1. Introduction

This paper explores the potential of actor-network theory (ANT) to developing an understanding of co-evolution of policy and large scale technological developments in emerging industries, such as wave energy. Between 2010–13 the UK wave energy sector was an especially promising site for studying technological change and the underpinning policy landscape for several reasons. These included the state of technology which was perceived as relatively immature and needed considerable effort by both industry and public policy to bring it to fruition; and uncertainties regarding the future of wave energy, availability of funding opportunities and long-term government support. The changing policy landscape made the wave energy sector a strategic site for observing policy(ies) in the making.

In a situation of uncertainty about technological development, to what extent do policies determine the destiny of an innovation project? Or would it be more productive to speak of certain policy 'effects' in and on innovation practices in emerging industries? A common understanding of policy adheres to a divide between micro and macro scale, whereby policy is often understood as a 'macro' context for innovation, e.g. in the form of an institutional and regulatory framework, or set of instruments for prediction, control, and assessment, exercised by government institutions. The task of this paper is to challenge such an approach by examining what an ANT perspective can offer to the analysis of policy development, in particular, exploring the idea of policy as an *actant*.

The case study discussed here offers an insight into the wave energy development based on analysis of a large renewable energy project, Wave Hub (Cornwall, UK). The controversial evolution of Wave Hub was an outcome of the political making of the project that suggested particular trajectories and their (predictable) results, as well as a certain reverse effect that this project had on policy and regulations in the field of marine energy. In order to illustrate these mutual influences and effects, Wave Hub is considered as an evolving socio-technical system and an actor-network. Using empirical evidence I illustrate how the links between a large technological project and policy were articulated in the Wave Hub case and how the role of policy and its effect on project development was assessed. This will help to build a critical discussion around the evolution of an actor-network with policy as its active element and to critically assess to what extent this approach might help to understand the destiny of a technological project.

The paper is structured as follows. First, I introduce ANT as a theoretical framework to inform analysis and provide a brief overview of ANT concepts and approaches that proved useful in this research. Second, the research methodology and the case study setting are introduced. Third, I discuss key policy themes that were found to be important in the Wave Hub case. Next, an ANT-inspired

analysis illustrates the reciprocal effects between innovation and policy around Wave Hub. I pay special attention to the role of policy (understood as an actant) in constructing an actor-network in renewable energy. In conclusion I summarise arguments that discuss how policy 'effects' were construed in the course of the development of the marine energy project.

2. Actor-network theory

The analytical framework provided by ANT offers the theoretical and methodological ground for researching emerging technologies and their environment. ANT's anti-determinism and flexibility, i.e. its ability to provide insights into any phenomena applying network thinking, make it a useful resource for studying the emergence and interplay of various kinds of entity.

The idea of heterogeneous network (or socio-technical network – Callon 1991) is at the heart of ANT, and the studies of such networks often accomplished through the lens of what is known as 'sociology of associations' (Latour 2005) or 'sociology of translation' (Callon 1986). According to ANT, human and non-human actors are linked together in a web of associations referred to as an actor-network. A network seems to be a neutral term standing for interconnectedness of points or nodes of any material and form. The modifications of networks can result into certain effects or new phenomena, and all phenomena are the effect or product of heterogeneous networks. While a network acts as a single block, it is replaced by action itself and we deal with a single actor; network as it is disappears (Law 1992).

The notion of an 'actor' central for ANT is defined as 'something that acts or to which activity is granted by others' (Latour 1997). For Callon (1991: 140), an actor is 'any entity that more or less successfully defines and builds a world filled by other entities with histories, identities, and interrelationships of their own'. Actors can be human and nonhuman, can have variable content and variable geometry; they might be hybrids or collectives (ibid.). The notion of an actant is used to refer to entities making part of a network emphasising agency attributed to entities, when they perform or act as a source of action. ANT adopts a 'minimal' conception of agency decoupling it from criteria of intentionality and free-will, changing the traditional humanistic understanding of agency (Sayes 2014; Bruun and Hukkinen 2003). This approach allows considering every entity that affects the actions of others (i.e. promotes a difference in a network) as having agency (Latour 2005; Sayes 2014). ANT employs the same analytical and descriptive framework dealing with both human and nonhuman actors which form a network. Such symmetric treatment of humans and nonhumans is probably the most provocative aspect of ANT (Czarniawska and Hernes 2005; Sayes 2014). Inclusiveness of nonhumans (but also intangible) in the list of actors is seen as an example of ANT's unwillingness to decide the shape of the world on behalf of the domains it examines, and demonstrates ANT's 'blank'

flexibility (Lee and Hassard 1999). Elaborating a Latourian understanding of agency (e.g. Latour 2004; Latour 2005), Sayes (2014) identifies four types of nonhumans acting in different senses, interpreting their agency in terms of contributions to social life (as mediators, as stabilisers of human collective, as members of moral and political associations, and as gatherings of actors of different temporal and spatial orders). Arguably, the term nonhuman cannot be used to label all that is not human; it can refer to animals, natural phenomena, technical artefacts, material structures, texts and economic goods but excludes entities composed of humans and nonhumans, entities that are entirely symbolic in nature or supernatural, although all of them can still be referred as actors or actants (Sayes 2014).

The ideas of power, irreversibility and stabilisation of networks help to examine consolidation and the character of network ordering (Callon 1991; Star 1991). Power in ANT is seen as a performative effect rather than something possessed by actors; the amount of power depends on the number of actors who enter into the composition and on the durability of associations built between them (Latour 1986). The notions of convergence and irreversibilisation can explain dynamics of networks, durability and robustness of translation, i.e. how different actor-networks reach durable 'agreements' (Callon 1991: 142). Strongly convergent and irreversible networks become predictable and can be assimilated to black boxes[1] or a 'punctualised nodes' in other networks playing the roles of actors or intermediaries (ibid.: 153). The general principle – 'networks of punctualised networks may themselves be folded up into points' – lets one move from micro-social to macro-social, explaining that macro is no different in kind from micro (ibid.: 153).

Questioning the idea of 'level' of analysis, ANT elaborated an 'alternative understanding of observable differences in scale' (Helgesson and Kjellberg 2005: 145) suggesting that large scale macro phenomena are not different in kind from micro phenomena, and should be analysed in the same terms (Callon and Latour 1981; Latour 1983). The difference between micro and macro-actors are not in their 'nature' but appears due to negotiations and associations; it depends on how many elements they are able to put into black boxes durably to make over their size (Callon and Latour 1981). This implies an analytic possibility to reject commonly assumed a priori distinctions between micro and macro and the idea of a 'macro context',[2] as in ANT a metaphor of scale is replaced by a metaphor of connections (Latour 1997). From an ANT perspective, successfully translated actors, i.e. mobilised without contradiction and reduced to 'stable and predictable entities', monoliths, constitute the context of a particular project (actor-network) as they become part of the background (Law and Callon 1989). Thus, the context itself is viewed as something beyond the 'negotiation space', created by mobilised actors for the growing actor-network (ibid.). By contrast, complex and intractable networks that still require translation are the focus of attention and constitute the content of the project. Both content and context are 'jointly created' and context is 'internalized in the object' or, in other words, 'the local network contains the global network' (Law and Callon 1989; Asdal 2012).[3]

An ANT approach to agency, power and scale makes it a useful strategy for studying large technological developments and related evolving policy landscapes. It allows going beyond the borders that are usually set, shifting the focus to connections between actors and networks. Importantly, ANT analysis focuses on the processes ('actor-networking') rather than on characteristics of objects/entities; it pays closer attention to how networks are performed suggesting that 'social structure is not a noun but a verb' (Law 1992). This makes an ANT approach useful for investigating the dynamics of innovation practices and related policies, with the focus of analysis on traceable interactions between phenomena in action.

3. Background and research methods

3.1. Case study

This paper is based on research conducted between 2010–13. The qualitative study was built around a large technological development, the Wave Hub project (Cornwall, UK), and the underpinning policy landscape. Wave Hub was presented as an attempt to facilitate the deployment and further development of wave energy technologies in the UK by providing shared offshore infrastructure for the demonstration and proving of wave energy generation devices.[4]

To provide some necessary background to the study, the story of Wave Hub began in 2002 with the UK government initiative to provide partial funding for developing regional renewable energy projects. For the South-West region, where EU financial support was also available,[5] consideration of a number of factors contributed to developing the concept of a consented grid-connected site for the demonstration of wave energy devices. The factors included an excellent wave climate, the existing infrastructure to support marine energy industry, and the available capacity in the electrical grid near the coast. Altogether, this constituted the most attractive proposition as part of a wider UK offer to the marine renewables industry.

The South West Regional Development Agency (SWRDA) relied heavily on expert advice and external expertise for developing the concept and delivering the project, including a multidisciplinary consultancy, a managing company with expertise in offshore engineering, other organisations that together formed a multidisciplinary team,[6] a research entity linked to Wave Hub – the PRIMaRE[7] institute. A number of studies (Technical Feasibility Study, Legal report, and Business case) were carried out to support the concept reflecting the ideas about the state of technology, relevant actors/stakeholders, their capabilities, intentions and roles, as well as a theory about how the wave energy industry would develop.

Although initially the concept of Wave Hub was actively supported by the industry (experts and potential users of the facility,) and stirred up enthusiasm as a promising idea for economic development of the region, the process of implementation was full of challenges, controversies and delays. Resolving controversies over the proposed location off the North coast of Cornwall was a serious challenge for project developers and for government and public bodies. The potential impact of Wave Hub on the safety of navigation and shipping routes, fishing activities, surfing and tourism, as well as concerns regarding the appropriateness of a wave powered generation project in principle, led to a number of objections that had to be taken into account by project developers and by the regulator during the consenting process. Planning decisions eventually made by the regulatory authorities were based on a judgement about the relevance and justification of the objections and often on a compromise. It was suggested that the deliberations about possible adverse impacts and related objections could not justify a refusal of development approval, as the proposed development (Wave Hub) was consistent with the Government's energy policy.[8] Difficulties with legal framework, e.g. the deficit of appropriate regulation in place for closing the area for shipping, were resolved by making subsequent changes in legislation.

Financial, organisational and technical challenges faced by project developers during the construction phase caused additional delays and led to revisions of the initial design of the core technology (e.g. removal of power connection units). The final design of the facility was the result of a number of compromises between reliability, cost and feasibility. The need to comply with EU tendering regulation made the process more complicated and costly. By the time the construction of the facility was completed, lack of investment was the key factor affecting the nascent wave energy industry, creating an uncertain future for Wave Hub.[9] Nevertheless, the political support for Wave Hub, recognised as a national asset, continued. A government proposal to make the South West region a leading centre for marine energy resulted in the announcement of further developments where Wave Hub became the key element of the offer (i.e. South West Marine Energy Park).[10] Changes in the concept introduced later and the creation of an operating company, Wave Hub Limited,[11] aimed at making the facility a more attractive proposition that could address the different needs of the developing offshore renewables industry.

3.2. Methodology

For analysis of the Wave Hub case an ANT approach was chosen as a theoretical resource and a methodological strategy. Appreciating Wave Hub as a complex socio-technical system, one could conceptualise it as emerging actor-network comprised of heterogeneous elements. This approach would allow opening up the case for analysis of contingencies and controversies, tracing various associations, successful translations and failures of enrolment, gaining explanations for changes in the initial network configuration. It also provides grounds for interpretations and theorising beyond the

technological project itself. In this study the main purpose for employing an ANT-inspired approach is to elaborate a view on policy as actor-network and an actant through tracing the interactions between the large technological project and relevant policy(ies) that affected the project's trajectory.

ANT can also be referred to as a strategy (Neyland 2006). The main approach for dealing with networks in ANT analytical discourse is the method of 'literary description' that helps to create a 'polyphonic narrative' (Callon 1991: 152). Constructing a narrative around the case study I relied on an ANT strategy to follow actors themselves (Latour 1987), which implies methods such as interviews, ethnographical observations, and work with different kind of 'inscriptions' (Latour and Woolgar 1986), for instance, texts/documents. Importantly, the Wave Hub case allowed studying a technological project in real time and collecting materials from primary sources, including interviews with project developers and studying relevant project documentation. I conducted 27 in-depth semi-structured interviews as the primary method of data collection. Respondents included developers of wave energy technologies, researchers and scientists, regional authorities, government officials (Department of Energy and Climate Change), professional associations and industry experts, and other social groups having interests in the Wave Hub project. The study analysed policy documents and other relevant documentation, i.e. Wave Hub official documentation (reports, studies, website information), press releases and articles in media sources that also helped to trace the evolution of the project and relevant policy(ies). Most documentation was freely available online at the time of data collection.

4. Renewable energy policy through the prism of Wave Hub

In this section I discuss the principle policy themes arising from the Wave Hub study, and investigate the effect of policy decisions on project evolution, as well as the process of policy shaping construed as a result of the development of this large energy project.

At the time of the study significant changes in the UK political landscape occurred. The Coalition Government was formed in 2010, making the pledge to be 'the greenest government ever' and announced the intention to encourage marine energy in the UK. Nevertheless, there was a high degree of uncertainty in the wave energy sector regarding funding opportunities and potential long-term government support. The reorganisation of the government was not always seen as a promising change by respondents in this study. The process of policy shaping was still ongoing and renewable energy policy was in state of flux, influenced by many stakeholders, involving deliberations about its direction and relevant constituencies. This uncertainty was reinforced by regional differentiation of financial mechanisms to support wave energy, i.e. ROCs,[12] the main support mechanism in place for large scale renewable electricity technologies. The Scottish parliament announced a higher level of

ROCs for wave energy in Scotland, which made other UK regions less attractive in the eyes of the industry and investors. At the same time, a strong promissory rhetoric framed in terms of both economic viability and technical expertise characterised public policy discourse around wave energy. It was widely recognised that there are significant resources distributed globally and a vast array of wave energy technology promoters with highly differentiated technology designs, with only a few of them claimed to be near commercialisation. This included UK device developers who managed to emerge as 'technology front-runners' pioneering the deployment and environmental monitoring techniques required for large scale commercialisation (Vantoch-Wood 2012). At this stage of wave energy industry development, promises and expectations were an important part of the articulated belief in its potential and formed the basis for promissory scenarios and continued support.

Not surprisingly, in a situation of uncertainty and an evolving policy landscape the story of Wave Hub was permeated by policy discourse. Industry representatives, device developers, scientists, managers, representatives of the national and regional authorities willingly discussed policy related issues, and the interviews with different groups of participants helped to construct a comprehensive and coherent narrative; there was no serious contradictions regarding their assessment of renewable energy policy and regulation. The main themes discussed in the interviews included the assessment of the UK political regime and its comparison with other jurisdictions, access to financial resources and the financial mechanisms in place to support wave/marine energy, the legal framework (including elements of EU regulations), and the competence and roles of national and regional authorities.

Different areas of public policy and governance were considered as relevant to and having impact on the development of wave energy in the UK, such as policies on innovation, research and development, environment protection, investments, market policies, and licensing. Concerns about climate change and energy security were recognised as setting the scene for renewable energy where climate change mitigation goals became an 'ideological' basis for UK and EU renewable energy policy, translating climate change goals into renewable energy initiatives. The Wave Hub case can serve an illustrative example, where the intention to fund projects in the renewable 'green' energy sector was determined by the 'increasing recognition of climate change as a big impact on the environment, on the society and on the economy' (*Convergence Partnership Office for Cornwall and Isles of Scilly – ERDF).*

Renewable energy policy was commonly perceived by participants as emergent from powerful institutions (government or those associated with government), which were making crucial decisions for the industry and could be spoken about as an object of critique. The critique of the government and its policy, in particular the financial resources available for the wave energy sector, was the most prominent theme in the interviews, as the ability to raise financial support was seen as the main factor for success of 'nascent' wave energy technologies. Comparisons with other energy-related

technologies, including Carbon Capture and Storage (CCS) and nuclear power, were used to illustrate the 'dramatic difference' in resource allocation.

At the time of study the financial mechanisms for renewable energy in the UK were a subject of criticism across different groups of participants. Some envisaged imminent changes in the system, often developing a link between the amount of ROCs and Wave Hub project success, although a few respondents questioned the efficiency of such changes demonstrating a more strategic vision of the situation around market mechanisms and their limitations. Other policy instruments and funding opportunities for marine wave energy technologies were characterised as very limited and inconsistent, first of all, MRDF[13] and MRPF[14]; the former was particularly criticised for being inefficient and inappropriate for the stage of technology development. Some forms of indirect support for Wave Hub were also acknowledged, i.e. publicly funded grants for companies – developers of wave energy devices whose aim to use Wave Hub for deployment of pre-commercial full scale devices was considered advantageous in funding competition:[15] 'TSB [Technology Strategy Board] makes it clear that it wants a UK location – EMEC [European Marine Energy Centre] or Wave Hub. <...> SWRDA put some money for TSB round, and they said that they would favour people who would use Wave Hub and would have a South-West consortium.' (*marine engineer, representative of renewable energy and climate change consultancy and developer of marine energy technologies*). Funding opportunities provided by TSB seemed to be essential for those few device developers who had accessed them.

The explanations provided for the politics behind government's policy and deficit of support for wave energy in the UK included a reference to the UK renewable energy targets[16] and the need for prioritising and creating an 'effective portfolio' for achieving them within budget limits. According to DECC, marine energy (including wave and tidal) was not seen as a potential contributor to 2020 policy goals due to its immaturity, compared, for example, with offshore wind, although with a potential to become 'major players' for 2030 or even 2050 targets.

The complexity of regulatory decision-making was another concern for the industry. Many interviewees articulated their concern about the UK policy regime as being too complicated, also pointing to the interdependence of renewable energy policy with policies in related fields and corresponding intricacy in interactions with the government: 'In the South-West at the moment it's incredibly challenging to see how you kind of navigate the policy domain to get the outcome you want which is to find the circumstances by which you can deploy [your devices] in Wave Hub. And a lot of that is to do with the national policies on innovation, energy economic development, all come together or all don't as the case may be.' (*company - pioneer in renewable wave-energy technology development*).

The UK legal framework and the government bodies responsible for implementation were mainly discussed in light of the difficulties experienced during the consenting process for Wave Hub. 'The old legislation' was characterised as 'complex' and 'built on lots and lots of little bits and bobs'. Mentioning a number of pieces of legislation, such as the Electricity Act, the Coastal Protection Act, the Food and Environmental Protection Act, the Town and Country Planning Act, and the new Marine Coastal and Access Act, participants saw some contradictions in UK law: '...the requirements of one bit of legislation might contradict the requirements of another, and we had to find our way through that for the first time, that's why it took quite a long time' (*Wave Hub management team*). The replacement of part of the 'old legislation' by the Marine Coastal and Access Act 2009 was characterised as a 'step in the right direction', which probably could lead to a 'one-stop shop' in the future, although raising a concern about such system to be 'vulnerable to abuse', 'not politically accountable', 'not auditable'.

The characteristics of 'the consenting authorities' and their consultees formed the core of the discussion about the UK regulatory system. The political support of the Wave Hub scheme in general was accompanied by regulatory bodies' concerns about 'all the little details', which created, in participants' views, additional barriers and difficulties for project implementation. An important factor affecting decision-making was the complex interrelations between government bodies and consultees and dependency on consultees' advice. A conflict of interests with those who were 'not interested in renewable energy' but provided advice to the Marine and Coastguard Agency (e.g. Trinity House and the Chamber of Shipping) created 'a bit of a nervous moment' for those seeking consent for the Wave Hub project. The careful attention to details was explained by the fact that Wave Hub was the first project of this kind and 'no one has done it before'; fear of making a 'mistake' and creating a precedent for the industry was the main motive for that 'extra-consciousness'. It was suggested by participants that the eventual decision was probably instituted 'for purposes of the greater public good' and objections were 'overruled' because 'we really need Wave Hub or a nuclear power station or whatever it is that the officer is considering' (*Wave Hub Management team*). This view was prominent in the official discourse suggesting that deliberations about possible adverse impacts and related objections could not justify a refusal of development approval, as the proposed development (Wave Hub) was consistent with the Government's energy policy, 'specifically its goals of reducing carbon emissions, maintaining the reliability of our energy supplies, promoting competitive markets, and ensuring that every home is adequately and affordably heated'.[17] It was also seen as important 'for the purpose of learning lessons that can be applied to future, larger scale projects'.

The efficiency of the regulatory decision-making process was deemed important for the emerging wave energy industry, as one participant put it: 'If you have a choice you'll spend your time where

you think you are going to get not only where the money is, but where you think you can get a reasonably quick decision' (*company - pioneer in renewable wave-energy technology development)*.

Another initiative, introduced by the government, although not directly addressing renewable energy sector, was criticised as undermining the ability of English regions to provide support for renewable energy – the abolition of the Regional Development Agencies (RDAs) in March 2012. It was argued that the RDAs were big enough to think about projects like Wave Hub, as they could take a wider view making decisions beneficial for the region as whole. The new Local Enterprise Partnerships, operating at lower levels of scale, would not have that strategic view or sufficient resources for renewable energy projects.[18]

Deliberations about 'favourable political regime' and 'the right conditions' (i.e. potential improvements in policy and regulation, including financial and other support mechanisms that could stimulate the growth of the wave energy industry) were often part of participants' accounts, along with a call for the government to demonstrate 'political will' and 'to work on a big strategic level' in regard to marine energy. The important feature of an efficient policy design would be a 'continuum of policy instruments' that could remove barriers (planning, opposition, technical, market-related) and work to assist deployment of wave energy devices. In order to 'ensure a smooth pathway' different policy instruments would be needed at different stages of technology progression, e.g. access to large capital funding that the market may not be able to deliver at the early stage of technological development, and subsidy mechanisms (e.g. the RO) when technologies are proven but still not economically viable.

European Union policy and regulatory frameworks was raised in interviews with regard to the EU 2020 target, sources of funding for the Wave Hub project, as well as obligations derived from this support. It is interesting to note that the potential availability of EU funding was seen as a key factor for initiating large-scale projects like Wave Hub. Besides this, EU policy and regulation were discussed in relation to various difficulties experienced surrounding the tendering process and the construction of the facility. EU and UK Government investment in Wave Hub were seen as important in determining project success.

Overall, the story of Wave Hub was largely told as negotiation of policy needs and wants, achievable and achieved outcomes, as well as relevant policy features that would ensure the efficiency of project implementation. At the same time, the interviews illustrated the process of policy shaping by providing assessments of the political making of Wave Hub. Below I discuss how these empirical findings provide fertile grounds for elaborating an alternative perspective on policy analysis from ANT perspective.

5. Elaborating an ANT perspective for policy analysis

How can ANT-informed thinking be applied to policy analysis and what interpretations of empirical findings can it produce? Here I discuss the idea of policy as an evolving network and an actant. This approach enhancesour understanding of co-evolution of policy and large technological developments.

Conceptualisation of policy as an evolving actor-network

An anthropological approach for interpretative policy analysis suggests that policy is more than an 'instrumental governmental tool', as policy can have agency and it changes entering into relations with other actors and institutions (Shore and Wright 2011: 20). A concept of policy different from conventional policy science is suggested – an idea of policy as an 'assemblage' (ibid.: 20). Freeman (2012) suggests thinking about policy in a wave form, as an echoing phenomenon that exists only because its elements are moving. Policy can be also presented as a shared understanding of a problem, 'a collective script' which exists only to the extent to which it is called up in the words and actions of those concerned with it (Freeman 2012: 13).

Employing ANT as a research lens helps to provide an explanation for policy that resembles the views on policy as an 'assemblage' and an evolving and echoing phenomenon. In ANT the right of representation can be granted to anything; any phenomenon, any object (not necessarily of material form) can be considered as an actor-network. It is argued that 'a network' is an 'image for describing the way one can link or enumerate disparate entities without making assumptions about level or hierarchy', where any entity or material can qualify for attention (Strathern 1996: 522). Following this presupposition, policy can also be conceived as a network (or actor-network) consisting of numerous entities, most of which are heterogeneous and hybrid elements (i.e. human-nonhuman hybrids).

With regard to UK renewable energy policy, various elements of variable ontologies can constitute this policy and regulatory framework, performing as actors in a network. Across the UK, relevant renewable energy policy actors include government departments, public officials (politicians and bureaucrats) at national, regional and district levels, budgets, research establishments and consultees, spatial planning processes, and the wide corpus of documents; all of them are assembled in the network of relations. Network operators and other utilities, industry representatives, professionals, academics, industrial and domestic consumers, and material artefacts (e.g. power stations and a national grid), can become part of the network. Policy discourse,[19] which acquires a material form in documents and practices and through which policy network achieves its credibility, is also an important element of this constellation.

It is also important to note that policy is not a single and coherent thing. As Law and Moser argue, there is no single policy but a 'patchwork' in practice: 'different policies at different times and places, variable interpretations of policy, artful inconsistencies in implementing policy in situated practices and resistances all contributed to this' (Law and Moser 2012: 348). Adopting a wider view, renewable energy policy network might be imagined as involving other types of policy, e.g. related to innovation, sustainable development and environment protection, energy economics, as well as elements and practices that characterise the political system and policy making in general. In the case of Wave Hub the discussions of policy also involved deliberations about different policy 'levels'- EU, the national government and the regional authorities - adding elements of EU policy to the policy network, as well as a regional component.

If one treats policy as an actor-network, it appears as heterogeneous and rather ambiguous. Theoretically, networks are without limit, they are cast as widely as their different elements can be enumerated (Strathern 1996). Addressing the problem of potentially endless networks, the concept of ownership was suggested as a mechanism for cutting networks and defining boundaries (ibid.). Without exploring the measurability and the scope of the policy network (and the principles of social organisation that can be used to cut it), the analysis here is built on the suggestion that the boundaries of this actor-network are negotiated by actors themselves and depend on what they articulate as relevant policy issues.

Importantly, the policy network configuration changes over time. Regulatory change and restructuring of government departments and redistribution of power between them can serve as illustrative examples.[20] The view of policy as an evolving phenomenon was supported by some participants, including policy experts: 'I would argue that to be successful, renewable energy policy has to be a process which implies change' (*energy policy expert*). While recognising change as inevitable and necessary, they however questioned the speed of change and the degree of policy responsiveness to developments in the renewable energy sector. The dynamics of policy networks and the nature of change are explained by its evolving character and an immature object of regulation, i.e. marine energy.

The ANT approach allows considering UK renewable energy policy not only as a network, but also as an actor, or an actant. This effect is achieved through punctualisation when actor-networks are strongly convergent and irreversibilised and when their behaviour is known and predicted (Callon 1991). Viewed as a single actor, a renewable energy policy actor-network can be punctualised as a node in other networks, for example, in the UK energy sector or in overall domestic policy network as one of the sectoral policies.

Participants discussed numerous policy themes and provided descriptions of different connections to the policy network important to them. Does this highlight the contested nature of the policy

network or could it be suggested that the representation and perception of an actor-network is perspectival? ANT implies a possibility of simultaneous existence of more than one version of an object. A network might have different 'faces'. It can be punctualised to a simple node and viewed as a black box; it can be unpacked revealing its complexity and constituent elements. Varying interpretations of the actor-network configuration, i.e. how one sees those elements and connections and which of them are brought into focus, depends on person's individual experience of the actor-network. As such, policy as an actor-network is a collective aggregative notion, based on different visions of a network and its components, the links and relations between them. As Mol (2003) suggested, such multiplicity does not imply fragmentation but reveals the richness of interpretations and connections of a network with other actors shaping the network and moulding its boundaries.

Overall, policy in this study is interpreted as a complex, relatively stabilised but evolving actor-network comprised of heterogeneous elements, not only human actors but also non-human and non-material ones, which boundaries and inner configuration can be identified through the participants' accounts.

5.2. Policy and Wave Hub as mutually constitutive networks?

Analysis of Wave Hub suggests that the project development was influenced significantly by policy and cannot be abstracted from it. A number of factors were reported as shaping this large technological project defining its destiny, including the decision of the UK government and EU to provide financial support for Wave Hub, the financial mechanisms that failed to provide enough incentives for developers to deploy their devices in the South-West of England, uncertainty in the sector and its ambiguous future in the UK, the lack of regulation in place, e.g. for the consenting process. Policy influenced Wave Hub development in an explicit form, e.g. the consenting process, but also indirectly, for example, through its impact on device developers by means of economic instruments such as ROCs, additional funding and subsidies, incentives for investors.

When viewed as an actor-network Wave Hub appeared as a complex system composed of associated entities, human and nonhuman elements that 'act' upon each other. Although these entities, in Callon's words, 'are susceptible to being moulded or shaped', they in turn could transform the actor-network of which they formed a part. In this respect, renewable energy policy and regulation can also be seen as an element of the actor-network, not merely a 'context' in its conventional understanding. From an ANT perspective, only successfully translated actors which were mobilised without contradiction become a background or a context (Law and Callon 1989). Although at first glance it seemed that the policy actor-network was mobilised without contradiction being a 'stable and predictable entity' (Law and Callon 1989) providing support for Wave Hub, later it appeared to be a complex evolving network which affected Wave Hub and processes around it continually due to changes and transformations happening in both networks.

Further, using the language of ANT, policy (as well as the whole wave energy sector) can be defined in relation to the Wave Hub project not only as one of the elements in the system but, using Law and Callon's language, as a 'pre-established pre-existing network'. It is even possible to talk about the promissory role of policy in relation to Wave Hub, considering the degree of support provided for the project, political and financial, which helped to create an image of Wave Hub as a highly desirable, viable and feasible initiative. Arguably, it is not only policy that can be a founding element – nature (particularly ocean waves), the wave energy industry (the existence of wave energy technologies, the desire to grow and search for optimal solutions, like new testing sites and infrastructure), the initiator (SWRDA) – all those elements were crucial for Wave Hub as the emerging actor-network and pre-existed it, making the very idea of Wave Hub possible. Can policy be considered as a powerful entelechy among them, a force that glues other elements, holds them together even when the actor-network is ready to fall apart? What are the features of this actor? The answer could be that policy is a powerful actant, an active formative element that acts upon other elements in the actor-network, i.e. having agency, and directs its growth. It guaranteed the survival of the project and pushed it forward ensuring project legitimacy. Considering policy as a founding actor, as 'seed capital' for Wave Hub, can probably provide the ground for a discussion of the credibility construct of the Wave Hub project. As evident from empirical data, the rather formal approach to the project was demonstrated from the national government where Wave Hub was perceived as vague and quite abstract. What is more important, the actual fulfilment of the project dominated over other aspects (timeline, cost, 'technicalities' etc.) in this conceptual meaning. Allowing variations in project implementation and accepting the changes (i.e. the design), the policy network did not seem to allow the abolition of the project. The explanation for this phenomenon from an ANT perspective could be that policy is a more complicated, more stabilised, less flexible, although still evolving, network, as it involves more nodes and connections. Once it has its trajectory and branched off another dependent actor-network (e.g. Wave Hub), it is unlikely that this new configuration would change radically (or be abandoned), as it is supported by plenty of other elements that constitute policy network, or in other words, there is a huge 'state machinery' which stands behind. As such, policy can create a momentum for a project like Wave Hub that is not easy to reverse. So the suggestion can be made that the political nature of the project, the status attributed to Wave Hub ('a national asset'), its dependence on Government support and funding limited its ability to manoeuvre and actually to fail or be cancelled despite of difficulties, various controversies and delays.

On the other hand, the construction of the facility arguably influenced the development of the related policy and regulation that could potentially lead to the desirable 'one-stop shop' in the future, as anticipated by some respondents. Relevant regulations were produced by legislators and changes in existing laws were made. For example, the data suggested that there was sufficient UK legislation to grant consent for building the project, but there was no legislation to close the area to shipping. There

were a number of legislative acts – the Electricity Act for connecting to the grid, the Coastal Protection Act (CPA) protecting the coastal environment, the Food and Environmental Protection Act (FEPA); and onshore planning requirements – the Town and Country Planning Act. This legal framework was referred to as complex and sometimes contradictory. Later, changes were introduced by the regulator as the Marine and Coastal Act replaced CPA and FEPA, which made it more adjusted for regulating marine energy projects in future. The proposed changes introduced to the UK's financial mechanism (5 ROCs instead of 2, in force from 2013) also created an impression that the voices of the industry who advocated this change were heard and were critical for the government influencing its decision-making. These changes were recognised as vital for Wave Hub development by all respondents. This illustrates that Wave Hub as an actor-network composed of series of heterogeneous elements was able to redefine and transform what it is made of, meaning that between the actor-network and its more dynamic elements (e.g. policy) there is a constant mutual process of adjusting one's development to others, transforming each other. This also supports the thesis that interacting networks can be simultaneously 'reworked and reshaped' (Law and Callon 1989).

Thus, the change enhanced the properties of the policy actor-network, as there seemed to be a reciprocal effect that caused certain changes in policy under the influence of Wave Hub. In this sense Wave Hub was not just a project that would move wave energy industry forward, but one that helped to reveal some weaknesses, gaps and contradictions of UK renewable energy policy making them more visible to policy makers and other actors. The effect caused by the project led to certain changes and helped to align the elements of policy with each other, improving the overall configuration for benefit of technological development and deployment of renewable energy technologies. These changes were not immediate, and it took time to see that the policy network reflected on the Wave Hub case.

To sum up, analysis of interaction between policy and Wave Hub revealed the complex constellation of these actor-networks. Employing an ANT approach for conceptualisation of policy and its role in the case of Wave Hub helped to understand their entanglement, mutual evolution and influences, and shed light on elements of credibility construct of Wave Hub as actor-network.

6. Conclusion

This paper offers new theoretical and empirical contributions to the Science & Technology Studies and policy analysis literature by providing an alternative perspective on the co-evolution of policy and large technological developments in emerging industries. An ANT-informed approach provides a useful theoretical resource to explore policy and innovation practices – its empirical and relational sensibilities and orientation towards more-than-human forms of agency challenges

established conceptions of policy; using a network metaphor as an analytical tool helps to better understand processes that shape and stabilise entities taken as actor-networks. ANT allows stepping beyond a contextual understanding suggesting a new way of thinking about the phenomenon, i.e. developing an idea of policy as an actant and providing an insight into the complexity of policy networks.

The investigation is based on a study of a controversial development of a wave energy project, Wave Hub, and its underpinning policy landscape. At the time this study was conducted, UK renewable energy policy was in a state of flux, which made it open to various inputs. I explored Wave Hub in order to locate it in relation to renewable energy policy and dominant narratives around renewable energy, particularly in the UK. My empirical data allowed tracing the connections between Wave Hub and policy networks and showed the richness of interaction between them. The empirical data revealed that policy was a very prominent theme for the story of Wave Hub. It was brought into focus when discussing various aspects of the project: starting with the very idea of Wave Hub, its funding and initial governmental support, moving to the discussion about problems and barriers for project implementation, speculations about its future and the incentives for companies willing to deploy their devices at Wave Hub, comparison with other testing facilities, i.e. EMEC, and other policy jurisdictions, and even talking about credibility and belief in the project's success.

Referring to the debate about context/content dichotomy in STS and ANT as analytical basis, I questioned the idea of policy as a 'macro context'. I formulated my approach to understanding policy as a relatively stabilised but still evolving powerful actor-network comprised of heterogeneous elements, and explored the idea of policy as an actant. I assessed the role of policy as an actant in a new network and examined how its 'effect' was construed, in particular the relationship between political decisions and the development of Wave Hub, as well as a reciprocal effect that Wave Hub had on policy and regulation, causing transformations in a policy network. Analysis of interactions between policy and Wave Hub revealed the complex constellation of these networks. They also appeared as *mutually constitutive* actor-networks. Being a pre-established, or pre-existing, network, policy became a powerful element in new configuration, a 'seed capital' for Wave Hub, contributing to project legitimacy. As an element of promissory discourse, policy could not be abstracted from this innovative project, and Wave Hub became extremely dependent on the policy network. Moreover, Wave Hub was often viewed as a result of implementation of contemporary renewable policy in the UK serving for assessing the readiness of renewable energy policy and related regulations for changes in the renewable energy sector instigated by technology development. It can be suggested that despite deliberations about its success, this project opened up the discussion about the weaknesses of policy in the field, making them more visible to policy-makers and other actors when the anticipated results were not achieved. As such, the project was perceived as helping to align the elements of policy network in a more effective way, which in turn might influence the development and deployment of

wave energy technologies. Studying the interweaving actor-networks of renewable energy policy and Wave Hub helps understanding network adjustment process revealing their weaknesses and disconnections, and how their identities are shaped as a product of such interaction. The paper suggests that the theoretical insights of ANT can better describe the complexity of transformation intrinsic to energy policy and offers more insights into the complex relational nature of renewable energy and policy networks.

The demonstrated contribution of ANT in understanding processes that are central to policy development proves its potential value for policy analysis. Although ANT has been little used within policy studies, it seems an appropriate tool for analysis of policy development and change, particularly around emerging or less conventional technologies. Using ANT to describe policy processes in detail can explain the emergence and transformation of actor-network structures, permitting us to conceive policy as a phenomenon in the making. The study lays out one of the potential contributions that the theory can make to policy analysis offering a point of departure for further investigations inspired by ANT-thinking.

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Notes

[1] The concept of ‘black boxes’ (Callon and Latour, 1981; Latour, 1987) helps to understand the growth of an actor-network. Black boxes contain elements that no longer need to be reconsidered, and therefore their contents have become a matter of indifference (Callon and Latour, 1981). The size of a network depends on how many elements they are able to put into black boxes durably to make over their size (ibid.).

[2] More conventional analyses of policy demonstrates a clear divide between micro and macro scale, and policy is often understood as a macro context, in the form of an institutional and regulatory/legal framework (e.g. Winskel et al. 2006; Aarset and Jakobsen 2009; Lehmann et al. 2012; Scarlat et al. 2015; Wright 2015).

[3] ANT adds to alternative interpretations of context in the social sciences where a notable shift from the conventional approaches to context treated as a ‘given’ or a self-evident ‘construct’, unproblematic, isolated, formally described, and taken as preassembled (Dilley 2002: 439) to recognising context as a social construct (Dilley 2002) and as a non-static emerging phenomenon (Augier et al. 2001) can be found. Context can be also understood as an individual construct based on the individual’s previous experience (Augier et al. 2001), and seen as a result of prior interpretations and knowledge (Dilley 2002). Understanding of context as a relational thing allows thinking about it in terms of connections and disconnections, as a ‘set of connections construed as relevant to someone, to something or to a particular problem’ (ibid.: 440).

[4] The official description of Wave Hub at the end of this research project was as follows: ‘Wave Hub provides shared offshore infrastructure for the demonstration and proving of arrays of wave energy generation devices over a sustained period of time. It consists of an electrical hub on the seabed 16 kilometres off the north coast of Cornwall in South West England to which wave energy devices can be connected. The 12-tonne hub is linked to the UK’s grid network via a 25km, 1300 tonne subsea cable operating at 11kV. The project holds a 25-year

lease for eight square kilometres of sea with an excellent wave climate. Wave Hub has the necessary consents and permits for up to 20MW of wave energy generation and offers a clearly defined and fully monitored site for marine energy production. Four separate berths are available to lease, each with a capacity of 4-5MW.' Later the proposition for Wave Hub was revised to include other offshore RE technologies, i.e. tidal and offshore wind. The current description of Wave Hub refers to it as the world's largest and most technologically advanced site for the testing and development of *offshore renewable energy* technology. http://www.wavehub.co.uk/wave-hub-site

[5] European Regional Development Fund. Convergence for economic transformation.

[6] E.g., the economic appraisal was done by a large renewable energy consultancy; one of the major offshore contractors was engaged for the purpose of assisting with the concept design.

[7] The Peninsula Research Institute for Marine Renewable Energy http://www.primare.org/

[8] Section 36 Consent. Wave Hub. Consenting and Safety Zone Information. http://www.wavehub.co.uk/information-for-developers/consenting-and-safety-zone/ (accessed 12.12.2013)

[9] The wave test site was fully commissioned in 2012, but the industry was not ready to utilise the facility straight away, and it took some time to see companies securing berths for their devices. At the time of data collection the negotiations with potential customers were underway. As at July 2016, there are four customers who have been allocated berths at Wave Hub. *Carnegie Wave Energy Ltd*. was awarded a berth in 2014 aiming to deploy CETO6 device of 1 MW targeted capacity at Wave Hub as part of a pre-commercial project commissioning in 2018, and build this out to a commercial project in 2020. *Seatricity Ltd.* signed a contract with Wave Hub to install an initial demonstration device, Oceanus 2 in 2014, followed by a 10MW array. The Oceanus 2 device has a capacity of 162kW, and is currently undergoing sea trials at Wave Hub. *Simply Blue Energy Ltd.*, working with Wave Hub since 2014, has an agreement for developing a wave farm using the Seabased Wave Energy Converter technology. On the completion of the project estimated for early 2017, 200 Seabased generators will be providing a 10MW installed generating capacity. *Fortum Corporation* signed a leasing agreement with Wave Hub in 2014. It allows the company to carry out 5-year Clean Energy From Ocean Waves (CEFOW) research project sponsored under Horizon 2020 research and innovation programme. CEFOW is coordinated by Fortum in order to research and develop the use of the Penguin wave energy converter, developed by Finnish company Wello.

[10] The South West Marine Energy Park was launched in 2012 as a collaborative partnership for marine energy development between commercial and academic organisations. https://www.regensw.co.uk/our-work/offshore-renewables/south-west-marine-energy-park/ This proposal was announced after the data collection was finished, and is beyond the scope of this paper.

[11] To date, Wave Hub Limited has an extended portfolio with three leased Crown Estate Demonstration Zones - Wave Hub Test Site, North Devon Demonstration Zone (tidal) and Pembrokeshire Wave Test Demonstration Zone.

[12] Renewable Obligation Certificate (ROC) is the name given to digital certificates which hold details of exactly how a unit of renewable electricity was produced, who produced it and who bought it. These certificates are effectively guarantees and are traded separately to the actual electricity itself. They were introduced by the

government to work as a 'bonus premium' on top of the unit price. http://www.buildingforafuture.co.uk/winter06/ROC'S.php

[13] The Marine Renewables Deployment Fund (MRDF) was the scheme established by the UK Government in 2004 to support the demonstration of small arrays of pre-commercial wave and tidal energy devices. The MRDF was criticised as it never had been accessed by a single device developer until its closure in 2011. In 2011 a replacement for MRDF was established – the Low Carbon Fund's Marine Energy Array Demonstrator (MEAD) to support the sector moving from single device prototypes to first arrays of full-scale devices.

[14] The Marine Renewable Proving Fund (MRPF) was launched in 2009 to accelerate the leading and most promising marine devices towards the point where they can qualify for the Governments then existing MRDF support scheme and, ultimately, be deployed at a commercial scale under the standard Renewables Obligation.

[15] One of the UK public bodies, established by the Government and sponsored by the Department for Business, Innovation and Skills (BIS), the Technology Strategy Board (TSB), in cooperation with regional authorities provided financial support for the companies whose aim to use Wave Hub for deployment of pre-commercial full scale devices was considered advantageous in competition (for two projects among nine 2010 competition winners the intention to collaborate with Wave Hub was clearly stated; one project announced EMEC as the test site). Technology Strategy Board, 2010. Driving Innovation. Press Release. http://www.innovateuk.org/_assets/pdf/press-releases/press%20release%20wave%20and%20tidal%2023july10%20final.pdf

[16] The 2009 Renewable Energy Directive sets a target for the UK to achieve 15% of its energy consumption from renewable sources by 2020 in accordance with the EU requirements.

[17] Section 36 Consent. Wave Hub. Consenting and Safety Zone Information. http://www.wavehub.co.uk/information-for-developers/consenting-and-safety-zone/ (accessed 12.12.2013)

[18] Eventually, the ownership was transferred to BIS which created a not-for-profit company Wave Hub Ltd. At the time of data collection this was unknown.

[19] Policy discourse can be defined as 'a specific ensemble of ideas, concepts, and categorisations that are produced, reproduced and transformed in a particular set of practices and through which meaning is given to social realities.' (Hajer 1995: 44)

[20] Initially, DTI had an interest in the Wave Hub project; later, DECC and BIS were created both having interest in the project.