (as system builders/ managers) are enabled to effectively peer inside what Rosenberg (1982) describes as the *black box* of innovation, illuminating informal activity and allowing for more informed and therefore effective policy decision making.

1.1. *A brief background of the wave energy sector*

The UK government has a record of providing support intermittently for wave energy technology. Starting in 1974 after the first oil crisis funding was committed towards original R&D under the Wave Energy Programme (Carbon Trust, 2006). This ambitious project initially sought to design a 2 GW wave energy device however, clearly fell well short of delivering its goal (Thorpe, 1999).

Programme funding continued until 1982 when—after a closed door meeting by the Advisory Council on Research and Development (ACORN), it was decided to drastically scale down support for the technology following an unpublished government report which predicted that wave energy technology would never feasibly produce energy at a competitive price (Salter, 2008; Jeffery, 1990). There was a great deal of controversy over this decision which advocates of wave energy power have suggested had been motivated by a wider ambition of the Thatcher administration (and UKAEA) to move towards the next generation of nuclear power stations (Salter, 2008; The Science and Technology Committee, 2001; Jeffery, 1990).

After this meeting marine energy research and the technology was downgraded onto a ‘technology watch′ status by the government and although many smaller devices continued to be funded, financial support declined and the programme was finally abandoned in 1994 in a decision that was later recognised by the Department of Trade and Industry (DTI, now BIS) to have been a mistake (The Science and Technology Committee, 2001, Thorpe, 1999). Over the next few years central government funding for wave energy research was virtually non-existent, decreasing from a low base of £100,000 per annum to just £50,000 by 1997 (SPRU, 1999).

A new era of interest in wave energy technology was ushered in from 1999. Through the New and Renewable Energy Programme, the DTI began funding wave energy research again albeit far more modestly than in the late 70s and early 80s. At the same time, the final tranche of the Scottish Renewables Obligation included three wave and tidal energy contracts to be delivered at £60–£70/MWh (Renewables Advisory Board, 2008). Only one wave energy device however, Wavegen′s (formerly ART) 500 kW Limpet device, successfully made it through to operation. This was the first commercial wave energy generator within the UK and is still in operation today.

Between this introduction of the Scottish Renewables Order in 1999 and until 2004 a new focus of interest from the UK government began and there were been several high level funding initiatives geared towards UK wave energy device development. The most notable at the start of the decade was the UK Government′s New and Renewable Technology R&D Programme which was established to evaluate the validity of 27 different marine energy device, (10 of which were wave energy converters) with a budget of £26M (Renewables Advisory Board, 2008). In 2006, the government introduced the Marine Renewable Deployment Fund.

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